CURRICULUM VITAE

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Area of Interest

Experimental Biofuels and Bioenergy: Algal Biorefinery; Metabolomics, CO_2 sequestration; Wastewater treatment; Bioremediation

Academic Qualification

Degree/Certificate	Borad/University	Passing Year	Grad/Marks
PhD	IIT Indore	2021	Awarded
M. Tech (Biotechnology)	BIT Mesra	2015	8.07/10
B. Tech (Biotechnology)	Anna University	2012	7.60/10
12th	C.B.S.E.	2006	67.8%
10th	C.B.S.E.	2004	77.8%

Ph.D. Thesis: Stress-Induced Lipid Enhancement in Microalgae-*Scenedesmus* sp.

Hands on experiences:

1. Sample Preparation: Triacylglycerides, Lipid, Carbohydrate, Protein, Native Enzymes
2. Characterization Techniques: Spectrophotometers (fluorescence measurement, UV-vis absorptions measurement, FTIR), Chromatography analysis (gas chromatography and mass spectroscopy), Molecular biology techniques (NATIVE PAGE and SDS PAGE), Microscopy techniques (Scanning electron microscope, confocal microscope, compound microscopy)
3. Data Analysis: Excel, GraphPad prism, Origin 8.5, Principal component analysis using R studio

UGC Project Fellow: Proteomic analysis and lipid profiling of *Chlamydomonas reinhardtii* and its relevance towards bio-fuel production**. (From 04-07-2015 to 26-04-2016)**

M. Tech. Thesis: Optimization of L-Glutaminase Production and Extraction by Aqueous Two-Phase System.

List of Publications

1. **Anand**, V., Kashyap, M., Sharma, M. P., & Bala, K. (2021). Impact of hydrogen peroxide on microalgae cultivated in varying salt-nitrate-phosphate conditions. Journal of Environmental Chemical Engineering, 9(5), 105814. https://doi.org/10.1016/j.jece.2021.105814
2. Samadhiya, K., Ghosh, A., Kashyap, M., **Anand**, V., & Bala, K. (2021). Bioprospecting of native algal strains with unique lipids, proteins and carbohydrates signatures: A Time dependent study. Environmental Progress & Sustainable Energy, e13735. https://doi.org/10.1002/ep.13735
3. Kashyap, M., Samadhiya, K., Ghosh, A., **Anand**, V., Lee, H., Sawamoto, N., ... & Bala, K. (2021). Synthesis, characterization and application of intracellular Ag/AgCl nanohybrids biosynthesized in *Scenedesmus* sp. as neutral lipid inducer and antibacterial agent. Environmental Research, 201, 111499. https://doi.org/10.1016/j.envres.2021.111499
4. **Anand**, V., Kashyap, M., Ghosh, A., Samadhiya, K., & Kiran, B. (2021). A strategy for lipid production in *Scenedesmus* sp. by multiple stresses induction. Biomass Conversion and Biorefinery, 1-11. https://doi.org/10.1007/s13399-021-01392-2
5. Kashyap, M., **Anand**, V., Ghosh, A., & Kiran, B. (2021). Superintending *Scenedesmus* and *Chlorella* sp. with lead and cobalt tolerance governed via stress biomarkers. Water Supply. https://doi.org/10.2166/ws.2021.065
6. Ghosh, A., Sangtani, R., **Anand**, V., Kashyap, M., & Kiran, B. (2021). Synergistic dynamics of critical cofactors effectuates fuel relevant metabolic profile of *Scenedesmus* sp.: Targeting cleaner energy production. Journal of Cleaner Production, 297, 126640. https://doi.org/10.1016/j.jclepro.2021.126640
7. **Anand**, V., Kashyap, M., Ghosh, A., & Kiran, B. (2020). Spectroscopic insights exploring triacylglyceride accumulation in *Scenedesmus* sp. via biomolecular transitions. Bioresource Technology Reports, 12, 100593. https://doi.org/10.1016/j.biteb.2020.100593
8. **Anand**, V., Kashyap, M., Samadhiya, K., Ghosh, A., & Kiran, B. (2019). Salinity driven stress to enhance lipid production in *Scenedesmus vacuolatus*: A biodiesel trigger?. Biomass and Bioenergy, 127, 105252. https://doi.org/10.1016/j.biombioe.2019.05.021
9. **Anand**, V., Kashyap, M., Samadhiya, K., & Kiran, B. (2019). Strategies to unlock lipid production improvement in algae. International Journal of Environmental Science and Technology, 16(3), 1829-1838. https://doi.org/10.1007/s13762-018-2098-8
10. Kashyap, M., Samadhiya, K., Ghosh, A., **Anand**, V., Shirage, P. M., & Bala, K. (2019). Screening of microalgae for biosynthesis and optimization of Ag/AgCl nano hybrids having antibacterial effect. RSC advances, 9(44), 25583-25591. DOI: 10.1039/C9RA04451E
11. Ghosh, A., Samadhiya, K., Kashyap, M., **Anand**, V., Sangwan, P., & Bala, K. (2020). The use of response surface methodology for improving fatty acid methyl ester profile of *Scenedesmus vacuolatus*. Environmental Science and Pollution Research, 27(22), 27457-27469. https://doi.org/10.1007/s11356-019-07115-5

