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ALGAL OMICS: SHOWCASING THE DIVERSITY OF BIO-PRODUCTS SYNTHESIZED BY ALGAE CELLS

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Abstract: Microalgal secondary metabolites are the source of the pharmaceutical goods made from them as well as the commercial innovations of several dietary supplements. *N. gaditana* lipid biosynthesis will allow genetic engineering tactics to increase this naturally prolific alga even more. Phylogenomic study identifies unique features of this organism, such as stramenopile photosynthesis genes and gene expansions. Microalgae are becoming increasingly desirable as potential sources of microbial cell factories. The full potential of microalgae is being unlocked thanks to quick developments in "omic" technology. We look at the diverse range of possible algal bioproducts with an emphasis on the function of omic technologies.

Keywords: Omics, Biofuels, Stramenopile, Microalgae, Tactic.

Introduction

Algae, which have a size range from 2 µm (*Nannochloropsis*) to 60 m (*Macrocystis*), and occupy a variety of biological niches, represent a particularly and stunningly varied group of eukaryotes. Algal genetic variety is mirrored by phenotypic diversity, with samples ranging from small plankton to tiny creatures (Erik R. Hanschen et.al.2020). Coral reefs have thrived in tropical shallow-water settings for over 240 million years. The crown of thorns starfish (COTS), illness, overfishing, & pollution have already posed credible threats mostly to coral reefs during the past 30 years. The coral-Symbiodinium symbiosis is being stressed to the point of its thermal tolerance due to rising ocean surface temperatures caused by global warming. (Bettina Glasl et al..2017). These microscopic photosynthesizers, despite their effective role in producing oxygen on Earth, are found in almost all water on Earth due to their high dispersion and frequency (Li et al. 2019). The potential of these microbes to produce bioactive chemicals with a variety of medicinal and food uses, along with their high nutritional value, has drawn the interest of many researchers worldwide (Majidian et al. 2018; Sigamani et al. 2016). Additionally, microalgae may be utilized as a raw material for the production of biofuels that are beneficial to the environment, as well as for monitoring and removing contaminants from the environment (Khaligh, S. F., & Asoodeh, A. 2022). Diatoms and other microalgae, as well as cyanobacteria, have been studied for more than a century. The Aquatic Species Program (ASP) was sponsored by the United States Department of Energy during 1978 - 1996 to produce renewable petroleum products, such as biodiesel, from algae cultivated in open ponds. Microalgae are a class of organisms from several eukaryotic lineages that have undergone numerous endosymbiosis events, but little is known about their metabolic and regulatory networks. Algal bioenomics has been impeded by a paucity of these available resources as well as the inherent quality difficulties encountered when dealing with microalgae (Weiqi

Fu et. al. 2019). The ability to sequence and assemble the genomes of practically any microalgae has improved over the past ten years to the point that this information is no longer a barrier to the domestication of algae. Our knowledge of how algal genes and genetic interaction networks work is constrained. However, the domestication of crops never just involves the genes which are available in a plant, thus it involves how these genes are controlled and interact, particularly in features that are the product of multiple genes working together. It's also crucial to note that crops with large yields are not the consequence of particular knowledge of genes or genetic regulators Instead, throughout time, the selection of features led to the proper combination of genes and gene interactions needed to create the desired phenotypes. *Nannochloropsis*, *Chlamydomonas reinhardtii*, and the diatom *Phaeodactylum tricornutum* are two of the best-established algae model species for biofuel generation. Before being used in biofuel applications, an alternative alga that has successfully been grown outdoors and has naturally acceptable biomass production properties has been required. A member of the Eustigmatophyceae, *Nannochloropsis gaditana* is an oleaginous stramenopile that accumulates a lot of fat as it grows. It can develop to high densities (>10 g l 1), produces a lot of photoautotrophic biomasses, and produces a lot of lipids while tolerating a broad variety of pH, temperature, and salinity conditions. Therefore, it would make an excellent candidate for evolution into a model organism for the generation of biofuel (Radakovits, R.2012). Our current understanding of algae genomes, along with high-throughput screening tools like as fast genome sequencing, enables us to swiftly associate genotypes with phenotypes. The phenotypic variation found in different wild-type isolates of the green algae *Chlamydomonas reinhardtii*, for example, may now be readily connected with the genomic sequence of these isolates to correlate genomic DNA sequence variations with desired phenotypes. We may be able to develop wide cultivated algal species in a fraction of the widely it required others to breed conventional genetically engineered crops due to the latest improvements in identifying the genetic component of significant features. In the future, as we get a better knowledge of algal gene activity and enhance computational tools for analyzing and predicting gene interactions, we will continue to boost algal productivity at a faster rate (Jonathan B. Shurin et. al. 2016).

