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Review

Content of Lipids, Fatty Acids, Carbohydrates, and Proteins in Continental Cyanobacteria: A Systematic Analysis and Database Application

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Abstract: The lipid, fatty acid, protein, and carbohydrate contents in cyanobacterial strains and biomass can vary by orders of magnitude. Many publications (thousands of peer-reviewed articles) require more work to extract their precise concentration values (i.e., different units, inaccurate data), which makes them not easily exploitable. For this purpose, tables have been compiled from the literature data, including lipids, fatty acids, proteins, and carbohydrates composition and quantities in cyanobacteria. A lot of data (323) were collected after careful a literature search, according to selected criteria in order to distinguish separately cyanobacteria, and according to categories of genus and species and generate average values of the contents of these cell components. These data are exploited in a first systematic analysis of the content in types of strains. Our database can be a powerful tool for biologists, chemists, and environmental agencies to determine the potential concentration of high-value chemical building blocks directly from low-value bloom biomass, cell cultures, or debris in the sediment, offering the potential to minimize environmental waste and add value to the agro-industrial residues. The database can also support strategies for food manufacturers to develop new products with optimized properties for veterinarian applications.

Keywords: biofuel; biomass; cyanobacteria; environmental waste; metabolites; review

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1. Introduction

Cyanobacteria can form blooms (excessive proliferation) according to changes in the natural environmental conditions (i.e., temperature, light, and nutrients) [1,2]. The leading causes of this increase are the environmental impacts caused by anthropic actions that promote the eutrophication of aquatic ecosystems, combined with climate change, increased water temperature, and the increased atmospheric levels of carbon dioxide [1,3]. As a result, the frequency, distribution, intensity, and duration of these blooms have been increasing worldwide. Among the organisms present in the blooms, cyanobacteria stand out, as they can produce toxic substances, which in large quantities can affect aquatic fauna, causing imbalances in the ecosystem [4–6].

On the other hand, non-toxic cyanobacterial species have great potential for biotechnological application. They can be used in several industrial sectors, for example, in the food, energy, and pharmaceutical industries, among others, adding value to a raw material that is still little explored [7–9]. The study of different strains of cyanobacteria is important due to the different characteristics that these microorganisms present, in addition to their capacity of producing different primary and secondary metabolites. For example, according to Rodolfi et al. [10], some species can fix carbon dioxide (CO_2) directly and produce cell biomass suitable for an economically viable dense culture of cyanobacteria [11]. Depending on the conditions, strains of *Microcystis aeruginosa* (i.e., CCIBt 3106, LTPNA 03, LTPNA 01, and LTPNA 05) can produce or not microcystins [12–14], and this suggests that without the extra energy cost of synthesizing cyanotoxin, these non-toxic strains could invest in nutrient reserves [13].

The main primary metabolites produced by cyanobacteria are lipids, carbohydrates, and proteins [15]. Lipids are essential chemical compounds in cyanobacteria, which can be used as a source of food, animal feed, and biodiesel [14,16,17]. According to Sinensky [18], the ability to modify the type and amount of cell lipids is one of the reasons that can explain the fact that cyanobacteria manage to survive under diverse and extreme conditions (e.g., extremophile species in Antarctica and hot springs).

The production of carbohydrates In cyanobacteria for industrial applications is a promising area for biotechnology [19]. For example, sucrose and glycogen from cyanobacteria can be considered good sources for the production of biofuels [20,21]. Since these microorganisms are also interesting producers of proteins, they can be used in food as valuable ingredients [22]. For example, cyanobacteria rich in proteins can be used in the food industry as a protein extract, which may have emulsifying or gelling properties [22]. Several studies have analyzed protein concentration in cyanobacteria [13,23–25].

Due to the satisfactory concentrations of nutrients in cyanobacteria, studies on the characterization of fatty acids, lipids, carbohydrates, and proteins are abundant. The large number of studies related to cyanobacteria in the molecular, environmental, and biotechnological areas, among others, makes it difficult to search for specific information on the amount of these macronutrients. Thus, the objective was to collect data on these biocompounds to create a database that compiles the important data for different researches.

2. Materials and Methods

Data selection depends on the purpose of the study and data availability [26]. From this premise, data were selected from published research articles using the Google Scholar, Scielo, PubMed, Science Direct, and Web of Science databases. The main inclusion criteria were the impact factor of journals and the publication of articles in the period from 2000 to 2023. The keywords cyanobacteria, lipids, lipid content, fatty acids, carbohydrates, proteins, and biofuel were used for the search (Figure 1). Review articles with consistent and clear data were considered; however, the concentration values were extracted from the original articles.

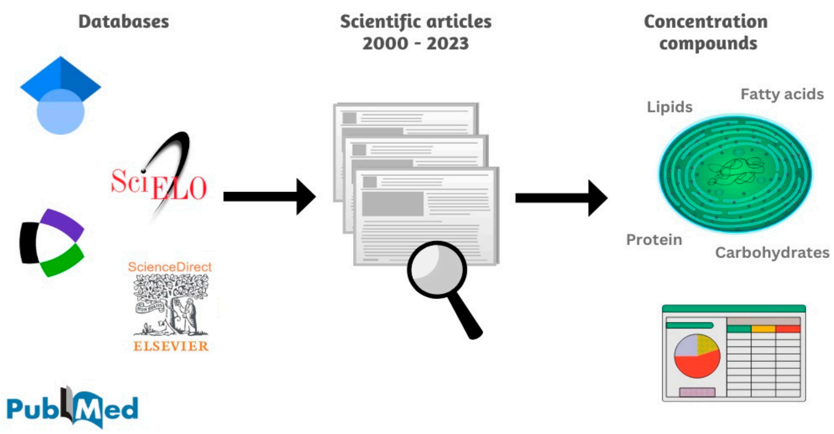

Figure 1. Platforms used in the search for scientific articles for review, date of chosen scientific articles, and primary metabolites revised.

Independent researchers extracted the necessary information from eligible articles, such as the cyanobacteria genus and species, investigated compounds' content, collection place, authors, year of publication, and digital object identifier (DOI). The details of the articles included were typed into an Excel spreadsheet (Office 2013, Microsoft, Redmond, WA, USA), contemplating the information mentioned in columns. The studies displayed on the different search platforms, according to the search criteria, were extracted in the "ris" format.

We also researched and compiled the data found in the Platform of National Center for Biotechnology Information (NCBI) of the species and/or genera selected for this review. These data are presented in the Supplementary Material (Table S1).

3. Results

Relevant studies on the concentration of fatty acids, lipids, carbohydrates, and proteins in cyanobacteria were selected, totaling 111 data on fatty acids, 119 on lipids, 60 on carbohydrates, and 33 on proteins (Figure 2). A total of 323 data were analyzed and presented in seven tables, gathering data on fatty acids (Tables 1–4), lipids (Table 5), carbohydrates (Table 6), and proteins (Table 7). We included articles with consistent or clear data and review articles. The fatty acid structures are presented in the Supplementary Material. Saturated fatty acids have simple structures with only single C–C bonds with a terminal carboxylic group (Table S2), while unsaturated fatty acids have more complex structures containing at least one or more C=C double bonds in the carbon backbone (Tables S3 and S4).

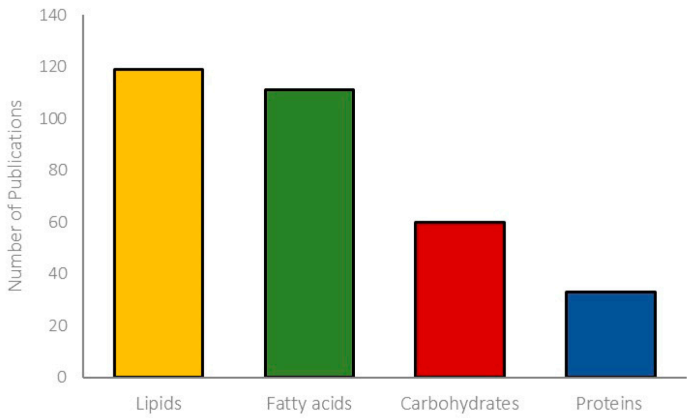

Figure 2. The number of publications (2000–2023) referring to the concentrations of lipids, fatty acids, carbohydrates, and proteins in freshwater cyanobacteria.

Table 1. Main information about classification, collection point, and the literature reference relating to the fatty acid composition of the cyanobacteria selected for this review [14,16,17,27–46].

Code N.	Genus and/or Species	Collection Point	Reference
1	*Phormidium* sp. (FW01)	-	[17] 1
2	*Phormidium* sp. (FW02)	-	[17] 1
3	*Oscillatoria* sp. (FW01)	-	[17] 1
4	*Oscillatoria* sp. (FW02)	-	[17] 1
5	*Mastigocladus laminosus* (S4BB)	Algeria	[27] 1
6	*Mastigocladus laminosus* (S4B11)	Algeria	[27] 1
7	*Mastigocladus laminosus* (S9BB)	Algeria	[27] 1
8	*Cyanobacterium* sp. (IPPAS B-1200)	Sorbulak reservoir of Almaty	[28] 1
9	*Cyanobacterium aponinum* (IPPAS B-1201)	Sorbulak reservoir of Almaty	[28] 1
10	*Desertifilum* sp. (IPPAS B-1220)	Sorbulak reservoir of Almaty	[28] 1
11	*Anabaena affinis* (NIES-40)	Tsukuba, Japan	[29] 1
12	*Anabaena affinis* (Inba3)	Chiba, Japan	[29] 1
13	*Anabaena affinis* (Inba10)	Chiba, Japan	[29] 1
14	*Anabaena planctonica* (TAC421)	Tsukuba, Japan	[29] 1