12. **Anand**, V., Singh, P. K., Banerjee, C., & Shukla, P. (2017). Proteomic approaches in microalgae: perspectives and applications. 3 Biotech, 7(3), 1-10. https://doi.org/10.1007/s13205-017-0831-5
13. **Anand**, V., Perween, Q., Sinha, R. K., Singh, H. R., & Jha, S. K. (2015). Screening of L-glutaminase Producer and Optimization of Production Process by Taguchi Orthogonal Array. International Journal of Pharmaceutical and Clinical Research, 7(04), 246-251.
14. Perween, Q., **Anand**, V., Singh, H. R., & Jha, S. K. (2015). Enhanced recovery of L-glutaminase by the optimization of a three-phase partitioning system using the Taguchi Doe Methodology. International Journal of Pharmaceutical and Clinical Research, 7(03), 216-220.

Conference /Workshop Attended

1. International conference on Emerging Areas in Biosciences and Biomedical Technologies (eBBT2), IIT Indore, January 7-9, 2020 (Participation)
2. International conference on Emerging Areas in Biosciences and Biomedical Technologies, IIT Indore, January 5-6, 2018 (Poster Presentation)
3. International Conference on Bioscience Research for Nutritional Security, Environmental Conservation & Human Health in Rural India; IINRG, Ranchi, December 22-24, 2014. (Poster Presentation)
4. National Conference on Empowering Mankind with Microbial Technologies (AMI- EMMT-2014), Tamil Nadu Agriculture University, Coimbatore, November 12-14, 2014. (Poster Presentation)
5. National Workshop on Immunoinformatics, Karpaga Vinayaga College of Engineering and Technology, Chennai, 21st September 2011. (Participation)
6. International Conference on Biomedical Instrumentation, Engineering and Environmental Management, Karpaga Vinayaga College of Engineering and Technology, Chennai, 22- 23rd July 2011. (Participation)
7. National Conference on Recent Biotechnological Perspectives in Human Diseases and Therapeutics, Bharath University, Chennai, 4th March 2011. (Oral Presentation)
8. National Level Technical Symposium on Bioinformatics, Sastra University, Chennai, 23-24th October 2010. (Participation)
9. National Level Workshop on Application of perl scripting and Bioinformatics Tools and Techniques for Biological Database, Karpaga Vinayaga College of Engineering and Technology, Chennai, 4-6th October 2010. (Participation)
10. Attended a short-term training course on Advanced Research Techniques on Genomics Proteomics and Bioinformatics (ARTGPB-2017) at National Facility for Marine Cyanobacteria, (NFMC), Tiruchirappall, November 7-21, 2017.
11. **Anand**, V., Kumar, R., & Bala, K. (2017) Potential of biofuel production from algae cultivated in wastewater, In Press: Proceedings of National Conference on Climate Change, Resource Conservation and Sustainability Strategies held on 16th – 17th March 2017 at GGS IPU, Delhi.

12. **Anand**, V., Ghosh, A., Shingdilwar, S., Kumar, R., & Bala, K. (2017). Fame production and fatty acid profiling of microalgae for biodiesel production. Phycologia, 56(4), 8.
13. **Anand**, V., & Bala, Kiran., (2017). Comparison of direct and indirect transesterification for fame profiling in *Chlorococcum* sp. Phycologia, 56(4), 8.

