

**Review Article**

**AN EMERGING AQUATIC GREEN GOLD FOR FOOD AND MEDICINE: A REVIEW OF ALGAE FROM NORTH EAST INDIA**

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**ABSTRACT**

Given that proper nutrition is a growing concern for rising global populations, sustainable sources of nutritional value are in need. The food product or food derived from nutrients is called nutraceuticals which not only rarely supplement food but also make the treatment or prevention of a disorder and or disease. Algae are a diverse community of autotrophic organisms with the capable of fix atmospheric CO<sub>2</sub>, efficiently use light energy, ability to grow rapidly and compare to vascular plants, and algae produce more biomass per acre. More than two thousand years, algae are used for the treatment of different ailments and also used as a potential source of food. Due to the characteristics of rapid growth and capable of producing diverse nutritional compound, algae are largely used in dietary supplements and nutraceuticals field. Many kinds of algae have been reported several health benefits from improving the immune system to combat cancer and heart disease. With this background, this current review aims to evaluate the health-promoting effect of *Chlorella*, *Haematococcus*, *Spirulina*, *Ankistrodesmus*, *Botryococcus* and *Scenedesmus* in North East India.

**Keywords:** Algae, Autotrophic, Health benefits, Nutraceuticals, Nutritional components, North East India

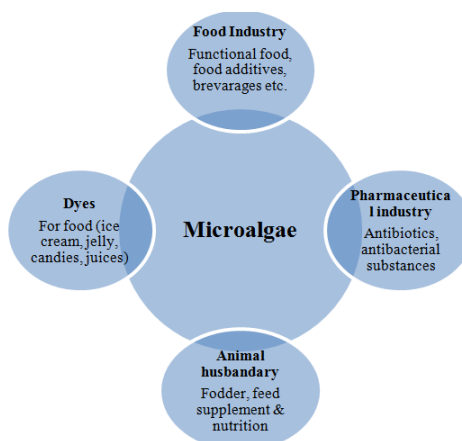
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**INTRODUCTION**

Microalgae are single-celled, microscopic, photosynthetic species occurring in both marine and freshwater environment. Different type of compounds produced by microalgae such as lipids, carbohydrates and protein along with different value compounds such as pigments, omega-3 fatty acids and triglycerides that could be exploited for their nutritional value. Most of the microalgae are photosynthetic microorganisms; unlike land plants, it does not contain cell organelles. Using water, solar energy and CO<sub>2</sub>, the microalgae can be cultivated photosynthetically in artificial tanks, raceway ponds, marginal ponds and shallow lagoons. Although, over 300,000 to 800,000 species of microalgae found in the environment, out of which only 30,000 are documented [1]. The orderly

systematic study of algae is called phycology [2]. The microalgae produce secondary metabolites, with potential biological functions and novel structure [3, 4].

Additionally, it can produce various useful bio-products including antioxidants, polysaccharides, natural dyes, eicosapentaenoic acid (EPA), bioactive and functional pigments, docosahexaenoic acid (DHA), astaxanthin and β-carotene [5] (fig. 1). Due to increasing consumer awareness on significant health benefits, the desire for nutraceuticals food products has been significantly increased recently [6]. Microalgae can be called as the factory for several biomolecules including beta-1,3-glucan, Polyunsaturated Fatty Acids (PUFAs), nutraceutical and pharmaceutical compounds, phycobiliprotein, chlorophyll, beta-carotene, lutein and astaxanthin [7].



**Fig. 1: Application of microalgae in different fields (Hemantkumar and Rahimbhai, [1])**

In recent years, a lot of efforts have been devoted to promoting the industrial implementation of microalgae. In this context, the present review provides a brief overview of studies conducted specifically in

the northeastern (NE) region, a region with two mega (flora and fauna) biodiversity hotspots of India with abundance. Although there are several review articles, have been published related to

nutraceuticals value of microalgae, to our knowledge, specific recent reviews of microalgae available in the NE region is scarce. In addition, reviews in the past had focused only a limited number of algae genus. Therefore, in this review, we attempted to discuss the health-promoting effect of potential strains, the current status of individual species in North East India. In order to identify the studies for this review, several databases were used, including PubMed, Embase, Google Scholar, and specific database such as Science Direct, Springer and Wiley were reviewed. The following keywords were used to extract the data from the identified studies. This includes 'Algae', 'Microalgae', 'Autotrophic', 'Health benefits', 'Nutraceuticals', 'Nutritional components', AND North East India. The paper also focuses on the various application of microalgae, challenges and conclude with the prospects.

**Microalgal diversity of Northeast India**

Human health and wellbeing directly reflect the health of biodiversity of that region. Northeast India, with its eight states Sikkim, Tripura, Manipur, Mizoram, Nagaland, Meghalaya, Arunachal Pradesh and Assam, is a part of the world's biodiversity hotspots in both the Himalayas and Indo-Burma. It is a treasure trove of a diversity of faunal and floral which is flourished by varied forms of

microalgae, and a member often occupies the lowest level of the food chain of every rivers, ponds, lakes and beels. Northeast India, especially Assam, been mesmerized by the different colures of the water bodies along the roadways because of the various algal blooms around the year [8]. Various studies have documented different microalgae species across the region. For instance, Jena and Adhikary recorded fifty-six taxa of algae belonging to 21 genera for the first time from this region from different water bodies [8].