Table 1. *Cont.*

Code N.	Genus and/or Species	Collection Point	Reference
15	*Anabaena planctonica* (TAC422)	Tsukuba, Japan	[29] [1]
16	*Anabaena planctonica* (TAC424)	Tsukuba, Japan	[29] [1]
17	*Anabaena planctonica* (TAC434)	Tsukuba, Japan	[29] [1]
18	*Anabaena planctonica* (TAC435)	Tsukuba, Japan	[29] [1]
19	*Anabaena planctonica* (1403/27)	Windermere, UK	[29] [1]
20	*Anabaena planctonica* (1403/19)	Windermere, UK	[29] [1]
21	*Anabaena planctonica* (NIVA66)	Oslo, Norway	[29] [1]
22	*Anabaena planctonica* (Inba2)	Chiba, Japan	[29] [1]
23	*Anabaena planctonica* (Inba6)	Chiba, Japan	[29] [1]
24	*Anabaena solitaria* (NIES-78)	Tsukuba, Japan	[29] [1]
25	*Anabaena solitaria* (NIES-80)	Tsukuba, Japan	[29] [1]
26	*Anabaena smithii* (TAC428)	Tsukuba, Japan	[29] [1]
27	*Anabaena smithii* (TAC431)	Tsukuba, Japan	[29] [1]
28	*Anabaena smithii* (TAC432)	Tsukuba, Japan	[29] [1]
29	*Anabaena smithii* (TAC450)	Tsukuba, Japan	[29] [1]
30	*Anabaena smithii* (TAC451)	Tsukuba, Japan	[29] [1]
31	*Anabaena kisseloviana* (NIES-74)	Tsukuba, Japan	[29] [1]
32	*Anabaena kisseloviana* (TAC34)	Tsukuba, Japan	[29] [1]
33	*Anabaena viguieri* (TAC433)	Tsukuba, Japan	[29] [1]
34	*Anabaena danica* (TAC453)	Tsukuba, Japan	[29] [1]
35	*Limnothrix* sp. (DDVG II)	-	[30] [1]
36	Wild cyanobacterial biomass	Nida, Lithuania	[31] [1]
37	*Camptylonemopsis minor* (MBDU 013)	Tamil Nadu, India	[32] [1]
38	*Calothrix marchica* (MBDU 602)	Tamil Nadu, India	[32] [1]
39	*Calothrix* sp. (MBDU 013)	Tamil Nadu, India	[32] [1]
40	*Nostoc* sp. (MBDU 009)	Tamil Nadu, India	[32] [1]
41	*Nostoc* sp. (MBDU 013)	Tamil Nadu, India	[32] [1]
42	*Anabaena sphaerica* (MBDU 105)	Tamil Nadu, India	[32] [1]
43	*Calothrix dolichomeres* (MBDU 013)	Tamil Nadu, India	[32] [1]
44	*Calothrix linearis* (MBDU 005)	Tamil Nadu, India	[32] [1]
45	*Nostoc piscinale* (MBDU 013)	Tamil Nadu, India	[32] [1]
46	*Anabaena* sp. (MBDU 006)	Tamil Nadu, India	[32] [1]
47	*Nostoc* sp. (MBDU 007)	Tamil Nadu, India	[32] [1]
48	*Dolichospermum spiroides* (MBDU 607)	Tamil Nadu, India	[33] [1]
49	*Anabaena variabilis* (MBDU 013)	Tamil Nadu, India	[33] [1]
50	*Anabaena anomala* (MBDU 629)	Tamil Nadu, India	[33] [1]
51	*Nostoc punctiforme* (MBDU 009)	Tamil Nadu, India	[33] [1]
52	*Nostoc calcicola* (MBDU 602)	Tamil Nadu, India	[33] [1]
53	*Nostoc carneum* (MBDU 709)	Tamil Nadu, India	[33] [1]
54	*Nostoc carneum* (MBDU 013)	Tamil Nadu, India	[33] [1]
55	*Nostoc entophytum* (MBDU 679)	Tamil Nadu, India	[33] [1]
56	*Desmonostoc muscorum* (MBDU 105)	Tamil Nadu, India	[33] [1]
57	*Calothrix brevissima* (MBDU 613)	Tamil Nadu, India	[33] [1]
58	*Tolypothrix tenuis* (MBDU 609)	Tamil Nadu, India	[33] [1]
59	*Nostoc* sp. (MBDU 013)	Tamil Nadu, India	[33] [1]
60	*Nostoc* sp. (MBDU 005)	Tamil Nadu, India	[33] [1]
61	*Nostoc commune* (MBDU 707)	Tamil Nadu, India	[33] [1]
62	*Nostoc* sp. (MBDU 303)	Tamil Nadu, India	[33] [1]
63	*Nostoc spongiaeforme* (MBDU 704)	-	[34] [1]
64	*Calothrix* sp. (MBDU 701)	-	[34] [1]
65	*Nostoc punctiforme* (MBDU 621)	-	[34] [1]
66	*Scytonema bohneri* (MBDU 104)	-	[34] [1]
67	*Calothrix* sp. (MBDU 901)	-	[34] [1]
68	*Cyanobium* sp. (CACIAM06)	Bolonha Lake	[35] [1]
69	*Limnothrix* sp. (CACIAM10)	Tucuruí Hydroelectric Reservoir	[35] [1]

Table 1. *Cont.*

Code N.	Genus and/or Species	Collection Point	Reference
70	*Nostoc* sp. (CACIAM19)	Bolonha Lake	[35] [1]
71	*Nostoc* sp. (MCC41)	India	[36] [1]
72	*Nostoc commune*	Negev Desert, Israel	[37] [1]
73	*Nostoc verrucosum*	Hula Lake, Israel	[37] [1]
74	*Nostoc* sp.	Collema cristatum, lichen	[37] [1]
75	*Aphanizomenon klebahnii*	CCALA collection, Trebon, Czech Republic	[38] [2]
76	*Arthronema africanum*	CCALA collection, Trebon, Czech Republic	[38] [2]
77	*Arthrospira maxima*	CCALA collection, Trebon, Czech Republic	[38] [2]
78	*Spirulina platensis*	CCALA collection, Trebon, Czech Republic	[38] [2]
79	*Plectonema boryanum*	CCALA collection, Trebon, Czech Republic	[38] [2]
80	*Lyngbya arboricum*	CCALA collection, Trebon, Czech Republic	[38] [2]
81	*Microcystis aeruginosa*	CCALA collection, Trebon, Czech Republic	[38] [2]
82	*Nostoc calcicola*	CCALA collection, Trebon, Czech Republic	[38] [2]
83	*Scytonema ocellatum*	CCALA collection, Trebon, Czech Republic	[38] [2]
84	*Synechococcus elongatus*	CCALA collection, Trebon, Czech Republic	[38] [2]
85	*Synechococcus leopoliensis*	CCALA collection, Trebon, Czech Republic	[38] [2]
86	*Anabaena variabilis*	CCALA collection, Trebon, Czech Republic	[38] [2]
87	*Aphanizomenon flos-aquae*	Klamath Lake, USA	[39] [2]
88	*Aphanizomenon flos-aquae*	Upper Klamath Lake, USA	[39] [2]
89	*Aphanizomenon ovalisporum*	Tiberias Lake, Israel	[39] [2]
90	*Aphanizomenon flos-aquae*	Queen Elizabeth Reservoir, UK	[39] [2]
91	*Calothrix* sp.	West coast, India	[40] [1]
92	*Leptolyngbya* sp.	West coast, India	[40] [1]
93	*Oscillatoria marina*	West coast, India	[40] [1]
94	*Oscillatoria acuta*	West coast, India	[40] [1]
95	*Lyngbya* sp.	West coast, India	[40] [1]
96	*Spirulina platensis*	West coast, India	[40] [1]
97	*Nostoc muscorum*	West coast, India	[40] [1]
98	*Synechococcus* sp.	West coast, India	[40] [1]
99	*Pseudanabaena mucicola GO0704*	Nakdong River, South Korea	[41] [1]
100	*Microcystis aeruginosa* (CAAT 2005-3)	Buenos Aires, Argentina	[16] [1]
101	*Microcystis aeruginosa* (LTPNA 01)	São Paulo, Brazil	[14] [2]
102	Bloom material	São Paulo, Brazil	[14] [2]
103	*Microcystis aeruginosa* (CAAT 2005-3)	Buenos Aires, Argentina	[42] [1]
104	*Synechocystis* (PCC 6803)	-	[43] [3]
105	*Dolichospermum lemmermannii*	Baltic	[44] [1]
106	*Aphanizomenon flos-aquae* (KAC 15)	Baltic	[44] [1]
107	*Nodularia spumigena* (KAC 12)	Baltic	[44] [1]
108	*Nostoc piscinale* (CENA21)	Hunan and Hainan, China	[45] [1]
109	*Nostoc* sp. (NIES-3756)	Hunan and Hainan, China	[45] [1]
110	*Anabaena variabilis* (ATCC 29413)	Hunan and Hainan, China	[45] [1]
111	*Spirulina* sp. (LEB 18)	-	[46] [4]

Information was obtained through the following databases and search terms: [1] Science Direct: cyanobacteria fatty acids; [2] Web of Science: cyanobacteria and fatty acids; [3] Web of Science: cyanobacteria and fatty acids and biofuel. [4] Science Direct: cyanobacteria and fatty acids and biofuel.

Table 2. Saturated fatty acid composition of cyanobacteria selected for this review [1,2].