References

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Impact of hydrogen peroxide on microalgae cultivated in varying salt-nitrate-phosphate conditions

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ABSTRACT

Microalgal biomass has received a great deal of attention as renewable and environmental-friendly biofuel feedstock as a rebuttal to climate change, energy crisis, and global warming. To improve the commercial viability of algal biodiesel production, the rise in lipid accretion and the enrichment of algal fatty acid profile are of utmost importance. In this experiment, lipid content and fatty acid methyl ester profiling of the microalgal strain, *Scenedesmus* sp. is done to understand the intercalating effect of different media composition for its suitability in context to biodiesel production. Various nutrient combinations (sodium nitrate, $NaNO_3$) and di-potassium hydrogen phosphate, (K_2HPO_4) were incorporated along with salinity (sodium chloride) exposure for first 48 h stage of algal cultivation, followed by oxidative stress via hydrogen peroxide (H_2O_2) for the second 24 h stage of cultivation. The results show that the presence of 100 mM NaCl, 35.29 mM $NaNO_3$, and 5.74 mM K_2HPO_4 followed by the addition of 10 mM H_2O_2 ($S_{100}H_{10}N_{35.29}P_{5.74}$) to the algal growth media led to the accumulation of maximum total lipid content (226.49 ± 16.6 μg/mg). Another nutrient combination, $S_0H_{10}N_{35.29}P_0$, increased the saturated fatty acid composition (C16:0) to 31.7%. Principal component analysis (PCA) also demonstrated the combined effect of multiple nutrient components and their relative concentrations on the growth parameters and algal biochemical profile, such as biomass, chlorophyll, lipid, carbohydrate, alongwith fatty acid profiling. Hence, this study demonstrate the potential of *Scenedesmus* sp. in response to a multi-component stress environment that has influenced the fate of fatty acid methyl esters (FAME) composition and significantly improved the quality of algal biofuels produced over a short period.

1. Introduction

Microalgae are unicellular species of sizes ranging from few micrometres to few hundreds of micrometres that can be found in both marine and freshwater environments [1]. Besides having viability for alternate and renewable energy source, they are also being used as a source of various pharmaceuticals products [2]. Photoautotrophy [3], heterotrophy [4] and mixotrophy [5] are three different survival modes of these microorganisms, which mainly depend upon the availability of carbon and light intensity. To commercialize algal biofuels, synergizing the enhancement of algal biomass along with lipid production is a major concern. Under standard conditions, microalgae are reported to accumulate 20–50% of lipid per dry cell weight, which can be further improved upto 80% under various stressful conditions [6]. Microalgae are highly explored for the biorefinery approach and are extensively channelled into biomass feedstock for a wide range of bioenergy and high-value products [7]. Essential ventures such as carbon-capture skills, oil reservoirs, and photosynthetic efficiency are numerous times higher in algae than terrestrial plants. Under extreme environmental physico-chemical parameters such as nutrient depletion, varying light intensity, salinity, pH, and extreme metal toxicity, microalgae are known to exacerbate TAGs [8]. Additionally, biotic stress conditions such as algae-bacteria consortia are also known to contribute to TAG's overproduction [9].

Furthermore, all these perturbations are reported to minimize biomass productivity, implicating a slower growth rate and reduced oil yields due to curtailed photosynthetic proficiency, which is economically unviable. In a study conducted by Qiao et al. [10] on *Monoraphidium* sp. QLY-1, where he observed 14.28% and 43.31% increment in lipid content. A similar kind of study conducted by Anand et al. [11], where the combined effect of salt and nutrients was observed on the examined species *Scenedesmus* sp. and found increased in saturated fatty

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ORIGINAL ARTICLE

A strategy for lipid production in *Scenedesmus* sp. by multiple stresses induction