Interestingly, authors in that study concluded that out of that 16 species were reported first time from north-eastern states of India. Baruah and Kakati [9] documented around 45 species of phytoplankton in the pond dug by the Ahoms, which is 600 y old (fig. 2). Sharma et al. [10] recorded *Cyanophyceae* sp., *Chlorophyceae* sp., *Bacillariophyceae* sp. and *Euglenophyceae* sp. in four pond ecosystems from Southern Assam. Another study by Ghosh et al., [11] isolated *Podohedriella* sp. (MC44) from the paddy field, located in Gomati district of Tripura State. This particular species has an efficient to trap carbon from the atmosphere, and therefore mitigate CO<sub>2</sub> gas emission from the industries. Further, Muthuraj et al. [12] did show high lipid content in *Chlorella* p., FC<sub>2</sub> IITG, and therefore, authors in this study demonstrated its potential for biodiesel production.

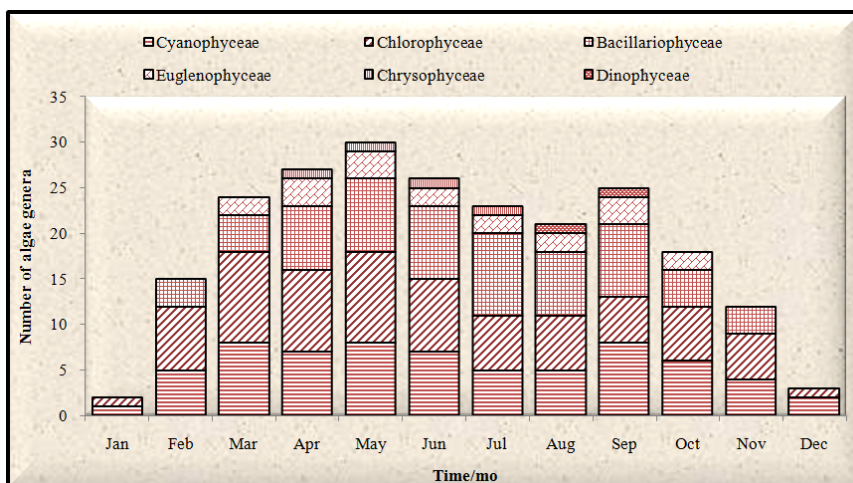


Fig. 2: Monthly occurrences of algal species in Assam [9, 13]

Similarly, around 59 species of microalgae were isolated by Lahan et al. [15, 16] from different freshwater bodies in Dhemaji district. The microalgae belong to *Xanthophyceae*, *Bacillariophyceae*, *Euglenphyceae*, *Cyanophyceae* and *Chlorophyceae* (fig. 3 and 3b). Authors in this study identified 17 species out of them, and quantified lipid content, as shown in fig. 4. Latest discoveries from

algae include two species of Diatom from Sikkim [14]. The 23-core project, Bioresource and Sustainable Livelihood in the Northeast, funded by the Union ministry of science and technology further provides an opportunity to explore further and commercialise endemic bioresources including potential candidate algal strains.

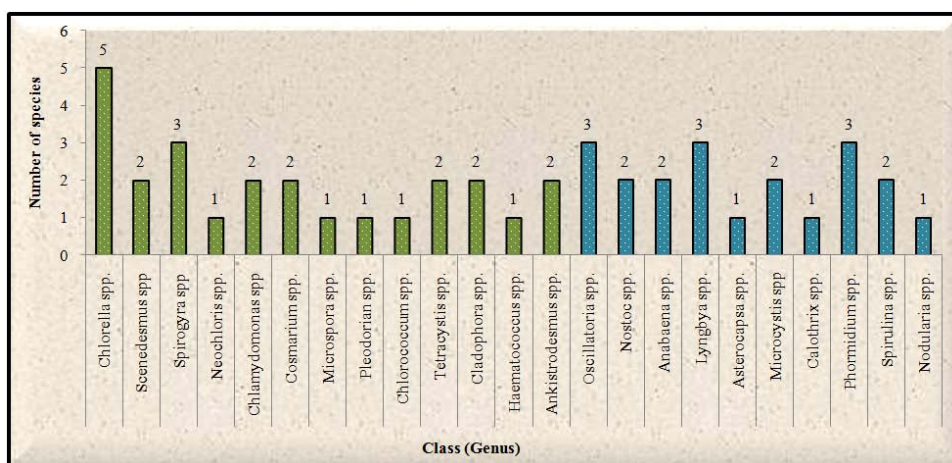


Fig. 3a: Distribution of algal groups isolated [13, 15, 16]