Code N.	4:0	6:0	8:0	10:0	12:0	13:0	14:0	15:0	16:0	17:0	18:0	20:0	22:0	23:0	24:0
1	-	1.02	-	-	7.60	6.7	1.92	-	18.55	-	-	-	-	1.23	-
2	1.23	-	-	8.88	6.33	1.65	-	19.56	-	-	-	-	1.06	-	1.23
3	-	1.33	-	-	9.22	7.4	2.2	-	21.70	-	-	-	-	1.04	-
4	-	1.08	-	-	7.60	6.9	3.12	-	19.44	-	-	-	-	1.78	-
5	-	-	-	0.12	0	-	1.17	0.18	53.16	-	3.44	0.13	0.16	-	0.06
6	-	-	-	0.03	0	-	0.99	0.15	51.41	-	2.98	0.18	0.17	-	0
7	-	-	-	0	0	-	1.38	0.30	52.71	-	4.40	0.19	0.26	-	0.12
8	-	-	-	-	0.1	-	30	1,5	165	-	1.5	-	-	-	-
9	-	-	-	-	0.1	-	308	0	131	-	1.5	-	-	-	-
10	-	-	-	-	0	-	0.4	0	230	-	1.5	-	-	-	-
11	-	-	-	-	-	-	4.4	-	30.3	-	1.0	-	-	-	-
12	-	-	-	-	-	-	5.6	-	29.1	-	1.5	-	-	-	-
13	-	-	-	-	-	-	2.8	-	26.0	-	1.3	-	-	-	-
14	-	-	-	-	-	-	5.0	-	39.5	-	0.8	-	-	-	-
15	-	-	-	-	-	-	4.4	-	36.0	-	1.0	-	-	-	-
16	-	-	-	-	-	-	3.8	-	37.4	-	1.8	-	-	-	-
17	-	-	-	-	-	-	2.7	-	37.0	-	0.8	-	-	-	-
18	-	-	-	-	-	-	2.0	-	37.0	-	0.8	-	-	-	-
19	-	-	-	-	-	-	2.6	-	39.7	-	1.0	-	-	-	-
20	-	-	-	-	-	-	3.7	-	42.1	-	1.7	-	-	-	-
21	-	-	-	-	-	-	5.3	-	36.5	-	1.1	-	-	-	-
22	-	-	-	-	-	-	4.7	-	35.3	-	1.6	-	-	-	-
23	-	-	-	-	-	-	4.2	-	33.6	-	1.8	-	-	-	-
24	-	-	-	-	-	-	5.5	-	38.4	-	0.6	-	-	-	-
25	-	-	-	-	-	-	5.7	-	41.6	-	1.0	-	-	-	-
26	-	-	-	-	-	-	3.3	-	46.1	-	1.9	-	-	-	-
27	-	-	-	-	-	-	3.2	-	37.0	-	0.7	-	-	-	-
28	-	-	-	-	-	-	3.2	-	40.8	-	1.2	-	-	-	-
29	-	-	-	-	-	-	2.8	-	35.1	-	0.8	-	-	-	-
30	-	-	-	-	-	-	3.2	-	37.0	-	1.0	-	-	-	-
31	-	-	-	-	-	-	2.7	-	40.1	-	1.1	-	-	-	-
32	-	-	-	-	-	-	2.7	-	43.4	-	tr	-	-	-	-
33	-	-	-	-	-	-	3.4	-	30.3	-	1.9	-	-	-	-
34	-	-	-	-	-	-	1.9	-	34.2	-	2.5	-	-	-	-
35	-	-	-	-	-	-	11.2	-	1.8	-	15.8	18.5	-	-	-
36	-	-	-	-	0.75	-	7.23	-	15.01	-	1.25	0	0	-	-
37	5.09	2.08	0	5.53	6.98	3.13	1.26	0	20.38	2.22	2.67	4.49	0	0	0
38	1.76	2.21	2.58	7.72	9.27	4.04	0.69	3.88	25.42	2.25	2.57	2.89	0	0	0
39	3.24	0.44	2.15	5.57	6.92	3.69	0.69	6.77	23.52	1.57	5.27	2.36	0.16	0	0
40	1.45	0.13	0.31	0.90	1.95	2.35	0.82	1.83	4.78	5.84	6.15	3.13	0	4.41	2.48
41	6.75	1.21	1.10	3.8	5.81	6.96	0.95	4.79	13.06	5.75	8.32	8.83	0	0	0
42	6.54	0.68	1.11	5.36	7.36	2.84	0.60	5.89	25.23	3.65	0.89	4.11	0	0	0
43	1.38	0.19	1.95	6.14	7.08	2.99	0.69	3.39	26.13	2.19	3.18	3.25	0.18	0	0
44	0	0	1.11	5.60	6.69	3.98	0.57	5.35	27.95	2.10	2.33	2.61	0	0	0
45	3.52	0.33	0.13	0.14	0.16	0.56	0	0.10	0.84	3.22	6.24	16.51	0	0	3.87
46	0.91	0.15	0	0	0.78	0.72	0	1.23	1.48	3.23	8.18	0.84	0	7.07	0
47	0	0	13.40	4.95	7.99	4.45	0.80	6.05	19.61	4.96	3.02	10.39	0	0	0
48	0	0.56	7.83	0.99	1.35	0	0	0	3.11	0.60	31.33	0.54	16.70	0	0
49	3.08	3.34	0	1.04	3.48	1.64	0	0	26.89	3.90	4.77	0	0	0	0
50	2.12	1.07	6.38	0.58	1.21	0.42	1.70	0.58	15.62	1.11	24.94	1.34	5.68	0.63	0.82
51	0.81	0.84	3.88	1.45	1.48	0	0	0	3.79	0.84	33.12	2.11	23.37	0	0
52	0.52	0.77	4.51	1.22	1.40	0	0.27	0	2.97	0.85	48.48	0.22	22.40	0	0
53	0.71	0.87	4.93	1.56	1.89	0	0.55	0.35	7.23	1.28	44.75	0.95	9.64	0	0
54	0.27	0.69	3.92	1.13	1.14	0	0	0.11	4.77	0.99	62.86	0.87	0	0	0
55	2.19	1.74	0	2.14	2.80	5.37	1.47	0	38.50	1.84	5.24	3.52	0	0	0
56	0.75	0.52	1.84	1.01	1.86	0.57	0.36	0.44	13.19	4.52	37.96	0.66	0.48	1.07	0.51
57	0.09	0.08	6.91	1.24	2.15	0	0	0.10	0.84	1.49	53.79	0.71	2.28	0	0.30
58	0.33	0.23	5.29	1.03	2.68	0	0	3.30	4.58	2.19	45.42	0.15	1.28	0	0.52

Table 2. *Cont.*

Code N.	4:0	6:0	8:0	10:0	12:0	13:0	14:0	15:0	16:0	17:0	18:0	20:0	22:0	23:0	24:0
59	0.17	0.54	2.24	0.92	1.12	0	0.18	0	4.56	0.72	64.85	0.73	8.43	0	0
60	0.60	0.26	10.15	0.76	0.82	0	0.27	0.18	2.58	0.56	44.95	0.15	4.39	0	0
61	1.22	0	3.19	2.90	6.69	0	0	0	5.73	4.95	34.84	1.21	2.37	0	1.43
62	0	0.51	0.37	0.66	2.13	0.92	2.57	0.56	26.42	11.21	3.50	0	14.06	0	0
63	-	-	8.96	0.58	0.67	0.43	1.17	1.20	14.39	4.03	10.93	0	0	2.06	-
64	-	-	3.31	0.33	0.65	0.19	0.26	0.08	23.47	3.88	1.23	1.20	1.23	0.52	-
65	-	-	2.95	0.19	0.51	2.43	0.40	0	21.84	3.88	0.53	0.70	2.38	0.42	-
66	-	-	5.58	1.08	3.38	0	1.35	0	37.39	0	4.80	0	0.46	0.88	-
67	-	-	0	1.83	13.37	1.01	1.75	0	25.34	6.89	1.50	2.69	6.13	2.04	-
68	0.60	-	-	0.83	41.91	-	27.96	0	11.35	0	3.42	0	0	-	-
69	0.09	-	-	0.14	22.12	-	25.41	0.11	17.01	0.14	4.52	0.11	0	-	-
70	0.15	-	-	0.18	27.48	-	26.81	0	17.85	0	5.86	0.25	0.08	-	-
71	-	-	-	-	0.3	-	0.9	-	34.9	0.4	2.0	0.6	-	-	0.3
72	0	0.2	0.3	0.5	0.9	0.6	2.4	1.2	20.7	0.7	1.9	0	-	-	-
73	0.2	0.2	0.2	0.2	0.6	0.3	2.8	1.1	23.7	0.2	3.2	-	-	-	-
74	0	0.3	0.1	0.2	0	0.2	1.8	0.4	19.6	0.3	2.6	-	-	-	-
75	-	-	-	-	-	-	0.5	-	29	-	0.3	-	-	-	-
76	-	-	-	-	-	-	0.1–0.9	-	26–40	-	0.3–1	-	-	-	-
77	-	-	-	-	-	-	0	-	52	-	1.5	-	-	-	-
78	-	-	-	-	-	-	1–3	-	41–55	-	0.1–0.9	-	-	-	-
79	-	-	-	-	-	-	0	-	44	-	4	-	-	-	-
80	-	-	-	-	-	-	1.8	-	26.8	-	5.5	-	-	-	-
81	-	-	-	-	-	-	0	-	48	-	0.4	-	-	-	-
82	-	-	-	-	-	-	3.3	-	27.5	-	3.5	-	-	-	-
83	-	-	-	-	-	-	1.8	-	29.1	-	6.5	-	-	-	-
84	-	-	-	-	-	-	0.4	-	42	-	0	-	-	-	-
85	-	-	-	-	-	-	0.3	-	38	-	0	-	-	-	-
86	-	-	-	-	-	-	1–3	-	45–55	-	0.3–0.9	-	-	-	-
87	0.19	0	0.08	0.19	0.44	-	13.70	3.15	32	0.68	0.51	-	-	-	-
88	0.15	0.18	0.09	0.11	0.26	-	12.71	1.51	36.98	0.18	1.74	-	-	-	-
89	0.11	0.24	0.12	0.21	0.31	-	2.01	0.95	40.13	0.22	1.14	-	-	-	-
90	0.05	0.16	0.13	0.29	0.18	-	3.22	0.84	43.09	0.31	0.98	-	-	-	-
91	-	-	-	-	-	-	-	-	26.95	-	3.99	-	-	-	-
92	-	-	-	-	-	-	-	-	13.74	-	4.73	-	3.57	-	-
93	-	-	-	-	-	-	0.21	-	18.74	-	4.74	0.65	1.60	-	-
94	-	-	-	-	-	-	-	-	13.61	-	8.53	-	-	-	-
95	-	-	-	-	-	-	1.23	-	26.49	-	3.24	-	-	-	-
96	-	-	-	-	-	-	-	-	22.53	-	5.21	-	5.52	-	-
97	-	-	-	-	-	-	-	-	26.89	-	-	-	-	-	-
98	-	-	-	-	-	-	-	-	8.74	-	-	-	-	-	-
99	-	-	-	-	<1.0	-	25.5	-	14.1	-	3.6	-	-	-	-
100	-	-	-	-	0.09	-	0.45	-	28.16	0.15	1.52	-	-	-	-
101	-	-	-	-	0	-	1.94	0.10	5.02	-	0.48	-	-	-	-
102	-	-	-	-	0.11	-	2.71	0.34	7.99	-	0.66	-	-	-	-
103	-	-	-	-	0.13	-	0.35	0.1	28	0.12	1.33	-	-	-	-
104	-	-	-	0	0	-	0	0	88.7	456.0	44.8	46.2	-	-	-
105	-	-	-	-	-	0.3	-	0	3.1	0	1.8	-	-	-	-
106	-	-	-	-	-	0.2	-	0	65.7	0.1	1.4	-	-	-	-
107	-	-	-	-	-	-	-	0	30.5	0	5.2	-	-	-	-
108	-	-	-	-	-	-	0.05	-	1.11	0	0.04	-	0.03	-	-
109	-	-	-	-	-	-	0.01	-	0.45	0.1	0.05	-	0.02	-	-
110	-	-	-	-	-	-	0	-	0.61	0	0.01	-	0	-	-
111	-	-	-	-	-	-	-	-	184.86	-	14.59	-	-	-	-

[1] Genus and/or species, collection point, and reference referred to each Code number are the same as in Table 1.
[2] Concentration unit: % for Code numbers from 1 to 99; μg/L for Code numbers from 100 to 104; μg/mm^3 for Code numbers from 105 to 107; mg/g for Code numbers from 108 to 111.

Table 3. Monounsaturated fatty acid composition of cyanobacteria selected for this review [1,2].

