UNIDAD DE VIGILANCIA TECNOLÓGICA E INTELIGENCIA COMPETITIVA

Microalgas

Junio 2017

Ministerio de Agroindustria
Presidencia de la Nación

Participan en Confección y Edición
Juan Ignacio Gori
Fernando Carlos Zelaschi

Contenido

BIOPRODUCTOS....8
PUBLICACIONES....8
Isolation of an indigenous Chlorella vulgaris from swine wastewater and characterization of its nutrient removal ability in undiluted sewage....8
Graphical abstract....9
Application of a microalgal slurry to soil stimulates heterotrophic activity and promotes bacterial growth....9
Graphical abstract....10
Graphical abstract....11
Application of agar liquid-gel transition in cultivation and harvesting of microalgae for biodiesel production....11
Graphical abstract....12
Advances in bioconversion of microalgae with high biomass and lipid productivity....12
Graphical abstract....13
Wastewater treatment by microalgae can generate high quality biodiesel feedstock....13
Economic analysis of drying microalgae Chlorella in a conveyor belt dryer with recycled heat from a power plant....14
Graphical abstract....15
Growth and physiological responses of a marine diatom (Phaeodactylum tricornutum) against two imidazolium-based ionic liquids ([C4mim]BF4 and [C8mim]BF4)....15
Biodegradation of naproxen by freshwater algae Cymbella sp. and Scenedesmus quadricauda and the comparative toxicity....16
Graphical abstract....16
Assisting cultivation of photosynthetic microorganisms by microbial fuel cells to enhance nutrients recovery from wastewater....17
Graphical abstract....17
Efficacy of Spirulina platensis diet supplements on disease resistance and immune-related gene expression in Cyprinus carpio L. exposed to herbicide atrazine....17
Performance of Raphidocelis subcapitata exposed to heavy metal mixtures....18
Graphical abstract....19

Kinetic modelling of starch and lipid formation during mixotrophic, nutrient-limited microalgal growth 19

Progress and perspective of biosynthetic platform for higher-order biofuels..... 20

Pre-treated digestate as culture media for producing algal biomass 21

Sustainable conversion of light to algal biomass and electricity: A net energy return analysis 21

A comparative analysis of biogas upgrading technologies: Photosynthetic vs physical/chemical processes 22

Graphical abstract 23

Performance of mixed LED light wavelengths on nutrient removal and biogas upgrading by different microalgal-based treatment technologies..... 23

Synechococcus nidulans from a thermoelectric coal power plant as a potential CO2 mitigation in culture medium containing flue gas wastes 24

Polishing of anaerobic secondary effluent by Chlorella vulgaris under low light intensity..... 24

Graphical abstract 25

The chemical profile and pharmacodynamic properties of extracellular Wollea saccata biopolymer 25

Impact of nutrient starvation on intracellular biochemicals and calorific value of mixed microalgae..... 25

Catalytic hydrothermal liquefaction of D. tertiolecta over multifunctional mesoporous silica-based catalysts with high stability 26

Graphical abstract 27

Comparative life cycle assessment study on environmental impact of oil production from micro-algae and terrestrial oilseed crops 27

Energy consumption and water-soluble protein release by cell wall disruption of Nannochloropsis gaditana 27

Effect of temperature, water loading, and Ru/C catalyst on water-insoluble and water-soluble biocrude fractions from hydrothermal liquefaction of algae 28

Effect of seasonality and Cr(VI) on starch-sucrose partitioning and related enzymes in floating leaves of Salvinia minima 28

Algae production platforms for Canada's northern climate 29

Light enhancement strategies improve microalgal biomass productivity 29

Graphical abstract 31

Diatomite reinforced chitosan composite membrane as potential scaffold for guided bone regeneration..... 31

Graphical abstract 32

Microalgae biodiesel: Current status and future needs for engine performance and emissions 32

A general reaction network and kinetic model of the hydrothermal liquefaction of microalgae Tetraselmis sp. 33

Graphical abstract 34

Graphical abstract 35

Assessment of potential zooplankton control treatments for wastewater treatment High Rate Algal Ponds 36

Growth of microalgae on undiluted anaerobic digestate of piggery effluent with high ammonium concentrations 36

Assessment of microalga biofilms for simultaneous remediation and biofuel generation in mine tailings water 37

Graphical abstract 37

Selection and adaptation of microalgae to growth in 100% unfiltered coal-fired flue gas 37