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Abstract
Microalgae are rich source of lipids and are one of the promising feedstocks for biofuel production, whereas enhancement of lipid, carbohydrate, and biomass production is crucial for commercialization of algal biofuels. Nutrients/salinity stresses are important to increase the synthesis of lipid. In the present study, *Scenedesmus* sp. is treated with a varying combination of sodium nitrate ($NaNO_3$), dipotassium hydrogen phosphate (K_2HPO_4), and sodium chloride (NaCl) to improve lipid accumulation. Results indicate that the modified media comprising of NaCl (100 mM), $NaNO_3$ (0 mM), and K_2HPO_4 (0.22 mM) ($S_{100}N_0P_{0.22}$) accumulated higher quantities of lipid (385.4 ± 34.2 μg/mg) along with considerable biomass (537.0 ± 22.3 μg/mL), chlorophyll "a" (6.2 ± 0.08 μg/mL), and palmitic acid (32.6%). Apart from biochemical analysis, stress-induced biomarker such as hydrogen peroxide (H_2O_2) was observed maximum for same combination (10854 μmolH_2O_2/g), with low lipid peroxidation (3.2 μmol/g). Catalase (CAT) and superoxide dismutase (SOD) activity were further studied to monitor the impact of reactive oxygen species (ROS) on lipid accumulation. This study revealed a better combination in terms of lipid and biomass profile, which can further be investigated for large-scale production. Multi-stress-driven lipid production is one of the significant outputs of the current study, which can further be explored in detail. Insight such interactions may provide directions for economical production of algal biodiesel.

Keywords Biomass · Carbohydrate · Enzymatic activity · Lipid · FAME · TAGs

1 Introduction

Microalgae can be exploited to produce high quantities of biofuels because they can be grown in a waste or barren land with a greater output in terms of lipids. Additionally, they have high growth rate and carbon capture efficiency in comparison to field crops or terrestrial plants [1, 2]. Biodiesel commercialization through microalgae is still in its initial phase as the production cost is high and biodiesel yield is low. Oleaginous microalgae are considered a feedstock for biofuel production as they can accumulate 30–70% lipids per unit dry cell weight [3]. Therefore, exploiting more species having high lipid accumulation capacity can contribute to overcome the demand for biofuels. Enhanced lipid accumulation can be achieved by treating microalgae with various physical (pH, temperature, photoperiod, and light intensity) and chemical treatment (nutrients variation, salinity, and hydrogen peroxide treatment) processes [4, 5].

Biochemical strategies are mainly concerned with nutrients' stress (viz., nitrogen, phosphorus, iron, and salt), whereas physical stress includes temperature, pH, light intensity, and photoperiod. Both these treatments can directly affect lipid accumulation and biomass production in microalgae [6–8]. Nitrogen is not only required for protein synthesis but is also involved in cell division and growth process of microalgae [9]. However, nitrogen assimilation is associated with carbon fixation and plays a vital role in the maintenance of metabolic balance, which can be achieved through an appropriate amount of nitrogen provided to cells [10]. In the case of nitrogen deficiency, protein synthesis is severely affected, which declines the photosynthetic rate ultimately resulting in change of metabolic flux towards lipid biosynthesis. Lipids are highly reduced molecules, which can be used as a source of energy under adverse conditions for the survival of microalgae [11]. *Nannochloropsis* sp., *Scenedesmus* sp., *Chlorella muelleri*, and *Neochloris oleoabundans*, are some

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Spectroscopic insights exploring triacylglyceride accumulation in *Scenedesmus* sp. via biomolecular transitions

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ABSTRACT

In current study, microalgae *Scenedesmus* sp. was treated with three different salts with varying levels from 10 to 100 mM: Sodium chloride (NaCl), Magnesium chloride hexahydrate ($MgCl_2.6H_2O$) and Calcium chloride dihydrate ($CaCl_2.2H_2O$). NaCl (100 mM) treated cells showed highest lipid accumulation in comparison to other salts. On the other hand, little improvement in lipid accumulation was also observed with varying concentrations of $CaCl_2.2H_2O$ and $MgCl_2.6H_2O$. Further, Fourier Transform Infra-Red (FTIR) spectroscopy reveals biomolecular transitions leading to changes in Triacylglycerides (TAGs) and hydrocarbon (CH) stretches from the lipids. It is observed that the maximum TAG was accumulated when treated with NaCl (70 mM). This was further confirmed through the ratio of TAGs to Amide and CH to Amide. Thus, in relevance to rapid analysis of algal samples for lipid accumulation and changes in biomolecular transitions of proteins and carbohydrates with salt treatment, FTIR can direct us to a noninvasive approach.

1. Introduction

Amongst various macromolecules, lipids have been emerged as an alternative source of renewable energy and are considered as favorable feedstock for biofuels production (Kumar et al., 2019). And microalgae, due to their high lipid accumulation potential, are being widely considered as renewable source of energy (Remmers et al., 2018; Alhattab et al., 2019). Microalgae produce biofuels, and can also be utilized for CO_2 fixation, which can assist in reducing global warming or greenhouse gas impacts (Ghosh and Kiran, 2017; Ghosh et al., 2020).