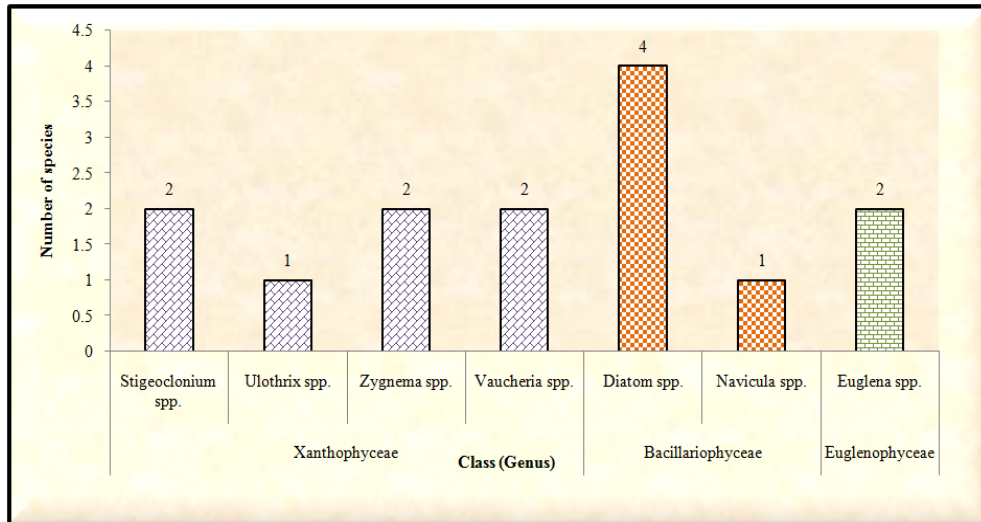


Fig. 3b: Distribution of algal groups isolated [13, 16]

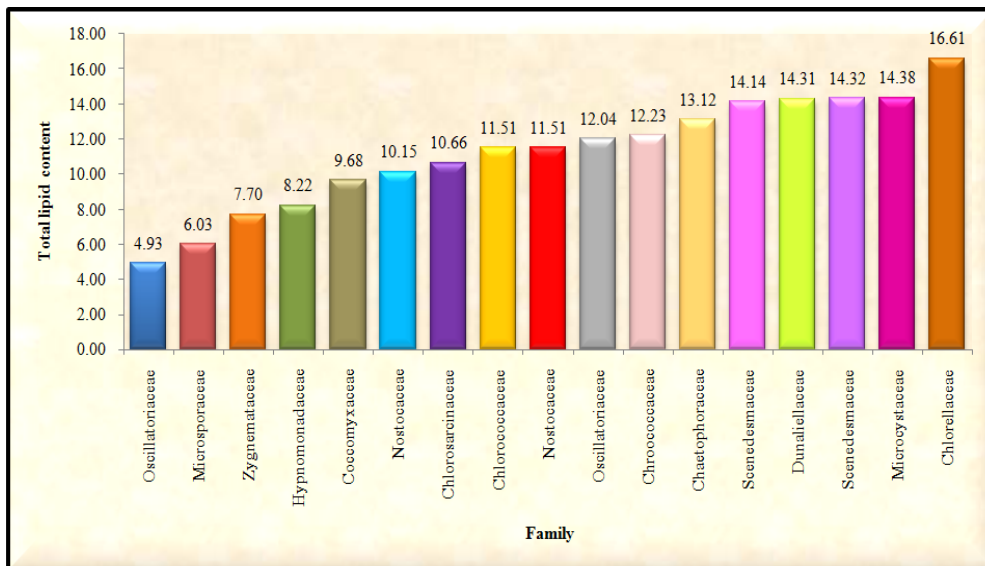


Fig. 4: Total lipid content of the oleaginous algal species isolated from Assam [13]

Thus, overall, several microalgae communities were reported from North East region of India were demonstrated in table 1.

An international organisation reports that approximately 805 million people have been undernourished chronically in 2012-14 by more than 100 million over the past decades and 209 million since 1990-92 according to the latest Food Agricultural Organisation (FAO). But, in the world, about 1 in every 9 individuals still has insufficient food for a healthy and active life that leads to malnutrition. India harbours the largest consumers of antibiotic and among the largest carrier of drug-resistant pathogens [34]. With the growing population, the production of nutritious as well as the necessary quantity of food is an eternal challenge. The United Nations Development Programme (UNDP) sustainable goals to be intended to be met by 2030, including wellbeing, good health, zero hunger and no poverty and clean and affordable energy demands an efficient source of nutrients. In order to meet the demands and to achieve UNDP goals, metabolomics is one of the key tools for nutrition research [35]. The two important deciding features of the so-called nutritional environment are both production and quality. From governments to ordinary individuals, the concern of

nutritional environment lies at the centre of everybody's attention. With the increasing world's population, there is also growing concerned to find solutions to feed these populations. To respond, in the last few decades, researchers are turning to non-conventional ways for food sources including "alga culture"-the farming algae for human consumption. For instance, six species of *Spirulina* have been reported and taxonomically characterised by Brahmaputra valley of Assam, North-East India [36]. Experts suggest the potential of *Spirulina* to tackle India's malnutrition. However, to develop and market value-added products from microalgae, food industries face several challenges, as shown in fig. 5. To overcome those challenges, and to develop and bring many innovative products and processes into the North East market, several initiatives have been adopted from the government. Recently Council of Scientific and Industrial Research, CSIR-CFTRI, Centre Food Technology Research Institute signed an MoU (Memorandum of Understanding) with Agricultural and Processed Food Products Export Development Authority (APEDA) for opening up a liaison office at Guwahati, Assam India. This agreement will further improve the sector of value addition to food industries including employing microalgae such as *Spirulina* cultivation.