In industrial biotechnology and biomedicine, the idea of the "microbial cell factory" has gained prominence. With over 200,000 species, algae are one of the most varied creatures on the planet (Guarnieri 2013; Radakovits et al. 2010), and they have the potential to be used in a variety of biofuel, nutraceutical, medicinal, and materials science applications. The key to unleashing microalgae's biocatalytic potential has been genomics technology. A variety of unique biosynthetic gene clusters have been discovered via the mining of many algae species, encoding a huge potential for the manufacture of a variety of chemicals (Guarnieri, M. T., et al 2014).

Algal diversity:

According to the conventional definition of an alga, it is a photosynthetic organism that produces oxygen but has no sterile tissue covering its sexual reproductive organ(s) (Bold, 1973). Some researchers omit prokaryotic blue-green algae (= cyanobacteria) from the concept of algae and limit it to eukaryotic cells exclusively (Stanier et al., 1971). Green algae have a far wider variety than all plants combined (Rowan, 1989).In terms of ecology, the group of living things known as algae is significant. Eukaryotic ultra-plankton, which is frequently found deep in the euphotic zone, contributes up to 80% of the biomass and primary production in open ocean waters (Platt et al., 1983; Takahashi and Bienfang, 1983; Takahashi and Hori, 1984; Glover et al., 1985; Murphy and Haugen, 1985; Platt and Li, 1986). The oceanic phytoplankton's small size is misleading. According to Murphy and Haugen's (1985) cautious estimate of 10 6 cells 1-1, there are 3.6 x 1025 cells in the waters at any given time Andersen, R. A. (1992).In ecological investigations, taxonomic information is crucial since many of the characteristics that are used to categorize algae have functional significance. Only cyanobacteria and a few diatoms are known to produce the accessory pigment phycoerythrin in freshwater phytoplankton. Some algal flagellates, such as *Dinobryon*, *Ochromonas*, and *Euglena*, can convert from feeding autotrophically to catching bacteria or organic particles (Wehr et al 2015). Vertical patterns of algal assemblages across microhabitats in lakes are influenced by size diversity. While bigger forms need elongated or complicated structures, or motility, to minimize sinking, smaller cells sink more quickly. *Ceratium hirundinella*, a big dinoflagellate, actively controls its location in the water column by vertical migration and alters the size and form of horn-like projections across lakes (Heaney and Furnass, 1980; Heaney et al.,1998).

Diversity of eukaryotic algae:

Algal systematics is dominated by the morphological species idea; however, biological and molecular species conceptions are also employed. The biological species notion is dependent on successful sexual reproduction (Mayr, 1948). Eight types of algae have no known sexual reproduction, hence clonal cultivation is required to determine the compatibility of mating. Scale morphology, which covers certain cells, is a key characteristic used to identify new species. The wisdom of distinguishing between each morphological variation of *S. costatum* has been contested by several researchers. According to recent molecular investigations, the morphological species notion may be excessively conservative. The notions of morphological, biological, and molecular species have been contrasted in red algae. The common freshwater alga *Pandorina morum* has 20 different syngens or mating complexes. The colonial green alga Scenedesmus has 330 morphological species and 1300 variations and forms (Hegewald and Silva, 1988). *Volvox*, *Haematococcus*, and *Chlorogonium* were all examined by Buchheim et al. in the same research in 1990. These genera are mixed in with the *Chlamydomonas* species in their cladograms. From a single clonal isolation, Spirogyra contains four morphologically diverse sub-clones (McCourt and Hoshaw, 1990). Changes in chromosomal number generated variations in phenotypic variety, which in turn induced changes in ploidy Andersen, R. A. (1992).

Algal biofuels:

Gaffron and Rubin, who discovered the metabolic capability for the production of both biohydrogen and biomethane, initially recognized algae as a source of biofuels in 1942. Triacylglycerides (TAGs), in particular from algal oils, have been discovered as suitable starting materials for biodiesel production. Numerous microalgal species have been seen to experience cell-cycle stoppage in nutrient-limited environments, with alterations in fatty acid speciation that are advantageous for later lipid conversion into fuels. The discovery of *Coccomyxa* sp. and *C. reinhardtii*. The principal fatty acid and TAG routes in microalgae have been mapped thanks in large part to Richard Grossman et al 2007 publication of their study on C-169 and the subsequent sequencing of more than 30 organellar and complete algal genomes. According to recent investigations, some algae can assemble and accumulate plastidial TAG. Numerous distinct algae species have had their transcriptional and proteomic responses to nitrogen shortage studied. Under nitrogen restriction, *Neochloris oleoabundans'* transcriptomic profiling revealed that components involved in fatty acid and TAG biosynthesis were overexpressed. Alterations in the nitrogen: carbon ratios in the TCA cycle and amino acid metabolism were discovered by complementary metabolomic analysis. Isoprene-derived hydrocarbons (MVA) and methylerythritol phosphate (MEP) pathways have led to the identification of novel entry points into the terpenoid biosynthesis pathway in Botryococcus braunii and *Chlamydomonas moewusii*, are used to biosynthesize microalgal terpenes. In *C. reinhardtii*, Sulphur deprivation raised the transcripts of genes implicated in stress response and detoxification, while at the same time, metabolic remodelling increased the amount of reducing equivalents. These studies have laid the groundwork for strain-optimization techniques and have begun to clarify the transcriptional dynamics driving H2 generation (Guarnieri, M. T., et al 2014). *Nannochloropsis, Scenedesmus dimorphus, Chlamydomonas reinhardtii*, and *Synechocystis* PCC 6803 etc. are Bio-hydrogen producing species (Patel V.K. et al. 2017).