Code N.	14:1ω-9	16:1	16:1ω-7	16:1ω-9	17:1	18:1	18:1ω-9
1	9.23	8.56	-	-	-	10.20	-
2	8.65	9.44	-	-	-	12.49	-
3	9.11	10.40	-	-	-	13.47	-
4	8.70	9.69	-	-	-	11.42	-
5	-	-	7.11	-	-	-	-
6	-	-	3.46	-	-	-	-
7	-	-	7.25	-	-	-	-
8	8.6	-	0.3	373	-	-	0.1
9	3.1	-	0.4	415	-	-	3.4
10	0	-	3.5	0.7	-	-	3.3
11	-	4.2	-	-	-	2.5	
12	-	9.0	-	-	-	4.8	-
13	-	15.8	-	-	-	1.6	-
14	-	4.1	-	-	-	2.5	-
15	-	3.3	-	-	-	2.5	-
16	-	2.3	-	-	-	3.2	-
17	-	16.1	-	-	-	0.8	-
18	-	14.0	-	-	-	0.8	-
19	-	6.6	-	-	-	7.6	-
20	-	3.1	-	-	-	10.8	-
21	-	6.0	-	-	-	3.3	-
22	-	3.3	-	-	-	1.1	-
23	-	2.3	-	-	-	3.2	-
24	-	4.8	-	-	-	2.1	-
25	-	5.1	-	-	-	2.1	-
26	-	2.7	-	-	-	1.3	-
27	-	3.4	-	-	-	2.6	-
28	-	3.0	-	-	-	2.5	-
29	-	3.4	-	-	-	3.5	-
30	-	3.7	-	-	-	4.5	-
31	-	17.2	-	-	-	0.9	-
32	-	17.1	-	-	-	2.2	-
33	-	2.7	-	-	-	2.3	-
34	-	11.8	-	-	-	5.0	-
35	-	6.6	-	-	-	27.2	-
36	0.63	2.16	-	-	-	-	8.49
37	0	0	-	-	-	-	2.46
38	0	0.17	-	-	-	-	1.86
39	0	0.80	-	-	-	-	1.02
40	0	0.17	-	-	-	-	11.18
41	0	2.14	-	-	-	-	2.76
42	0	0.72	-	-	-	-	0.79
43	0	0.38	-	-	-	-	3.73
44	0	0.20	-	-	-	-	2.15
45	0	0	-	-	-	-	13.57
46	0	0.13	-	-	-	-	12.07
47	0	1.35	-	-	-	-	1.82
48	1.15	15.37	-	-	n.d. [3]	-	1.02
49	4.13	3.39	-	-	n.d.	-	3.02
50	0.87	8.69	-	-	n.d.	-	1.09
51	1.47	5.98	-	-	0.28	-	0.91
52	1.36	4.36	-	-	n.d.	-	0.18
53	1.85	9.15	-	-	n.d.	-	0.44
54	1.02	2.73	-	-	0.66	-	0.34
55	2.40	2.34	-	-	n.d.	-	2.67
56	2.09	2.60	-	-	1.33	-	0.89
57	2.07	2.95	-	-	0.43	-	0.21
58	2.88	3.29	-	-	n.d.	-	0.58

Table 3. *Cont.*

Code N.	14:1ω-9	16:1	16:1ω-7	16:1ω-9	17:1	18:1	18:1ω-9
59	1.06	2.12	-	-	0.73	-	0.51
60	0.91	5.65	-	-	n.d.	-	0.34
61	6.27	2.05	-	-	6.22	-	1.42
62	0.52	1.04	-	-	0	-	3.97
63	5.89	5.34	-	-	2.70	-	0
64	2.26	22.22	-	-	1.23	-	3.04
65	1.92	6.13	-	-	1.41	-	3.74
66	4.57	0	-	-	2.99	-	1.11
67	4.05	1.46	-	-	0	-	3.64
68	-	-	-	-	-	12.79	-
69	-	-	-	-	-	16.21	-
70	-	-	-	-	-	15.91	-
71	-	15.8	-	-	-	12	-
75	0	32.8	-	-	-	10.4	-
76	0	18–36	-	-	-	3–20	-
77	0	4	-	-	-	3	-
78	1–2	5–18	-	-	-	4–9	-
79	0	25	-	-	-	12	-
80	1.1	24.4	-	-	-	9.7	-
81	0	9	-	-	-	3.6	-
82	0	10.5	-	-	-	32.5	-
83	0	15.8	-	-	-	16.6	-
84	2.6	46	-	-	-	8	-
85	2.6	49	-	-	-	8	-
86	1–2	5	-	-	-	4–9	-
87	-	-	-	2.39	-	-	20.94
88	-	-	-	1.02	-	-	19.95
89	-	-	-	2.34	-	-	26.71
90	-	-	-	1.85	-	-	26.07
91	-	-	6.55	-	-	-	55.52
92	-	-	1.53	-	-	-	69.52
93	-	-	2.01	-	-	-	63.15
94	-	-	0.0	-	-	-	68.68
95	-	-	5.37	-	-	-	54.53
96	-	-	2.34	-	-	-	56.54
97	-	-	-	-	-	-	54.01
98	-	-	82.12	-	-	-	1.73
99	< 1.0	8.1	-	-	-	23.1	-
100	0.14	-	1.12	-	0.11	-	-
101	-	-	0.12	-	-	-	0.45
102	-	-	0.12	-	-	-	4.19
103	-	-	-	1.26	0.12	-	1.81
104	0	0	-	-	0	44.8	-
105	-	-	1.3	-	-	-	-
106	-	-	0.1	-	-	-	-
107	-	-	5.8	-	-	-	-
108	-	1.10	-	-	-	0.22	-
109	-	0.61	-	-	-	0.14	-
110	-	0.67	-	-	-	0	-
111	-	-	10.69	-	-	-	79.58

[1] Genus and/or species, collection point, and reference referred to each Code number are the same as in Table 1.
[2] Concentration unit: % for Code numbers from 1 to 99; μg/L for Code numbers from 100 to 104; μg/mm^3 for Code numbers from 105 to 107; mg/g for Code numbers from 108 to 111. [3] n.d. = not determined.

Table 4. Polyunsaturated fatty acid composition of cyanobacteria selected for this review [1,2].

Code N.	16:2	16:3	18:2	18:3	18:2ω-6	18:3ω-6	18:3ω-3	18:4ω-3	20:2	20:3
1	-	-	8.10	11.68	-	-	-	-	2.34	3.97
2	-	-	6.78	13.20	-	-	-	-	1.20	5.76
3	-	-	5.80	11.80	-	-	-	-	1.56	3.40
4	-	-	6.10	12.06	-	-	-	-	1.96	2.87
5	-	-	-	-	0.69	0.10	0.05	0	-	-
6	-	-	-	-	0.32	0.02	0.04	0	-	-
7	-	-	-	-	1.76	0	0.21	0	-	-
11	5.3	8.5	6.2	35.6	-	-	-	-	-	-
12	3.8	3.1	11.2	29.8	-	-	-	-	-	-
13	0	0	10,7	41.9	-	-	-	-	-	-
14	4.9	3,8	11.0	26.2	-	-	-	-	-	-
15	4.7	4.0	13.4	58.6	-	-	-	-	-	-
16	3.5	4.8	1.09	30.2	-	-	-	-	-	-
17	0	0	7.6	35.0	-	-	-	-	-	-
18	0	0	9.1	36.1	-	-	-	-	-	-
19	2.1	3.4	9.8	24.7	-	-	-	-	-	-
20	2.5	4.4	5.8	21.3	-	-	-	-	-	-
21	3.4	6.3	6.8	30.3	-	-	-	-	-	-
22	5.9	8.8	10.1	27.1	-	-	-	-	-	-
23	3.5	4.8	10.9	25.4	-	-	-	-	-	-
24	5.4	4.7	9.4	26.5	-	-	-	-	-	-
25	4.6	4.4	8.2	24.9	-	-	-	-	-	-
26	2.3	4.2	5.7	31.0	-	-	-	-	-	-
27	6.3	4.2	14.1	25.8	-	-	-	-	-	-
28	6.4	3.4	13.9	22.8	-	-	-	-	-	-
29	6.3	4.2	15.5	25.3	-	-	-	-	-	-
30	6.0	3.3	16.2	21.1	-	-	-	-	-	-
31	0	0	7.4	31.5	-	-	-	-	-	-
32	0	0	3.5	30.6	-	-	-	-	-	-
33	4.8	6.0	10.9	36.2	-	-	-	-	-	-
34	0	0	6.1	35.2	-	-	-	-	-	-
35	-	-	2.19	13.8	-	-	-	-	-	-
36	-	-	-	-	8.14	-	33.81	-	-	-
37	-	-	-	-	5.74	15.35	0	-	0	-
38	-	-	-	-	2.93	8.53	0	-	0	-
39	-	-	-	-	5.17	11.66	0	-	0	-
40	-	-	-	-	3.01	10.31	0	-	0	-
41	-	-	-	-	4.62	2.28	0	-	0	-
42	-	-	-	-	2.64	2.57	1.93	-	0	-
43	-	-	-	-	1.75	11.54	0	-	0	-
44	-	-	-	-	2.94	5.86	0	-	0	-
45	-	-	-	-	16.22	0	13.99	-	0	-
46	-	-	-	-	15.96	15.06	0	-	0	-
47	-	-	-	-	3.02	2.75	0	-	0	-
48	-	-	-	-	2.69	0.40	0	-	3.22	-
49	-	-	-	-	0	1.92	0	-	0	-
50	-	-	-	-	0	1.18	0.69	-	0	-
51	-	-	-	-	1.61	0.59	0	-	1.67	-
52	-	-	-	-	0.87	0.46	0	-	0.78	-
53	-	-	-	-	0	1.55	0	-	0	-
54	-	-	-	-	0.31	0.29	5.11	-	0	-
55	-	-	-	-	0	0	4.68	-	0	-
56	-	-	-	-	0.40	0	2.52	-	0	-
57	-	-	-	-	0.08	0.12	0	-	0	-
58	-	-	-	-	0.21	0.15	17.84	-	0.13	-
59	-	-	-	-	0.49	0.22	3.49	-	0	-
60	-	-	-	-	0	0.26	1.73	-	0	-
61	-	-	-	-	0	2.78	0	-	0	-