Table 1: Microalgae reported from North East region of India

Authors	State(s)	Habitat	Algae division/family/genus/species	Application(s)	References
Jena and Adhikary	Assam, Nagaland and Sikkim	Pond	Chlorophyta	-	[17]
Devgoswami et al.	Assam	-	<i>Chlorella</i> , <i>Scenedesmus</i> and <i>Haematococcus</i>	Lipid production	[18]
Goswami and Kalita	Assam	Freshwater	<i>Scenedesmus quadricauda</i> and <i>Scenedesmus dimorphus</i>	Lipid production	[19]
Deka and Sharma	Assam	Fresh water	<i>Oscillatoria</i> , <i>Lyngbya</i> , <i>Phormidium</i> , <i>Spirulina</i> , <i>Hydrocoleum</i> , <i>Microcoleus</i> , <i>Symploca</i> , <i>Polychlamydom</i> , <i>Porphyrosiphon</i> and <i>Katagnymene</i>	-	[20]
Gunapati et al.	Manipur	Soil samples	<i>Anabaenopsis</i> , <i>Wollea</i> , <i>Aulosira</i> , <i>Nostoc</i> , <i>Anabaena</i> , <i>Scytonema</i> , <i>Tolypothrix</i> , <i>Microchaete</i> , <i>Calothrix</i> and <i>Dichothrix</i>	-	[21]
Devi and Tiwari	Manipur	Different ecological habitats	<i>Plectonema</i> , <i>Lyngbya</i> , <i>Spirulina</i> , <i>Oscillatoria</i> , <i>Limnothrix</i> and <i>Phormidium</i>	-	[22]
Singh and Gupta	Manipur	Different rivers	<i>Lemanea australis</i> , <i>L. torulosa</i> , <i>L. fluviatilis</i> , <i>L. mamillata</i> and <i>L. catenata</i>	-	[23]
Basu et al.	Assam	Freshwater	<i>Scenedesmus obliquus</i> (KC733762)	Production of carbohydrate, protein, lipid, and chlorophyll	[24]
Kumar et al.	Assam	Freshwater	<i>Chlorella sorokiniana</i> FC6 IITG	Biomass and lipid accumulation	[25]
Yasmin et al.	Assam	Stagnant water bodies	Chlorophyceae (59 species), Bacillariophyceae (15 species) and Cyanophyceae (17 species)	-	[26]
Bora et al.	Meghalaya	Different ecological habitats	<i>Anabaena</i> , <i>Nostoc</i> , <i>Calothrix</i> , <i>Westiellopsis</i> , <i>Gloeocapsa</i> , <i>Fischerella</i> , <i>Tolypothrix</i> , <i>Stigonema</i> , <i>Cylindrospermum</i> , <i>Loriella</i> and <i>Plectonem</i>	-	[27]
Thajamanbi et al.	Assam	Rice fields soil	<i>Nostoc</i> , <i>Calothrix</i> , <i>Anabaena</i> , <i>Cylindrospermum</i> , <i>Lyngbya</i> , <i>Oscillatoria</i> and <i>Phormidium</i>	-	[28]
Ghosh et al.	Tripura	Moist soil	<i>Chlorococcum</i> sp. (NITAAP019)	High lipid, protein, carbohydrate and biofuel production	[29]
		Paddy field	<i>Korshikoviella</i> sp. (NITAAP017)	Significant production of lipid, chlorophyll, carbohydrate and protein	
		Moist soil	<i>Chlorella</i> sp. (NITAAP009)	Production of carbohydrate, protein and chlorophyll	
		Moist soil	<i>Chlorococcum</i> sp. (NITAAP008)	High lipid, protein, carbohydrate and biofuel production	
		Lake	<i>Chlorella</i> sp. (NITAAP011)	Significant production of chlorophyll, carbohydrate, lipid and protein	
Sehgal et al.	Assam	Fresh water	<i>Chlorella sorokiniana</i> (NEIST BT-2)	High lipid productivity and biomass yield	[30]
Das and Deka	Assam	Oil field formation water	<i>Chlorella vulgaris</i> BS1	High biomass productivity	[31]
Manchanda et al.	Assam	Water sample	<i>Botryococcus braunii</i> (GUBIOT)TBB1)	Hydrocarbon and oil production	[32]
Sarkar et al.	Tripura	-	<i>Chlorella thermophila</i>	High valued pigments chlorophyll and carotenoids	[33]