Cellular level abiotic stresses viz. osmotic, oxidative, nutrient variation, temperature, pH, light intensity and metal-stress are mainly employed to accumulate enhanced levels of lipids in microalgae (Srivastava and Goud, 2017; Kiran et al., 2016a, 2016b). Nevertheless, due to the high production cost along with water footprint, these stresses aren't proving to be profitable at pilot-level (Kim et al., 2016). Consequently, salinity stress has come up as a complementary and practical method for improving lipid accumulation in microalgae. However, it is noteworthy that the stress-induced by salts such as $CaCl_2$, NaCl, and $MgCl_2$, is a complex process which not only affects the biochemical mechanism but also physiological conditions related to the development of microalgae. Hence the role and detailed mechanism of these salts for lipid enhancement in microalgae is yet to be determined (Anand et al., 2019; Chokshi et al., 2017; Minhas et al., 2016).

It is worth mentioning here that salts, generally, produce three types of stresses, – oxidative, ionic and osmotic (Zhu, 2002). For example, in the case of KCl/NaCl induced salinity stress, sodium ion competes with potassium ion for the uptake, which leads to the shortage of potassium ions in the cytosol. Salts in excessive amounts either in soil or other adjacent environment reduces the amount of water uptake, which leads to low osmotic potential. Oxidative stress leads to an imbalance in the metabolic process, which generally results in the initiation of reactive oxygen species (Affenzeller et al., 2009). Similarly, Yilancioglu et al. (2014) has also stated an increase in microalgae lipids through oxidative stress.

Fluorescent staining, chromatographic and colorimetric analysis have emerged as cost-effective and fast lipid detection techniques and are advantageous for the commercialization of algal biofuels (Krank et al., 2007). Fluorescent method involving Nile red dye, helps to visualize the neutral lipids produced inside the cell through confocal microscopy and can also be used to quantify lipids with fluorescence spectroscopy (Cooksey et al., 1987; Elsey et al., 2007). Chromatographic technique is utilized for both lipid quantification and lipid separation. However, the Chromatography technique involves chemical/solvent extraction, which is a time-consuming method whereas Nile red dye method is not as quantitative as the chromatography separation

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Research paper

Salinity driven stress to enhance lipid production in *Scenedesmus vacuolatus*: A biodiesel trigger?

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A R T I C L E I N F O

Keywords:
Microalgae
Biodiesel
FAME
Salinity

A B S T R A C T

The main aim of the present study is to understand algae behaviour and enhancement of the intracellular neutral lipid content of freshwater green microalgae, *Scenedesmus vacuolatus*, under salt exposure. Effects of various salts (sodium chloride, magnesium chloride and calcium chloride) on this species were analysed by measuring parameters such as growth rate, chlorophyll content, neutral lipid intensity and conducting FAME profiling. When under stress, microalgae divert their metabolic pathways towards lipid synthesis, and this is evidenced in the current study. Compared to controlled and unmodified media cultivation, sodium chloride and magnesium chloride exposure promoted 383% and 340% higher fluorescence intensities, respectively, and there was a significant increase in the FAME content, particularly of saturated fatty acids (such as palmitic and stearic acid) at a magnesium chloride concentration of 50 mM and calcium chloride exposure of 70 mM, with percentage increases of 109% and 253%, respectively, compared to the control. Algal cells were found to be more tolerant towards NaCl than other salts, and this was confirmed through the biomass accumulation profile. Biomass productivity was highest at exposure to 100 mM sodium chloride (33 $mgL^{-1}d^{-1}$) followed by calcium chloride (19.5 $mgL^{-1}d^{-1}$) and magnesium chloride (12.6 $mgL^{-1}d^{-1}$). Confocal imaging further supported the results, and scanning electron microscopy revealed changes in algal surface morphology. This study provides further information about stress-driven lipid biosynthesis and analyses changes in cellular morphology and physiology. However, further exploration and systematically studies are required to determine exact mechanism involved in neutral lipid enhancement inside cells and associated metabolomics.