Table 4. *Cont.*

Code N.	16:2	16:3	18:2	18:3	18:2ω-6	18:3ω-6	18:3ω-3	18:4ω-3	20:2	20:3
62	-	-	-	-	6.15	0	0	-	0	-
63	-	-	-	-	3.16	0	0	-	0.65	-
64	-	-	-	-	0.31	0.88	2.27	-	1.33	-
65	-	-	-	-	0.27	0.15	2.10	-	2.08	-
66	-	-	-	-	2.00	0	0	-	3.55	-
67	-	-	-	-	4.85	0	0	-	0	-
68	0	0.21	0.68	-	-	-	-	-	-	-
69	4.41	5.46	1.61	-	-	-	-	-	-	-
70	0	1.41	1.96	-	-	-	-	-	-	-
71	1.3	1	10.6	19	-	-	-	-	-	-
75	-	-	18.7	8.2	-	-	-	-	-	-
76	-	-	4–30	0.5–33	-	-	-	-	-	-
77	-	-	17.4	21.4	-	-	-	-	-	-
78	-	-	5–15	17–48	-	-	-	-	-	-
79	-	-	14	5	-	-	-	-	-	-
80	-	-	26	4.8	-	-	-	-	-	-
81	-	-	19.5	20	-	-	-	-	-	-
82	-	-	18.4	4.3	-	-	-	-	-	-
83	-	-	23.2	6.3	-	-	-	-	-	-
86	-	-	5–15	15–20	-	-	-	-	-	-
91	-	-	-	-	6.94	-	-	-	-	-
92	-	-	-	-	5.36	-	1.56	-	-	-
93	-	-	-	-	8.90	-	-	-	-	-
94	-	-	-	-	9.17	-	-	-	-	-
95	-	-	-	-	4.00	-	5.15	-	-	-
96	-	-	-	-	7.74	-	-	-	-	-
97	-	-	-	-	7.85	-	11.24	-	-	-
98	-	-	-	-	5.45	-	1.94	-	-	-
99	-	-	20.3	4.3	-	-	-	-	-	-
100	-	-	-	-	2.81	4.14	2.78	4.09	-	-
101	-	-	-	-	0.12	-	-	-	-	-
102	-	-	-	-	0.28	-	-	-	-	-
103	-	-	-	-	3.6	5.3	2.12	3.7	-	-
104	-	-	81.8	160.6	-	-	-	-	-	-
105	-	-	-	-	0.6	0	0.9	0.1	-	-
106	-	-	-	-	0.5	0.5	2.7	0	-	-
107	-	-	-	-	2.8	0.9	7	9.2	-	-
108	-	-	0.36	0.71	-	-	-	-	-	-
109	-	-	0.49	0.54	-	-	-	-	-	-
110	-	-	0.28	0.73	-	-	-	-	-	-
111	-	-	-	-	41.37	-	-	-	-	-

[1] Genus and/or species, collection point, and reference referred to each Code number are the same as in Table 1.
[2] Concentration unit: % for Code numbers from 1 to 99; μg/L for Code numbers from 100 to 104; μg/mm^3 for Code numbers from 105 to 107; mg/g for Code numbers from 108 to 111.

Table 5. Lipid content in cyanobacteria selected for this review [17,28,32,35,36,40,41,45,47–67] [1].

Code N.	Genus and/or Species	Lipids	Collection Point	Platform (Search Term)	Reference
1	*Oscillatoria* sp. (U-55)	31.9	Sri Lanka	ScienceDirect (cyanobacteria lipids)	[47]
2	*Synechococcus* sp. (Sub-10)	30.6	Sri Lanka	ScienceDirect (cyanobacteria lipids)	[47]
3	*Chroococcidiopsis* sp. (Sub-16)	22.7	Sri Lanka	ScienceDirect (cyanobacteria lipids)	[47]
4	*Leptolyngbya* sp. (U-1)	21.15	Sri Lanka	ScienceDirect (cyanobacteria lipids)	[47]
5	*Limnothrix* sp. (U-67)	20.73	Sri Lanka	ScienceDirect (cyanobacteria lipids)	[47]

Table 5. *Cont.*

Code N.	Genus and/or Species	Lipids	Collection Point	Platform (Search Term)	Reference
6	*Calothrix* sp.	18.15	Sri Lanka	ScienceDirect (cyanobacteria lipids)	[47]
7	*Nostoc* sp.	15.43	Sri Lanka	ScienceDirect (cyanobacteria lipids)	[47]
8	*Cephalothrix* sp.	13.95	Sri Lanka	ScienceDirect (cyanobacteria lipids)	[47]
9	*Cephalothrix komarekiana* (U-41)	13.8	Sri Lanka	ScienceDirect (cyanobacteria lipids)	[47]
10	*Westiellopsis prolifica* (U-58)	12.80	Sri Lanka	ScienceDirect (cyanobacteria lipids)	[47]
11	*Dolichospermum affine*	10.67	Ankara, Turkey	GoogleScholar (cyanobacteria lipids)	[48]
12	*Nostoc* sp. (MCC41)	15.69	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
13	*Nostoc* sp. (g17)	9.62	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
14	*Nostoc* sp. (g15)	9.85	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
15	*Nostoc muscorum*	8.45	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
16	*Nostoc calcicola*	6.55	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
17	*Anabaena* sp. (g24)	16.15	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
18	*Anabaena* sp. (g19)	9.88	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
19	*Anabaena doliolum*	9.02	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
20	*Tolypothrix* sp.	7.74	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
21	*Synechocystis* sp.	3.61	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
22	*Westiellopsis* sp.	9.3	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
23	*Anabaena* sp. (g14)	3.28	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
24	*Anabaena fertilissima*	7.6	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
25	*Anabaena cilíndrica*	6.95	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
26	*Anabaena cycadeae*	9.75	Chennai, Tamil Nadu e Sambhar Lake, Rajasthan, India	ScienceDirect (cyanobacteria lipids)	[36]
27	*Cyanobacterium* sp. (IPPASB-1200)	22	-	-	[28]
28	*Desertifilum* sp. (IPPASB-1220)	19	-	-	[28]
29	*Cyanobacterium aponinum* (IPPAS B-1201)	15	-	ScienceDirect (cyanobacteria lipids)	[28]
30	*Cyanobium* sp.	5.48	Tucuruí Hydroelectric Reservoir and Lagoa Bolonha	ScienceDirect (cyanobacteria lipids)	[35]
31	*Limnothrix* sp.	9.12	Tucuruí Hydroelectric Reservoir and Lagoa Bolonha	ScienceDirect (cyanobacteria lipids)	[35]
32	*Limnothrix* sp.	7.87	Tucuruí Hydroelectric Reservoir and Lagoa Bolonha	ScienceDirect (cyanobacteria lipids)	[35]
33	*Nostoc* sp.	0.43	Tucuruí Hydroelectric Reservoir and Lagoa Bolonha	ScienceDirect (cyanobacteria lipids)	[35]

Table 5. *Cont.*

Code N.	Genus and/or Species	Lipids	Collection Point	Platform (Search Term)	Reference
34	*Nostoc* sp.	1.74	Tucuruí Hydroelectric Reservoir and Lagoa Bolonha	ScienceDirect (cyanobacteria lipids)	[35]
35	*Cyanobium* sp.	0.5	Tucuruí Hydroelectric Reservoir and Lagoa Bolonha	ScienceDirect (cyanobacteria lipids)	[35]
36	*Synechocystis* (PCC 6803)	13.1	University of Allahabad, Uttar Pradesh, India	ScienceDirect (cyanobacteria lipids)	[49]
37	*Synechococcus* (PCC 7942)	11.0	University of Allahabad, Uttar Pradesh, India	ScienceDirect (cyanobacteria lipids)	[49]
38	*Nostoc muscorum*	7.5	University of Allahabad, Uttar Pradesh, India	Web of Science (cyanobacteria lipids)	[49]
39	*Oscillatoria* sp.	8.9	University of Allahabad, Uttar Pradesh, India	Web of Science (cyanobacteria lipids)	[49]
40	*Anabaena cylindrica*	4.8	University of Allahabad, Uttar Pradesh, India	Web of Science (cyanobacteria lipids)	[49]
41	*Lyngbya* sp.	10.3	University of Allahabad, Uttar Pradesh, India	Web of Science (cyanobacteria lipids)	[49]
42	*Phormidium* sp.	8.4	University of Allahabad, Uttar Pradesh, India	Web of Science (cyanobacteria lipids)	[49]
43	*Synechococcus* sp.	6–11	Garhwal Himalaya, Uttarakhand, India	ScienceDirect (cyanobacteria lipids)	[50]
44	*Gloeothece* sp.	6–11	Garhwal Himalaya, Uttarakhand, India	ScienceDirect (cyanobacteria lipids)	[50]
45	*Lyngbya* sp.	2.5–8	Garhwal Himalaya, Uttarakhand, India	ScienceDirect (cyanobacteria lipids)	[50]
46	*Pseudanabaena* sp.	2–7.5	Garhwal Himalaya, Uttarakhand, India	ScienceDirect (cyanobacteria lipids)	[50]
47	*Phormidium* sp.	2–8.5	Garhwal Himalaya, Uttarakhand, India	ScienceDirect (cyanobacteria lipids)	[50]
48	*Oscillatoria* sp.	2–4	Garhwal Himalaya, Uttarakhand, India	ScienceDirect (cyanobacteria lipids)	[50]
49	*Leptolyngbya* sp.	4–10.5	Garhwal Himalaya, Uttarakhand, India	ScienceDirect (cyanobacteria lipids)	[50]
50	*Nostoc piscinale* CENA21 (B)	8.22	-	ScienceDirect (cyanobacteria lipids)	[45]
51	*Nostoc piscinale* CENA21 (B-BS)	5.55	-	ScienceDirect (cyanobacteria lipids)	[45]
52	*Nostoc* sp. NIES-3756 (J)	6.51	-	ScienceDirect (cyanobacteria lipids)	[45]
53	*Nostoc* sp. NIES-3756 (J-BS)	7.97	-	ScienceDirect (cyanobacteria lipids)	[45]
54	*Anabaena variabilis* ATCC 29413 (L)	4.91	-	ScienceDirect (cyanobacteria lipids)	[45]
55	*Anabaena variabilis* ATCC 29413 (L-BS)	4.82	-	ScienceDirect (cyanobacteria lipids)	[45]
56	*Phormidium* sp. (FW01)	6.7	-	ScienceDirect (cyanobacteria lipids)	[17]
57	*Phormidium* sp. (FW02)	8.2	-	ScienceDirect (cyanobacteria lipids)	[17]
58	*Oscillatoria* sp. (FW01)	10.2	-	ScienceDirect (cyanobacteria lipids)	[17]
59	*Oscillatoria* sp. (FW02)	9.4	-	ScienceDirect (cyanobacteria lipids)	[17]
60	*Chrysotila pseudoroscoffensis*	6.4	-	ScienceDirect (cyanobacteria lipids)	[51]