Algal nutraceuticals:

The MVA or MEP pathways are used to create the terpene class known as carotenoids, which is prized for its antioxidant potential. Microalgae have long been grown for commercial purposes to provide food, dietary supplements, and animal feed on a big scale. The possibility of using microalgae as biofactories to produce these high-value goods has been thoroughly examined. Under stressful conditions, the mRNA levels of the *Dunaliella salina* 4-hydroxy-3-methyl but-2-enyl diphosphate reductase (HDR, Fig. 2), a crucial enzyme in isoprenoid biosynthesis, were shown to be greater. Some red algae were found to have parts of the MVA and MEP pathways, which sheds light on their evolutionary history (Guarnieri, M. T., et al 2014).

Table 1: Different biochemicals are used as Nutraceuticals.

Biochemicals	Species	Activity	References
Polyunsaturated fatty acids (PUFA) (EPA & DHA)	*Haematococcus, Spirulina, Schizachyrium,* and *Crypthecodinium*	Prevention of cardiovascular disease in adults, blood coagulation, functions of nervous system and blood pressure maintenance	Chu W-LJI (2012) Barkia I et al (2019)
EPA	*Phaeodactylum*	food supplement	Soni K. and Singh S. (2022); Siddiki, S. Y. A. et al (2022)
Carbohydrates (sulfated polysaccharides	*Porphyridium cruentum*	Stabilizers in the food industry, and hydrating agents in cosmetics and pharmaceuticals, stimulate the human immune system	Barkia I et al (2019) Hamed I (2016)
Amino acids, Peptides, and Proteins	*Spirulina* and *Chlorella vulgaris*	Reduce inflammation and allergies	Barkia I et al (2019)
Carotenoids (β-carotene, astaxanthin, lutein, zeaxanthin, and lycopene)	*Chlorella*	Antioxidant activity for the prevention of cancer, skin protection, empowering the immune system	Chu W-LJI (2012) Hamed I (2016)

Algal pharmaceuticals and therapeutics:

Algal pharmacological and therapeutic development has benefited greatly from genomic data. Several strains of algae can now be quickly and successfully converted, but *C. reinhardtii* has emerged as the most effective eukaryotic microalga to do so. Algal vaccines provide a variety of distinct benefits over traditional plant-based medicines, including quick growth and little need for processing (Guarnieri, M. T., et al 2014).

Table: 2 Bioactive compounds which are used in pharmaceuticals

Bioactive compounds	Species	Activity	References
Fucoidans	*Undaria pinnatifida*	anticancer activity PC-3 prostate cancer cells	Yang et al. (2008) Boo et al. (2013).
Fucoidan	*Cladosiphon novae-caledoniae*	enhanced activity of chemotherapeutic agents such as cisplatin, tamoxifen and paclitaxel the breast cancer treatment, induced apoptosis and reduced expression of Bcl-xL and Mcl-1	(Zhang et al. 2013)
Fucoidans	*Laminaria cichorioides* and *Fucus evanescens*	their influence on blood coagulation Dose-dependent inhibition of thrombin and Xa factor	Drozd et al. (2006).
Phlorotannins (class of polyphenol compounds)	*Ecklonia*	antimicrobial activity against *Campylobacter jejuni*, *Vibrio parahaemolyticus*, *Staphylococcus aureus*	Eom et al. (2008; Nagayama et al. 2002)
Phenolic compounds	*Ascophyllum nodosum*	reduced the prevalence of *Escherichia coli*	(Braden et al. 2004)
Lutein, β-carotene, α-carotene, α-tocopherol	*Chlorella* sp.	help in decreasing the occurrence of certain cancer and in preventing macular degeneration	Santhosh S et al. (2016)
Docosahexaenoic acid	*Crypthecodinium cohnii*	-	Santhosh S et al. (2016)
Carotenoids, astaxanthin, lutein	*Haematococcus pluvalis*	-	Santhosh S et al. (2016)
Eicosapentaenoic acid	*Nannochloropsis gaditana*	-	Santhosh S et al. (2016)
Lutein, β-carotene	*Scenedesmus almeriensis*	as a colourant in pharmaceuticals, cosmetics, and foods,	Soni K. and Singh S. (2022); Santhosh S et al. (2016)
Glycerol	*Chlamydomonas reinhardtii*	-	Santhosh S et al. (2016)
Cyanovirin	biomass of *Nostoc*	anti-viral activities treating symptoms of HIV and influenza A (H1N1)	Santhosh S et al. (2016