1. Introduction

Microalgae are able to accumulate a high lipid content, grow under varying environmental conditions and produce a higher aerial biomass than conventional energy crops [1]. Optimization of algal biomass productivity and associated lipids is a major focus of biofuel production research, and various strategies have been employed to optimize conditions in both photobioreactors and open pond systems, with the aim of obtaining high lipid accumulation in algal cells without significantly compromising biomass productivity [2]. Algae based fuels can be successfully employed if the algae growth process is sustainable and the species used can generate high lipid bodies in normal conditions. If these conditions are met, they can then be further enhanced using conventional methods, such as the stress-derived enhancement of lipid production, which leads to an overall increase in the FAME content. Achieving bulk production of lipid rich algal biomass is a crucial parameter for the sustainability of algae-based biofuels, as they can then be used to replace at least the current market share of conventional fossil fuels.

It has already been well established that the algal biochemical composition can be controlled through defined cultivation conditions. These cultivation conditions include exposure to variable nutrients (nitrate and phosphate) and the application of different types of stress (such as salinity induced osmotic stress, H_2O_2 induced oxidative stress, light, temperature and pH), which can enhance accumulation of desired metabolic products [3]. Although these variable conditions have their own limitations and may result in low biomass productivity through stress behaviour, the use of two-stage cultivation has addressed this issue to some extent (where algae strains are firstly grown in nutrient sufficient conditions and then transferred to nutrient starved conditions in the second stage) [4].

Osmotic/salinity stress has also been found to enhance lipid accumulation. Salinity stress is multifarious and it affects the metabolism of algae via several physiological and biological mechanisms relating to growth. It is known that osmotic stress assists in manipulating metabolic pathways and increasing lipid production [5]. In addition, under

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REVIEW

Strategies to unlock lipid production improvement in algae

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Abstract

In recent years, algal research revolves comprehensively in tapping the prospective of various approaches viz. energy sources and nutritional supplements. Researchers worldwide are exploring various aspects of microalgae as they attract the scientific community because of their various unique properties. It has been shown that changing the parameters for algae growth can stimulate these beautiful cells to form substances which are of high value. Biosynthesis of a number of compounds is governed through several enzymatic steps which are further influenced and controlled by the type and concentration of nutrient provided or present in the natural habitat that can act as rate-limiting factor. Algal omics has turned out to be the finest option in recent years for tapping algae as biofuel resource. Genomics and transcriptomics of algae have delivered decisive information to understand lipid biosynthesis. On the other hand, proteomics and metabolomics complement algal omics by offering accurate and useful understandings into the linked physiological settings. Although genomic study reveals many important parameters for various applications using algae, which can be further enhanced when complemented well with the techniques of proteomics, transcriptomics, metabolomics and lipidomics. Combination of datasets from various lipid enhancement approaches can deliver a system-wide impression. These approaches permit closer consideration in the future with an opinion to different practical impacts that are projected in modern era.

Keywords Microalgae · Lipids · Biofuels · Lipidomics

Introduction

Microalgae are of huge interest while finding alternative options for lipid production and refining it to biodiesel. These can be used for the production of many other useful products like enzymes, medicine, biogas, syngas and biofuels. Microalgae have also been used to produce food supplements like PUFA (DHA, EPA), β-carotene and polysaccharides since late 1990s. Neutral lipids are the storage lipids and are stored as TAGs in thylakoid membrane. These lipid bodies can be used as a source for producing biofuels, whereas structural lipids are used as structural units of membranes such as phospholipids and glycolipids. Environmental stresses such as variation in levels of pH, light intensity, temperature, and salinity are used to improve lipid accumulation in algae (Kiran et al. 2016). Growth rate may get reduced under stress conditions resulting in lower biomass production; therefore, monitoring of optimal growth condition is an important step in enhancement of total lipid content or biodiesel production. Such issues can be monitored through overexpression of key gene involved in lipid biosynthesis using genetic engineering or molecular approach (Levitan et al. 2015; Arora et al. 2018). Lipid synthesis stimulation can be achieved through better understanding of metabolic process and genetic information among the species of concern. In this review, different methods are discussed in context to algal lipids identification and enhancement through proteomics, genomics, transcriptomics and lipidomics. Technologies used in the “omics” provide the tools required to distinguish among DNA, RNA, proteins and other molecules between species and among the individuals of various species. “Omics” provide a huge set of data at different levels of biological organization which uses various techniques to integrate data and obtain a general view of functioning of the whole system. Algae have attracted the scientific world because of many advantages like fast growth rate, minimum land requirement, CO_2-capturing potential (Ghosh and Kiran 2017) and wastewater treatment. Transgenic

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