Table 5. *Cont.*

Code N.	Genus and/or Species	Lipids	Collection Point	Platform (Search Term)	Reference
61	*Spirulina* sp. (LEB18)	12.77	-	ScienceDirect (cyanobacteria lipids)	[52]
62	*Synechococcus elongatus*	18.5	Hot spring of Ramsar, north of Iran	ScienceDirect (cyanobacteria lipids)	[53]
63	*Oscillatoria calcuttensis*	20	Western Ghats region of Dakshina Kannada district of Karnataka, Southern India	Scielo (cyanobacteria lipids)	[54]
64	*Synechococcus* sp. (PCC 7942)	26.9	-	GoogleScholar (cyanobacteria lipids)	[55]
65	*Microcystis aeruginosa* (NPCD-1)	28.0	-	GoogleScholar (cyanobacteria lipids)	[55]
66	*Trichormus* sp. (CENA77)	23.7	-	GoogleScholar (cyanobacteria lipids)	[55]
67	*Leptolyngbya foveolarum* (HNBGU-001)	32.10	Garhwal Himalaya	GoogleScholar (cyanobacteria lipids)	[56]
68	*Synechocystis* sp. (CACIAM05)	15.3–25.6	Hydroelectric plant of Tucuruí Lake and the Bologna reservoir	PubMed (cyanobacteria lipids)	[57]
69	*Microcystis aeruginosa* (CACIAM08)	12.37–43.97	Hydroelectric plant of Tucuruí Lake and the Bologna reservoir	PubMed (cyanobacteria lipids)	[57]
70	*Pantanalinema rosaneae* (CACIAM18)	20.6–37.9	Hydroelectric plant of Tucuruí Lake and the Bologna reservoir	PubMed (cyanobacteria lipids)	[57]
71	*Limnothrix* sp. (CACIAM25)	7.0–58.3	Hydroelectric plant of Tucuruí Lake and the Bologna reservoir	PubMed (cyanobacteria lipids)	[57]
72	*Arthrospira platensis*	30.23	-	PubMed (cyanobacteria lipids)	[58]
73	*Oscillatoria calcuttensis*	25.70	Mangalore dairy effluents	GoogleScholar (cyanobacteria lipid content)	[59]
74	*Oscillatoria acuminata*	24.65	Water tank at Malavalli of Mandya District	GoogleScholar (cyanobacteria lipid content)	[59]
75	*Nostoc linckia*	18.45	Kukkarahalli tank of Mysore	GoogleScholar (cyanobacteria lipid content)	[59]
76	*Calothrix fusca*	22.60	Sulfur spring in Dakshina Kannada District	GoogleScholar (cyanobacteria lipid content)	[59]
77	*Lyngbya limnetica*	18.10	Sulfur spring in Dakshina Kannada District	GoogleScholar (cyanobacteria lipid content)	[59]
78	*Phormidium purpurascens*	26.45	Sulfur spring in Dakshina Kannada District	GoogleScholar (cyanobacteria lipid content)	[59]
79	*Microcystis aeruginosa*	28.15	Kukkarahalli tank of Mysore	GoogleScholar (cyanobacteria lipid content)	[59]
80	*Lyngbya dendrobia*	10.55	Shimsha reservoir of Mandya District	GoogleScholar (cyanobacteria lipid content)	[59]
81	*Oscillatoria perornata*	14.10	Kukkarahalli tank of Mysore	GoogleScholar (cyanobacteria lipid content)	[59]
82	*Phormidium ambiguum*	10.48	Bhadra reservoir of Chikmagalur District	GoogleScholar (cyanobacteria lipid content)	[59]
83	*Oscillatoria amoena*	18.63	Hemavathi reservoir of Hassan District	GoogleScholar (cyanobacteria lipid content)	[59]
84	*Scytonema bohnerii*	22.22	Sulfur spring in Dakshina Kannada District	GoogleScholar (cyanobacteria lipid content)	[59]
85	*Oscillatoria chlorina*	16.62	Sewage drain of Mangalore	GoogleScholar (cyanobacteria lipid content)	[59]
86	*Synechococcus* sp.	42.8	-	GoogleScholar (cyanobacteria lipid content)	[60]
87	*Cyanobacterium aponinum*	45.0	-	GoogleScholar (cyanobacteria lipid content)	[60]

Table 5. *Cont.*

Code N.	Genus and/or Species	Lipids	Collection Point	Platform (Search Term)	Reference
88	*Phormidium* sp.	38.2	-	GoogleScholar (cyanobacteria lipid content)	[60]
89	*Calothrix* sp. (MBDU 013)	11.2	Rice fields and freshwater ponds in Tiruchirappalli and Thanjavur, Tamil Nadu, India	GoogleScholar (cyanobacteria lipid content)	[32]
90	*Nostoc* sp. (MBDU 013)	6.7	Rice fields and freshwater ponds in Tiruchirappalli and Thanjavur, Tamil Nadu, India	GoogleScholar (cyanobacteria lipid content)	[32]
91	*Calothrix dolichomeres* (MBDU 013)	10.3	Rice fields and freshwater ponds in Tiruchirappalli and Thanjavur, Tamil Nadu, India	GoogleScholar (cyanobacteria lipid content)	[32]
92	*Calothrix linearis* (MBDU 005)	6.4	Rice fields and freshwater ponds in Tiruchirappalli and Thanjavur, Tamil Nadu, India	GoogleScholar (cyanobacteria lipid content)	[32]
93	*Nostoc piscinale* (MBDU 013)	4.6	Rice fields and freshwater ponds in Tiruchirappalli and Thanjavur, Tamil Nadu, India	GoogleScholar (cyanobacteria lipid content)	[32]
94	*Anabaena* sp. (MBDU 006)	8.6	Rice fields and freshwater ponds in Tiruchirappalli and Thanjavur, Tamil Nadu, India	GoogleScholar (cyanobacteria lipid content)	[32]
95	*Nostoc* sp. (MBDU 007)	9.5	Rice fields and freshwater ponds in Tiruchirappalli and Thanjavur, Tamil Nadu, India	GoogleScholar (cyanobacteria lipid content)	[32]
96	*Synechocystis* sp.	44.7	-	GoogleScholar (cyanobacteria lipid content)	[61]
97	*Pseudanabaena* sp. (SK01)	12.85	Lake water samples, southern areas of Iran, and an urban lake in the north of Iran	GoogleScholar (cyanobacteria lipid content)	[62]
98	*Pseudanabaena* sp. (SK02)	7.4	Lake water samples, southern areas of Iran, and an urban lake in the north of Iran	GoogleScholar (cyanobacteria lipid content)	[62]
99	*Synechococcus* sp. (HS01)	12.33	Lake water samples, southern areas of Iran, and an urban lake in the north of Iran	GoogleScholar (cyanobacteria lipid content)	[62]
100	*Pseudanabaena* sp. (SK03)	15.66	Lake water samples, southern areas of Iran, and an urban lake in the north of Iran	GoogleScholar (cyanobacteria lipid content)	[62]
101	*Nodosilinea* sp. (AK01)	8.33	Lake water samples, southern areas of Iran, and an urban lake in the north of Iran	GoogleScholar (cyanobacteria lipid content)	[62]
102	*Plectonema terebrans* (BERC10)	33–49	Wastewater sample showing greenish growth, Faisalabad, Punjab, Pakistan	GoogleScholar (cyanobacteria lipid content)	[63]
103	*Calothrix* sp.	3.42	West coast, India	GoogleScholar (cyanobacteria lipid content)	[40]
104	*Leptolyngbya* sp.	3.23	West coast, India	GoogleScholar (cyanobacteria lipid content)	[40]
105	*Oscillatoria marina*	6.61	West coast, India	GoogleScholar (cyanobacteria lipid content)	[40]
106	*Oscillatoria acuta*	4.47	West coast, India	GoogleScholar (cyanobacteria lipid content)	[40]
107	*Lyngbya* sp.	2.52	West coast, India	GoogleScholar (cyanobacteria lipid content)	[40]
108	*Spirulina platensis*	7.75	West coast, India	GoogleScholar (cyanobacteria lipid content)	[40]

Table 5. *Cont.*

Code N.	Genus and/or Species	Lipids	Collection Point	Platform (Search Term)	Reference
109	*Nostoc muscorum*	3.22	West coast, India	GoogleScholar (cyanobacteria lipid content)	[40]
110	*Synechococcus* sp.	4.20	West coast, India	GoogleScholar (cyanobacteria lipid content)	[40]
111	*Synechocystis* sp. *CCNM 2501*	16.34	Brackish waters of Diu, India	ScienceDirect (cyanobacteria lipids)	[64]
112	*Microcystis aeruginosa*	18.5	Wangsong Reservoir, Korea	ScienceDirect (cyanobacteria lipids)	[65]
113	*Pseudanabaena mucicola GO0704*	18	Nakdong River, South Korea	ScienceDirect (cyano-bacteria lipids)	[41]
114	*Synechocystis salina*	13.9	-	ScienceDirect (cyanobacteria lipids)	[66]
115	*Oscillatoria subbrevis*	11.2	Urban area of Silchar town of Cachar district, Assam, India	GoogleScholar (cyanobacteria lipids)	[67]
116	*Cylindrospermum muscicola*	4.2	Urban area of Silchar town of Cachar district, Assam, India	GoogleScholar (cyanobacteria lipids)	[67]
117	*Phormidium lucidum*	8.7	Urban area of Silchar town of Cachar district, Assam, India	GoogleScholar (cyanobacteria lipids)	[67]
118	*Lyngbya diguetii*	7.3	Urban area of Silchar town of Cachar district, Assam, India	GoogleScholar (cyanobacteria lipids)	[67]
119	*Nostoc carneum*	5.1	Urban area of Silchar town of Cachar district, Assam, India	GoogleScholar (cyanobacteria lipids)	[67]

[1] Concentration unit: % for Code numbers from 1 to 113; mg/g for Code number 114; and µg/mL for Code numbers from 115 to 119.

Table 6. Carbohydrate content in cyanobacteria selected for this review [15,41,49,64,68–75] [1].