A glimpse from the ongoing trend in the field of functional foods and supplements revealed bioactive molecules play a major therapeutic role in human disease. Recently with the mushrooming population, a great impact can be seen in the food scenario involving the several products appearance derived from these bioactive molecules. These botanicals, nutraceuticals, and other products influenced the market due to their hybrid nature, somewhere between medicinal drugs and ordinary food. Stephen Defelice coined the term nutraceutical in 1989 by combining the terms nutrition (food or nourishment) and

pharmaceuticals (a medical drug). The food product or food derived from nutrients is called nutraceuticals which not only rarely supplement food but also make the treatment or prevention of a disorder and disease. Nutraceuticals have reported health benefits and the treatment of possible fatal illnesses (i.e. cancer, Parkinson's disease, heart disease) [37, 38]. These all algal components gained a lot of attention for having the character to be a candidate for a replace the synthetic components, animal feed and natural supplement for human. With the skyrocketing high-quality nutrients demands, it seems that it

is the green gold as it will play vital roles in the near future to a food crisis, remedy energy and environment prevailing in the world. Exploring the full potential of algal nutraceuticals is another key step

for fulfilling "Aatmanirbhar Bharat Abhiyan" or North-East India. Some important algae, their biologically active compounds are listed in table 2 and for detailed review, refer a paper by Bhattacharjee [39].

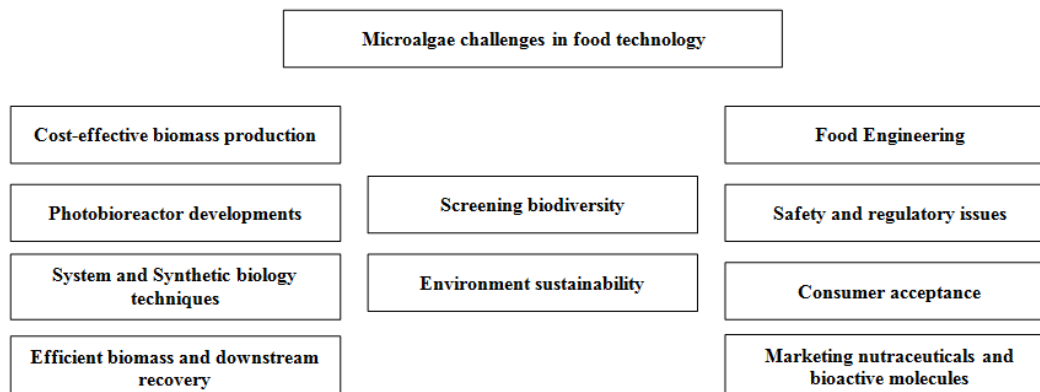


Fig. 5: Microalgae challenges in food technology [13]

Table 2: Bioactive compounds isolated from the various algal genus

Genus	Bioactive compounds	References
<i>Spirulina</i>	Secondary metabolites, photosynthetic pigments, minerals, fatty acids, vitamins, proteins	[40]
<i>Chlorella</i>	Pigments, polysaccharide, vitamins, peptides, amino acids, proteins, sterols, volatile compounds, phenolic compounds, Long-Chain Polyunsaturated Fatty Acids	[41]
<i>Haematococcus</i>	Astaxanthin, lutein, fatty acids	[42]
<i>Scenedesmus</i>	Astaxanthin, Vitamins, Lutein, Haemagglutinin, sporopollenin, Mycosporine-like amino acids, PUFA, MUFA, Chlorophyll a, b, c,	[43]
<i>Botryococcus</i>	Carotenoids, fatty acids, hydrocarbons	[44]
<i>Ankistrodesmus</i> sp.	Phenolic acids and flavonoids	[45]

### Chlorella

In the *Chlorella* genus is marketed as a "growth factor" which is an extract of water-soluble extract substances, including  $\beta$ -glucans, glycoproteins, polysaccharides, minerals, vitamins, amino acids, and nucleic acids [46]. Many useful properties have been indicated by *Chlorella* sp. extracts, such as antitumor, antioxidant and antibacterial activities and decreasing cholesterol level as well as properties of antioxidant [47–49]. Depending on the extraction conditions, the antioxidant and antibacterial activity varies [50]. Report from the research work with extracts from *Chlorella* reveals to possess antitumor [47], antioxidant activity in rainbow trout [51], anti-inflammatory [52] and antimicrobial activities [4]. Dried powder of *Chlorella* sp. as a dietary supplement to stroke-prone spontaneously hypertensive rats (SPSHR) show a beneficial effect on vascular function [53]. Regular supplementation of *Chlorella* sp. to subjects with mild hypercholesterolemia may act to optimise serum lipid profile TG, apo B, HDL-C/TG, VLDL-C, non-HDL-C and TC [48]. A beneficial immunostimulatory effect can be seen in normal uninfected people by short term supplementation with *Chlorella* sp. tablets [54]. Different studies also suggest *Chlorella* sp. supplementation improves the symptoms in fibromyalgia patients [55, 56]. A major lutein source of *Chlorella* sp. has been demonstrated to contains properties of anti-cataract and prevent macular degeneration.