Bioactive compounds produced by Algae used in Cosmetics:

Algae are naturally subjected to oxidative stress, generating several effective defense mechanisms against reactive oxygen species and free radicals, creating substances that can protect cosmetics from UV radiation's damaging effects. Various secondary metabolites of some microalgae can cure seborrhea, block some inflammatory processes, and prevent blemishes in addition to repairing damaged skin and maintaining skin hydration (S.K. Kim, et al 2008; Ariede, M. B., et al 2017).

Table 3: Different biochemicals are used as Cosmetics.

Bioactive compounds	**Species**	**Activity**	**References**
Beta Carotene	*Dunaliella salina*	Antioxidant and Anti inflammatory	Purwar V. and Singh S. (2022)
Chlorophyll	*Chlorella*	The pigment used in deodorants	Purwar V. and Singh S. (2022)
Canthaxanthin	*Nannochloropsis salina*	Tanning products	Purwar V. and Singh S. (2022)
Phycocyanin	*Spirulina platensis* & *Porphyridium*	Eye shadows	Purwar V. and Singh S. (2022)
Lycopene	*Anabaena species*	Antioxidant, Antiaging and used in sunscreen	Purwar V. and Singh S. (2022)
Scytonemin	*Scytonema*	Sunscreens	Purwar V. and Singh S. (2022)
Vitamin E (alpha-Tocopherol)	*Dunaliella salina* *Tetraselmis suecica*	Antioxidant	Soni K. and Singh S. (2022); Purwar V. and Singh S. (2022)
Polysaccharides	*Chlorella* & *Macroalgae*	Moisturizing and thickening agents	Purwar V. and Singh S. (2022)
Sulphated polysaccharides	*Porphyridium* & *Rhodella reticulata*	Antioxidant	Purwar V. and Singh S. (2022)
Biomass extract	*Ulva lactuca* *Codium tomentosum* *Postelsia palmaeformis*	moisturizing and skin-softening agents	Soni K. and Singh S. (2022); Guleri, S. et al (2020); Trivedi, J. et al (2015)
Astaxanthin	*Haematococcus pluvialis*	Antioxidant properties	Purwar V. and Singh S. (2022)
Chlorophyll and carotenoids	*C. vulgaris, Nostoc,* and *Spirulina platensis*	against the harmful effects of UV radiation	Ariede et al. (2017)
Liposomal Extract	*Chlamydocapsa* sp.	Prevent or delay skin ageing Avoid loss of the barrier function Reduce trans epidermal water loss (TEWL)	Stutz C.S. et al (2012)
Phycocyanin	*Spirulina*	Antioxidant properties	Purwar V. and Singh S. (2022)
Phycoerythrin	*Porphyridium*	Pigment for eyeliner and lipstick	Purwar V. and Singh S. (2022)

Conclusion:

Algae represent a particularly and stunningly varied group of eukaryotes. Coral reefs have thrived in tropical shallow-water settings for over 240 million years. The coral-Symbiodinium symbiosis is being stressed to the point of its thermal tolerance due to rising ocean surface temperatures. Nannochloropsis, Chlamydomonas reinhardtii, and the diatom Phaeodactylum tricornutum are two of the best-established algae model species for biofuel generation. We may be able to develop widely cultivated algal species in a fraction of the time it required others to breed conventional genetically engineered crops. Microalgae are organisms that produce oxygen but have no sterile tissue covering their sexual reproductive organ(s). Green algae have a far wider variety than all plants combined. Eukaryotic ultra-plankton contributes up to 80% of the biomass and primary production in open ocean waters. Taxonomy is dominated by the morphological species idea but includes biological and molecular species conceptions. Scale morphology, which covers certain cells, is a key characteristic used to identify new species. Eight types of algae have no known sexual reproduction, hence clonal cultivation is required to determine the compatibility of mating. The notions of morphological, biological, and molecular species have been contrasted in red algae. The common freshwater alga *Pandorina morum* has 20 different syngens or mating complexes. Spirogyra contains four morphologically diverse sub-clones. Changes in chromosomal number generated variations in phenotypic variety.

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