Code N.	Genus and/or Species	Carbo-Hydrate	Collection Point	Platform (Search Term)	Reference
1	Wastewater-borne cyanobacteria	69	-	ScienceDirect (cyanobacteria carbohydrate)	[15]
2	*Synechocystis* sp.	68.9	-	ScienceDirect (cyanobacteria carbohydrate)	[15]
3	*Arthrospira platensis*	65	-	ScienceDirect (cyanobacteria carbohydrate)	[15]
4	*Synechocystis* sp. (PCC 6803)	39	-	ScienceDirect (cyanobacteria carbohydrate)	[15]
5	*Synechococcus* sp.	68.9	-	ScienceDirect (cyanobacteria carbohydrate)	[15]
6	*Synechococcus elongatus* (PCC 7942)	28	-	ScienceDirect (cyanobacteria carbohydrate)	[15]
7	*Synechococcus* sp.	59	-	ScienceDirect (cyanobacteria carbohydrate)	[15]
8	*Arthrospira platensis*	58	-	ScienceDirect (cyanobacteria carbohydrate)	[15]
9	*Leptolyngbya* sp.	40	-	ScienceDirect (cyanobacteria carbohydrate)	[15]
10	*Synechococcus* (PCC 7002)	25	-	ScienceDirect (cyanobacteria carbohydrate)	[15]
11	Synechococcus (PCC 7002)	60	-	ScienceDirect (cyanobacteria carbohydrate)	[15]

Table 6. *Cont.*

Code N.	Genus and/or Species	Carbo-Hydrate	Collection Point	Platform (Search Term)	Reference
12	Wastewater-borne cyanobacteria	48	-	ScienceDirect (cyanobacteria carbohydrate)	[15]
13	*Gleiterinema* sp.	54	-	ScienceDirect (cyanobacteria carbohydrate)	[15]
14	Cyanobacteria dominated culture	69	-	ScienceDirect (cyanobacteria carbohydrate)	[15]
15	*Synechococcus* (PCC 7002)	60	-	ScienceDirect (cyanobacteria carbohydrate)	[15]
16	*Synechococcus elongatus* (PCC 7942)	28–35	-	ScienceDirect (cyanobacteria carbohydrate)	[68]
17	*Synechococcus* sp. (PCC 7002)	59	-	ScienceDirect (cyanobacteria carbohydrate)	[68]
18	*Spirulina* sp.	20	-	ScienceDirect (cyanobacteria carbohydrate)	[69]
19	*Spirulina maxima*	13–16	-	ScienceDirect (cyanobacteria carbohydrate)	[69]
20	*Synechococcus* sp.	15	-	ScienceDirect (cyanobacteria carbohydrate)	[69]
21	*Anabaena cylindrical*	25–30	-	ScienceDirect (cyanobacteria carbohydrate)	[69]
22	*Arthrospira platensis*	65	California, USA	ScienceDirect (cyanobacteria carbohydrate)	[70]
23	*Spirulina platensis*	63–65	California, USA	ScienceDirect (cyanobacteria carbohydrate)	[70]
24	*Synechocystis* sp. (PCC 6803)	28.9–36.8	California, USA	ScienceDirect (cyanobacteria carbohydrate)	[70]
25	*Spirulina maxima*	23–70	California, USA	ScienceDirect (cyanobacteria carbohydrate)	[70]
26	*Leptolyngbya* sp.	48.2	Pratas, Greece	ScienceDirect (cyanobacteria carbohydrate)	[71]
27	*Leptolyngbya*	43	Pakistan	ScienceDirect (cyanobacteria carbohydrate)	[72]
28	*Synechococcus*	54	Pakistan	ScienceDirect (cyanobacteria carbohydrate)	[72]
29	*Leptolyngbya valderiana* (BDU 41001)	34.2	Bathidasan University, Tiruchirappalli, Tamil Nadu, India	ScienceDirect (cyanobacteria carbohydrate)	[73]
30	*Nostoc* sp. (BDU 0051)	27.9	Bathidasan University, Tiruchirappalli, Tamil Nadu, India	ScienceDirect (cyanobacteria carbohydrate)	[73]
31	*Oscillatoria formosa* (BDU 91041)	33.3	Bathidasan University, Tiruchirappalli, Tamil Nadu, India	ScienceDirect (cyanobacteria carbohydrate)	[73]

Table 6. *Cont.*

Code N.	Genus and/or Species	Carbo-Hydrate	Collection Point	Platform (Search Term)	Reference
32	*Oscillatoria salina* (BDU 10142)	31.3	Bathidasan University, Tiruchirappalli, Tamil Nadu, India	ScienceDirect (cyanobacteria carbohydrate)	[73]
33	*Synechococcus elongatus* (BDU 141741)	30.0	Bathidasan University, Tiruchirappalli, Tamil Nadu, India	ScienceDirect (cyanobacteria carbohydrate)	[73]
34	*Spirulina subsalsa* (BDU 30311)	30.7	Bathidasan University, Tiruchirappalli, Tamil Nadu, India	ScienceDirect (cyanobacteria carbohydrate)	[73]
35	*Arthrospira platensis* (SAG 21.99)	16–60	-	PubMed (cyanobacteria carbohydrate)	[74]
36	*Arthrospira platensis* (NIES-39)	18–65	-	PubMed (cyanobacteria carbohydrate)	[74]
37	*Arthrospira platensis* (CS-328)	20–50	-	PubMed (cyanobacteria carbohydrate)	[74]
38	*Synechococcus* sp. (PCC 7002)	48–62	-	PubMed (cyanobacteria carbohydrate)	[74]
39	*Spirulina platensis*	65	California, United States of America	ScienceDirect (cyanobacteria carbohydrate)	[70]
40	*Synechocystis* sp. (PCC 6803)	36.8	California, United States of America	ScienceDirect (cyanobacteria carbohydrate)	[70]
41	*Spirulina maxima*	70	California, United States of America	ScienceDirect (cyanobacteria carbohydrate)	[70]
42	*Pseudanabaena mucicola* (GO0704)	52	Nakdong River, South Korea	ScienceDirect (cyanobacteria carbohydrate)	[41]
43	*Synechocystis* sp. *CCNM 2501*	10.13	Brackish waters of Diu, India	ScienceDirect (cyanobacteria carbohydrate)	[64]
44	*Arthrospira platensis*	0.212	Varanasi, India	PubMed (cyanobacteria carbohydrate)	[75]
45	*Synechococcus* sp. (PCC 7002)	0.5	Varanasi, India	PubMed (cyanobacteria carbohydrate)	[75]
46	*Synechocystis* sp. (PCC 6803)	0.112	Varanasi, India	PubMed (cyanobacteria carbohydrate)	[75]
47	*Synechococcus elongatus* (PCC 7942)	0.144	Varanasi, India	PubMed (cyanobacteria carbohydrate)	[75]
48	*Synechococcus elongatus* (PCC 7942 ieAB)	0.564	Varanasi, India	PubMed (cyanobacteria carbohydrate)	[75]
49	*Lyngbya limnetica*	0.423	Varanasi, India	PubMed (cyanobacteria carbohydrate)	[75]
50	*Oscillatoria obscura*	0.351	Varanasi, India	PubMed (cyanobacteria carbohydrate)	[75]
51	*Acaryochloris marina* (BERC03)	0.5	Punjab, Pakistan	ScienceDirect (cyanobacteria carbohydrate)	[72]
52	*Oscillatoria* sp. (BERC04)	0.51	Punjab, Pakistan	ScienceDirect (cyanobacteria carbohydrate)	[72]

Table 6. *Cont.*

Code N.	Genus and/or Species	Carbo-Hydrate	Collection Point	Platform (Search Term)	Reference
53	*Pleurocapsa* sp. (BERC06)	0.63	Punjab, Pakistan	ScienceDirect (cyanobacteria carbohydrate)	[72]
54	*Synechocystis* (PCC 6803)	98.81	University of Allahabad, Uttar Pradesh, India	Google Scholar (cyanobacteria carbohydrate)	[49]
55	*Synechococcus* (PCC 7942)	147.98	University of Allahabad, Uttar Pradesh, India	Google Scholar (cyanobacteria carbohydrate)	[49]
56	*Nostoc muscorum*	319.89	University of Allahabad, Uttar Pradesh, India	Google Scholar (cyanobacteria carbohydrate)	[49]
57	*Oscillatoria* sp.	185.92	University of Allahabad, Uttar Pradesh, India	Google Scholar (cyanobacteria carbohydrate)	[49]
58	*Anabaena cylindrica*	261.97	University of Allahabad, Uttar Pradesh, India	Google Scholar (cyanobacteria carbohydrate)	[49]
59	*Lyngbya* sp.	172.89	University of Allahabad, Uttar Pradesh, India	Google Scholar (cyanobacteria carbohydrate)	[49]
60	*Phormidium* sp.	277.94	University of Allahabad, Uttar Pradesh, India	Google Scholar (cyanobacteria carbohydrate)	[49]

[1] Concentration unit: % for Code numbers from 1 to 43; mg/g for Code numbers from 54 to 60. Biomass productivity unit: g L^{-1} day^{-1} for Code numbers from 44 to 53.

Table 7. Protein content in cyanobacteria selected for this review [41,46,64,76–92] [1].

Code N.	Genus and/or Species	Total Protein	Soluble Protein	Collection Point	Platform (Search Term)	Reference
1	*Desertifilum tharense*	28.1	4.4	Turkey	ScienceDirect (cyanobacteria protein)	[76]
2	*Anabaena variabilis*	34.4	0.8	Turkey	ScienceDirect (cyanobacteria protein)	[76]
3	*Phormidium animale*	27.6	5.8	Turkey	ScienceDirect (cyanobacteria protein)	[76]
4	*Cyanothece* sp.	34.3	-	Western Greece	ScienceDirect (cyanobacteria protein)	[77]
5	*Anabaena* sp.	50	-	Western Greece	ScienceDirect (cyanobacteria protein)	[77]
6	*Spirulina* sp.	43.20	-	-	ScienceDirect (cyanobacteria protein)	[46]
7	*Nostoc* sp. (PCC 7936)	5.69	-	-	ScienceDirect (cyanobacteria protein)	[78]
8	*Nostoc* sp. (PCC 7413)	6.29	-	-	ScienceDirect (cyanobacteria protein)	[78]
9	*Arthrospira platensis*	22.04–38.13	-	-	ScienceDirect (cyanobacteria protein)	[79]
10	*Arthrospira platensis* (F&M-C256)	63.9	-	-	Scopus (cyanobacteria protein)	[80]