It is a unicellular green alga and considered as whole foods because of its richness in protein vitamins and minerals [56]. Its nutrient composition can be listed as chlorophyll 1-4%, protein 55-67%, dietary fibre 9-18% and a large amount of vitamins and minerals [56]. Two isolated *Chlorella* sp. strains including NITAAP009 and NITAAP011 from Tripura demonstrated chlorophyll 5%, 5–6.4%, carbohydrate 22–33%, 30–50%, and protein 41–50%, 48–60% respectively [57]. Former strain show higher specific growth rate of 0.125 d<sup>-1</sup> than the later one with 0.10 d<sup>-1</sup> [57]. The growth profile of *Chlorella* sp. that was isolated from Assam, investigated in batch mode culture with varying concentration of sodium bicarbonate and

CO<sub>2</sub> [18]. Highest growth rate (189.1% increase in biomass; specific growth=0.704, g/l/day) and content of lipid achieved when supplying CO<sub>2</sub> gas (and 1.015 doublings/day, lipid content by weight of dry cells 31%). A novel microalgae strain isolated from freshwater samples identified as *Chlorella sorokiniana* FC6 IITG isolated from North East India was collected [58]. In order to achieve both cell density (biomass) as well as lipid accumulation, different pilot strategies have been formulated. The growth of *Chlorella* sp. FC2 IITG has been characterized under mixotrophic, heterotrophic and photoautotrophic cultivation conditions [59]. Different strategies for process engineering of *Chlorella sorokiniana* sp. growth been reported in studies. For instance, under mixotrophic growth of this strain, FC6 IITG led to synchronised growth with high lipid productivity [60]. Cultivation of heterotrophic *Chlorella* sp. FC2 IITG with novel two-stage continuous was showed for increased productivity of lipid [61]. Thermophilic *Chlorella* sp. strain was isolated from Tripura processed for the production of high valued pigments chlorophyll and carotenoids using a green solvent like ethanol in less than 6 min [62]. Among the different culture processes employed for *Chlorella* sp. cultivation thermophilic *Chlorella* culture of 30 L carried out on 50 L capacity flat-panel photo-bioreactor [62]. Further, to study the growth performance of *Chlorella* sp. in fluctuating environmental conditions and the presence of contaminants open pond cultivation was employed [59]. The study also shows the Continuous culture regime as a potential tool for *Chlorella vulgaris*. The microalgae strain collected from Tripura and identified as *Chlorella* sp. (NITAAP009). The strain had chlorophyll 5% with a specific growth rate of 0.125 d<sup>-1</sup>, 22–33% carbohydrate and 41–50% protein. Similarly another strain isolated from lake area in Tripura and identified as *Chlorella* sp. (NITAAP011) with large content of chlorophyll (5–6.4%), low lipids (1–10%) with lower specific growth rate (0.10 d<sup>-1</sup>), 48–60% protein and 30–50% carbohydrate [57].

A species of algae were isolated from the oil field formation water in Assam and identified based on the 18S rRNA as *Chlorella vulgaris*

BS1. The strain showed high productivity in biomass of 1,76 gm L<sup>-1</sup> d<sup>-1</sup> (initial inoculum: 1500 mg L<sup>-1</sup>, specific growth rate: 0.21 d<sup>-1</sup>) [31]. Recently, the strain *Chlorella sorokiniana* (NEIST BT-2) isolated from freshwater in Assam and showed high lipid productivity (107.60 ± 10.175 mg L<sup>-1</sup> d<sup>-1</sup>) and biomass yield (2.09 ± 0.037 g L<sup>-1</sup>) [30]. The association of prokaryotes, which synthesise vitamin B12 with the surface of the seaweed, promotes this amount of vitamin present in the algae. In microalgae such as *Chlorella* sp. the vitamin B12 content is stated to be higher, offering 33.3g/kg of fresh weight. The active vitamin B12 coenzymes in *Chlorella* supplements constituted around 60 per cent of the total vitamin B12 [63].

#### **Haematococcus sp**

It is a green free-floating alga and can accumulate up to 5% DW (dry weight) of astaxanthin for which it occupies the top position in the list of natural sources of astaxanthin. Astaxanthin has recorded at least ten times stronger antioxidant activity than beta-carotene and 1000 times stronger than vitamin E. It functions effectively in reducing non-esterified fatty acids, plasma triglycerides levels and arterial blood pressure [64].

Astaxanthin possesses various health benefits in humans like pigmentation and reproductive behaviour, immune response, enhanced vision, protection against the effects of UV radiation and protection of polyunsaturated fatty acids against oxidation [65]. The pigment documented to have anti-inflammatory, anti-oxidative, antibacterial, anti-cancer, activities. Natural astaxanthin also found to be effective against dyspepsia caused by *Helicobacter pylori* [66]. Moreover, this enigmatic pigment also plays a significant role in the neural damage treatment and prevention linked with age-related macular degeneration. Astaxanthin already got the tagline of "A rising star" because of its effective treatment in central nervous system injuries, spinal cord damage, Parkinson's disease, Alzheimer disease [67]. These high-value carotenoids are also striding its beneficiary effect towards the prevailing diabetes problem by preserving the beta-cell function and reducing the glucose toxicity [68]. Compared to synthetic one natural astaxanthin produced by *Haematococcus* sp. has significantly greater antioxidant capacity. Mass manufacturing companies of *Haematococcus* sp. primarily for astaxanthin, include Aquasearch Inc., Alga Technologies, Valensa International, Fuji Health Science, BioReal, Inc., Parry Nutraceuticals, Cynotech Corporation.

*Haematococcus* sp. with a concentration of 30 ppm of sodium bicarbonate can develop in BG11 media. The best growth of *Haematococcus* sp. strain was observed in CO<sub>2</sub> gas at 4758 mg/l (134.1 mg/l for 7 d) and 30 ppm bicarbonate (72.9 mg/l/day for 17 d) [18]. Various studies report *Haematococcus* sp. from different regions within Assam. Using the Winogradsky Column, it was among the algal varieties isolated from the Guwahati Panikhaiti area, Assam [69]. Further *Haematococcus* sp. was reported from Umiew river in Meghalaya [70] and vegetable fields of Cachar district, Assam [71]. The *Haematococcus* sp. is grown commercially either in controlled photobioreactors or in large-scale outdoor systems. Though this species is reported from different localities within North East India, until now, no reports are present for characterisation of bioactive metabolites from this particular strain. This opens up many avenues for characterization starting from culture parameters optimization to value added chemicals extraction including astaxanthin from this endemic potential strain.

#### **Spirulina**

*Spirulina* is a prokaryotic cyanobacterium that has been developed commercially for use for more than thirty years, including nutraceuticals, pharmaceuticals, aquaculture, food dyes, food dyes, vitamin supplements and fish food [72–74]. The nutrients compositions that make the *Spirulina* a superfood are minerals, omega-6 fatty acids, vitamin E, chlorophyll, phycocyanin and B-vitamins [73]. The large amount of natural proteins found in the *Spirulina*, i.e. 60-70 %, up to ten times more beta-carotene and five times than of meat than carrot per unit mass. In microalgae *Spirulina*, the vitamin B12 content found to be higher, offering 15.3g/kg of fresh weight [63]. It is the main vitamin B12 vegetable source and contains two and a half times the liver content.

The nutrient profile of *Spirulina* vs other foods can be summarized as more anti-inflammatory and antioxidant activity in 3 g of *Spirulina*

than in five servings of vegetables and fruits, 5100% more iron than spinach, compared to carrots, 3100% more beta carotene, 670% more protein than tofu and 180% more calcium than whole milk [75]. Incredible benefits have been reported in the health areas like hypertension, high blood pressure, diabetes, and weight loss due to its antimicrobial and antioxidant effect [74]. Its anticancer and antiviral properties are well known. Consumption of *Spirulina* can bring balanced metabolism of cholesterol by levels of HDL increasing, which in turn result in healthy cardiovascular function. *Spirulina* actually helps to develop immunity by enhancing phagocytic activity in macrophages and by generating antigen-specific antibodies in people with depression and hyperactivity disorder with attention deficit. *Spirulina*, along with conventional supplementation of iron-folic when used to tackle nutritional anaemia in remote tribal population of India, show improvements [76]. In terms of production, the market of *Spirulina* is dominated by companies like Watershed Wellness Centre, Bio-Alternatives, Valley Naturals, Springtime Inc and Puritan's Pride. The *Spirulina* powder costs about 1000 rupees per kg. It is a prokaryotic multicellular filamentous cyanobacterium and consists of mainly two genera *Spirulina* and *Arthrospira* [77]. Species of *Spirulina* have been reported from Goalpara district Assam [20]. Directorate of Biotechnology, Government of Tripura, initiated mass cultivation of *Arthrospira platensis* in combination with open mass cultivation in Tripura. The Micro Small Medium Enterprises (MSME) Development Institute offered training programme on "*Spirulina* cultivation" which constitute an algae introduction, innovative international and national marketing, harvest and post-harvest technology, *Spirulina* culture and production and *Spirulina* functions. Moreover, the Ministry of MSME has set up one national-level entrepreneurship development institute in Guwahati Assam.

#### **Ankistrodesmus sp**

In Kajiranga National park, Assam [78], *Ankistrodesmus septatus* Oetli reported from Ribhoi district, of Meghalaya. *Ankistrodesmus falcatus* (Corda) Ralfsa freshwater oleaginous microalgae were grown in batch culture, and the media constituents influence, calorific value (CV), total lipid (TL) content, nitrogen sources and pH on growth ( $\mu$ ) was compared [79]. *Ankistrodesmus falcatus* growth was tested in various concentrations of sodium chloride (0.04M to 0.34M), and results reveal the highest growth as well as lipid content at 0.17M NaCl concentration [80].

#### **Botryococcus sp**

In Chandrapur locality of Kamrup district, Assam, the strain *Botryococcus braunii* (GUBIOT)TBB1) was isolated from the collected water samples of a freshwater reservoir. One strain is isolated from Loktak lake Manipur, and the effect of various nutrient stress condition on biofuel production was investigated [32].