Table 7. *Cont.*

Code N.	Genus and/or Species	Total Protein	Soluble Protein	Collection Point	Platform (Search Term)	Reference
11	*Nostoc sphaeroides* (F&M-C117)	50.8	-	-	Scopus (cyanobacteria protein)	[80]
12	*Arthrospira maxima*	61.7	-	-	Scopus (cyanobacteria protein)	[81]
13	*Myxosarcina* sp.	19.4	-	-	Scopus (cyanobacteria protein)	[82]
14	*Arthrospira platensis*	36.90	-	-	Scopus (cyanobacteria protein)	[83]
15	*Arthrospira maxima*	43.05	-	-	Scopus (cyanobacteria protein)	[83]
16	*Spirulina major*	66.7	-	-	Scopus (cyanobacteria protein)	[84]
17	*Phormidium tenue*	46.56	-	-	Scopus (cyanobacteria protein)	[84]
18	*Synechococcus cedrorum*	45.9	-	-	Scopus (cyanobacteria protein)	[84]
19	*Oscillatoria* sp.	50.96	-	-	Scopus (cyanobacteria protein)	[84]
20	*Arthrospira strains* (LEB 18)	86.0	-	-	Scopus (cyanobacteria protein)	[85]
21	*Arthrospira strains* (LEB 52)	82.5	-	-	Scopus (cyanobacteria protein)	[85]
22	*Arthrospira strains* Paracas	73.7	-	-	Scopus (cyanobacteria protein)	[85]
23	*Arthrospira maxima*	73.6	-	-	Scopus (cyanobacteria protein)	[85]
24	*Arthrospira platensis*	34.4	-	-	Web of Science (cyanobacteria protein)	[86]
25	*Arthrospira platensis*	61.55	-	-	Web of Science (cyanobacteria protein)	[87]
26	*Synechocystis* sp. *CCNM 2501*	66.56	-	Brackish waters of Diu, India	ScienceDirect (cyanobacteria protein)	[64]
27	*Pseudanabaena mucicola GO0704*	23	-	Nakdong River, South Korea	ScienceDirect (cyanobacteria protein)	[41]
28	*Raphidiopsis raciborskii*	25.41	-	Brazil	ScienceDirect (cyanobacteria protein)	[88]
29	*Arthrospira platensis*	45	-	Peru	ScienceDirect (cyanobacteria protein)	[89]
30	*Spirulina* spp.	5.92	-	-	Scopus (cyanobacteria protein)	[90]
31	*Arthrospira platensis*	129.11	-	-	Scopus (cyanobacteria protein)	[86]
32	*Spirulina* sp.	57.47	-	-	Scopus (cyanobacteria protein)	[91]
33	*Arthrospira maxima*	67.6	-	-	Scopus (cyanobacteria protein)	[92]

[1] Concentration unit: % for Code numbers from 1 to 27; mg/g for Code numbers from 28 to 29; and g/100 g for Code numbers from 30 to 33.

4. Discussion

Cyanobacteria are rich in primary metabolites and have biotechnological potential for energy production and the pharmaceutical and food industries [14,25,93,94]. There are many works in the literature about cyanometabolites. However, some articles need to present the data clearly and concisely. This work proposes setting up a review of the data published in scientific journals making use of important scientific platforms to facilitate finding this information.

Many studies have analyzed how environmental conditions (e.g., temperature, pH, and nitrogen and phosphate levels) can increase the biochemical composition of microalgae and cyanobacteria, mainly fatty acids and lipids [48]. These compounds are essential for cyanobacteria. In cells, lipids are found mainly in the cell membranes, featuring mainly polyunsaturated fatty acids (FAs) in their structure. The unsaturated FAs play an essential role in membrane physiology, and the proportion of unsaturated and saturated FA determines membrane fluidity [95]. Several authors have been quantifying the concentration of fatty acids and lipids in cyanobacteria worldwide [17,27,28,30,36,47,48,96].

Cyanobacteria exhibit high lipid production, as observed in the data collected in Table 5 (119 strains of cyanobacteria). These microorganisms, which can adapt themselves to culture conditions and exhibit high cell growth, are considered ideal lipid sources for pharmaceutical and biofuel production [97]. For example, they produce a wide variety of lipids with antibiotic and antibiofilm activity [98]. Using these compounds in clinical treatments alone or in association with antibiotics can be considered an alternative to current treatments for human diseases. Examples of commercially important lipids produced by cyanobacteria are polyhydroxyalkanoates (PHAs) and polyhydroxybutyrates (PHBs), which are considered a good alternative to synthetic plastics due to their natural origin, optical purity, thermoplasticity, and biodegradability [99].

Cyanobacteria are among the third-generation raw materials that are viable and increasingly studied for use in biodiesel production [100,101]. Large-scale biodiesel production directly depends on the availability of interesting fatty acids in the raw material. Lipids and fatty acids' total content may depend on the species and strain studied (Tables 1–5), and their content may be altered or induced by different abiotic factors (e.g., pH, mode of operation, photobioreactor configuration, light, and temperature) [102,103].

Some species of cyanobacteria, such as *Oscillatoria* sp. FW01, can optimize their yield when cultivated under specific conditions. According to the study by Yadav et al. [17], the cultivation of this strain under controlled light and temperature showed a 12% increase in the production of lipids, as well as a 57% increase in that of fatty acids. Thus, the authors considered *Oscillatoria* sp. FW01 as a raw material to be potentially used for the sustainable production of biodiesel [17].

According to the data gathered in Table 2, it is possible to observe quite a high content of palmitic acid (C16:0) (approximately 36.5%) in the reviewed cyanobacterial species. One of the characteristics of this acid is its small saturated carbon chain with its low oxidation and melting point [104]. These characteristics make this type of acid especially suitable for biodiesel production. The demand for lipids from microorganisms as possible substitutes for fossil fuels has stimulated research into synthetic biofuels. Oliveira et al. [35] investigated the lipid profile of three strains of Amazonian cyanobacteria (*Cyanobium* sp., *Limnothrix* sp., and *Nostoc* sp.), among which *Limnotrix* sp. showed the best lipid profile and highest amount of C16:0, which are favorable properties for biodiesel production. In addition, it also showed good values of biodiesel quality parameters, i.e., a high oxidative stability (34.9 h) and a cetane number (58.06) above the minimum established by the American Society for Tests and Materials (ASTM).

In the work by Santana-Sánchez et al. [105], the *Synechococcus* strains were the only ones that exhibited fatty acid profiles mainly composed of C14:0, C16:0, and C16:1 and without polyunsaturated fatty acids. Boutarfa et al. [27] also analyzed the fatty acid profile of the strains of *Mastigocladus laminosus* (an extremophile found in hot springs), which revealed C16:0 as the main fatty acid (51–53%) and a medium length chain (from C14 to C20). *Nostoc* sp. MCC41 presents high concentrations of palmitic acid, can grow under mixotrophic conditions, and fixes atmospheric nitrogen [36]. Thanks to these properties, they may represent excellent raw materials for the production of biodiesel.

Carbohydrates are among the leading products of photosynthesis, and in some species of cyanobacteria, their content can reach up to 50% of the dry weight [106]. These compounds are present in the cell wall (structural support) in addition to being stored as an energy source for the cell [97]. A possible biotechnological application of carbohydrates from cyanobacteria is in the area of biofuels, due to the high content of fermentable sugars and low hemicellulose and lignin contents [15,107]. In particular, the feasibility of producing bioethanol from the cyanobacterial biomass depends on the content and composition of the carbohydrates in the cell, both varying and depending on factors such as cultivation conditions and species type. Therefore, the production of carbohydrates by cyanobacteria has become the focus of much research [15,72,73,108] due to their potential application as a substrate for biofuels [109].

Some cultivation conditions favor the accumulation of carbohydrates in cyanobacterial cells, including the limitation of nitrogen in the medium where it is cultivated [72]. In Table 6, where the data referring to the accumulation of total carbohydrates can be found, we can observe a large variability according to the species, i.e., from 15% in *Synechococcus* sp. [69] up to 70% in *Spirulina maxima* [70]. However, the best carbohydrate-accumulating species were also grown in nitrogen-poor media (e.g., wastewater-borne cyanobacteria, *Arthrospira platensis* NIES-39, and *Spirulina platensis*) [15,21,70]. In other words, some species are able to accumulate carbohydrates more than others, but this capacity can be influenced by the medium in which they are grown.

Another critical question is the demand for food, which is a worrying factor in the world because of the growing population. According to the United Nations, the world population could reach 8.5 billion in 2030 and increase even more to 9.7 billion in 2050, creating a significant challenge related to food production. In this way, the food sector looks for foods or inputs that can add nutritional value and benefit human and animal health. These products are called functional foods, which provide metabolic and nutritional effects on health and essential physiological functions [80,83,107,109].

The search for a healthy diet and lifestyle causes consumers to purchase products that complement their physiological and metabolic needs. As a result, there has been an increase in this food sector, which focuses on consuming carbohydrates, lipids, and proteins. However, food alternatives have been sought as a source of protein, replacing animal sources [80,83,107,110]. Algae and microalgae have emerged as promising alternative sources of macronutrients. However, one of the problems encountered is the high cost of producing biomass, limiting the applications of its use. Due to this problem, research is being carried out on cyanobacteria, mainly due to the ease of their proliferation, generating much biomass.

As the results collected in Table 7 show, cyanobacteria are an excellent source of proteins, either as a food supplement or as an input to increase the concentration of this nutrient in food. Among these microorganisms, *Spirulina* sp. have stood out due to their excellent properties. They can be applied as biostimulants or biofertilizers, animal feed, or to produce human foods enriched in *Spirulina* sp., which are already commercially available. In addition, they are used in cosmetics, medicines, and functional foods. These applications, mainly as a source of protein, are possible because they are safe, nutritious, and sustainable raw materials.

For this reason, there is much research into the literature on cyanobacteria, as seen in the above tables. Data related to *Spirulina* sp. can be compared with those of other species and strains of cyanobacteria, demonstrating that it is still an area to be explored [111]. In addition to those presented, cyanobacteria produce other metabolites that can improve and contribute to a healthy diet, adding value to different products or these raw materials [107,110]. However, as seen in this review article, there are still few reports on the concentrations of proteins in different species and strains of cyanobacteria.

Since proteins have different functions in microorganisms, cyanobacteria show a significant variation in their total content (2.5–66.7%), with an average concentration of 36.9% (Table 7). However, there are still few reports on protein concentration in cyanobacterial biomass. This small overview on protein content demonstrates that this is an area of research still to be explored, mainly by the food industry [77,80,83].

5. Conclusions

The biochemical diversity presented by cyanobacteria has favored the study of these microorganisms in several areas of science. This review is essential to facilitate the consultation and location of data from scientific articles on the composition of cyanobacterial species and strains, including the contents of fatty acids (111), lipids (119), carbohydrates (60), and proteins (33). It was also possible to discuss how these characteristics can be commercially relevant since cyanobacteria have been considered good candidates for several applications; for example, as a source of food supplements for humans and animals and in the production of biofuels.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app13053162/s1, Table S1: NCBI (National Center for Biotechnology Information) data for genera and/or species of cyanobacteria selected for this review; Table S2: Main saturated fatty acids detected in cyanobacteria selected for this review; Table S3: Main monounsaturated fatty acids detected in cyanobacteria selected for this review; Table S4: Main polyunsaturated fatty acids detected in cyanobacteria selected for this review.

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