#### **Scenedesmus**

The maximum growth showed by *Scenedesmus* strain in CO<sub>2</sub> gas at 4758 mg/l (103.8 mg/l for seven days) and bicarbonate at 45 ppm (30.9 mg/l/day for 17 d). Two potent indigenous microalgae strain *Scenedesmus quadricauda* and *Scenedesmus dimorphus* isolated from Assam and studied for CO<sub>2</sub> mitigation and biomass production [19]. It has also been isolated from Kaziranga National Park (KNP) Assam [78]. Another high temperature and CO<sub>2</sub> *Scenedesmus obliquus* SA1 strain was isolated from Assam, India and studied for CO<sub>2</sub> sequestration efficiency [81]

#### **Future prospects**

Compounds from microalgal extracts have accepted as having greater biological and economic importance than dried biomass. In the sense of global population growth and availability of terrestrial food items, microalgae may provide sustainable and reliable replacements for widely used commodities of animal or plant origin. To date, however, only a limited number of strains have been utilised in the nutritional and pharmaceutical purposes. Major research and development would entail the transition from a niche market to the widespread use of algal products as food commodities. In turn, this will include improving existing strains through genetic engineering, and modifications or screening new species to the growth of microalgae with increased targeted metabolite production.

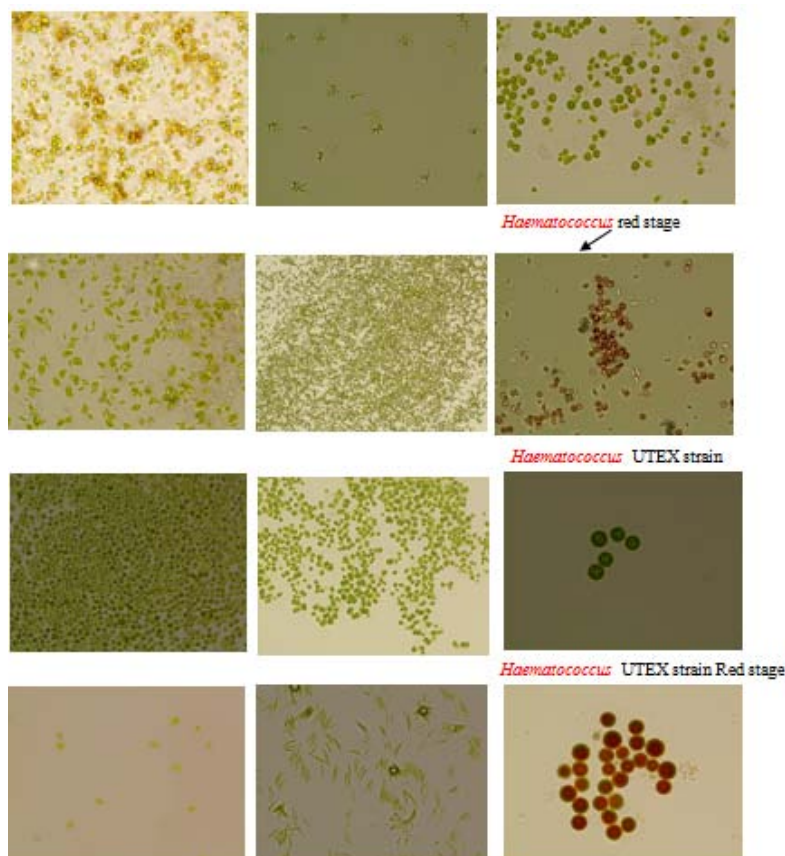


Fig. 6: Strains isolated from different water bodies of Assam, India [30, 78]

## CONCLUSION

Northeast India provides plentiful opportunities to explore the biodiversity at its habitat. There is evidence that there are some algae which already came into an endangered list and the day is not far that many will become extinct without being discovered. It is the peak time to address big questions regarding the conservation of algae and attempt to bring together expertise for the same. Evidence also report that algae have small means of survival that must be accounted into account in the context of biogeography. It is now a big matter of concern to apply possible tactics and methods necessary to achieve realistic protection, including culture collections potential use and application of legislation for in situ conservation.

In Northeast India, the concept of Nutraceutical is still at in the stage of infancy. Despite having rich algae resources in Northeast India, the commercialisation of value-added products are still at infancy. For a successful economy from value-added products from algae resource, the processes should be optimised as following 1. Identification and preservation, 2. Cost-efficient large-scale cultivation with quality 3. Efficient harvesting, 4. Commercialisation. However, this demands awareness training as well as skilled infrastructure development. Different institutes including Gauhati University, IIT Guwahati, Tezpur University Institute of Bioresources and sustainable development, Imphal are working on the varied perspective of algae. Strategies including co-cultivation, start-up pilot projects, the opening of nutraceutical Food Park would stride up to translate these studies from a laboratory to mass commercialisation. It will further pave the way to not only the herb-based but also algae-based nutraceuticals market from North East India. Therefore, we should join hands together to develop new ways and move on with the idea “think outside the box” that will in return be a wow factor for achieving a prosperous economy of our region that is North East India.

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## AUTHORS CONTRIBUTIONS

All the authors have contributed equally.

## CONFLICT OF INTERESTS

Declared none

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