Assessing the agricultural reuse of the digestate from microalgae anaerobic digestion and co-digestion with sewage sludge 38

Graphical abstract 39

Cross-study analysis of factors affecting algae cultivation in recycled medium for biofuel production 40

Pulsed Electric Field for protein release of the microalgae Chlorella vulgaris and Neochloris oleoabundans 41

Catalytic upgrading of fractionated microalgae bio-oil (Nannochloropsis oculata) using a noble metal (Pd/C) catalyst 41

Graphical abstract 42

Enhancement of biogas production from microalgal biomass through cellulolytic bacterial pretreatment 43

Graphical abstract 43

Optimizing the gas distributor based on CO2 bubble dynamic behaviors to improve microalgal biomass production in an air-lift photo-bioreactor 44

Graphical abstract 44

Enhancement of carotenoid and bacteriochlorophyll by high salinity stress in photosynthetic bacteria 44

Graphical abstract 45

Graphical abstract 46

Effect of sulfate ions on growth and pollutants removal of self-flocculating microalga Chlorococcum sp. GD in synthetic municipal wastewater 46

Sustainable power generation from bacterio-algal microbial fuel cells (MFCs): An overview 47

Graphical abstract 47

Graphical abstract 48

Occurrence forms of key ash-forming elements in defatted microalgal biomass 49

Heterogeneous-catalysed direct transformation of microalga biomass into Biodiesel-Grade FAMEs 49

Graphical abstract 50

A strategy for promoting lipid production in green microalgae Monoraphidium sp. QLY-1 by combined melatonin and photoinduction 50

Graphical abstract 51

Molecular challenges in microalgae towards cost-effective production of quality biodiesel 51

Optimization of pilot high rate algal ponds for simultaneous nutrient removal and lipids production 52

Graphical abstract 52

Enzymes produced by biomass-degrading bacteria can efficiently hydrolyze algal cell walls and facilitate lipid extraction 53

Bioethanol production from acidic and enzymatic hydrolysates of mixed microalgae culture 53

Graphical abstract 54

A novel option for reducing the optical density of liquid digestate to achieve a more productive microalgal culturing 55

Graphical abstract 55

Green compressed fluid technologies for downstream processing of Scenedesmus obliquus in a biorefinery approach 56

Graphical abstract 56

Effects of CO2 sequestration on lipid and biomass productivity in microalgal biomass production 57

Biological CO2 mitigation from coal power plant by Chlorella fusca and Spirulina sp. 57

Comparison of red microalgae (Porphyridium cruentum) culture conditions for bioethanol production 58

Graphical abstract 59

Cylindrospermopsin induced changes in growth, toxin production and antioxidant response of Acutodesmus acuminatus and Microcystis aeruginosa under differing light and nitrogen conditions....60

Biogas from microalgae: Review on microalgae's cultivation, harvesting and pretreatment for anaerobic digestion....60

Nutrient recovery and biogas generation from the anaerobic digestion of waste biomass from algal biofuel production....61

Harvesting of microalgae Chlorella vulgaris using electro-coagulation-flocculation in the batch mode....61

Global optimization of microalgae-to-biodiesel chains with integrated cogasification combined cycle systems based on greenhouse gas emissions reductions....62

UV–C radiation increases sterol production in the microalga Pavlova lutheri....62

Graphical abstract....63

PATENTES....63

Method for synchronously enhancing yields of lutein and carbohydrates of autotrophic microalgae....63

PRODUCTION OF DOCOSAHEXAENOIC ACID AND/OR EICOSAPENTAENOIC ACID AND/OR CAROTENOIDS IN MIXOTROPHIC MODE BY NITZSCHIA....64

New strains of microalgae belonging to the Nitzschia genus allow high-yield production of lipids such as docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), and/or carotenoids such as fucoxanthin. Biomass containing the microalgae can be charged with fucoxanthin representing more than 0.2% by weight of the dry matter. 64

Production of lutein in mixotrophic mode by Scenedesmus....65

NOVEL MICROALGAE AND METHODS FOR PRODUCING BIOFUEL USING THE SAME....65

Method for culturing microalgae by adding anaerobic digestion liquid of kitchen waste to natural seawater....66

A fermentation process....66

MANIPULATION OF MICROALGAL LIPID METABOLIC PATHWAY BY ALTERING CAMP SIGNALING PATHWAYS....67

METHOD FOR PROMOTING CELL GROWTH OF MICROALGAE AND ACCUMULATION OF NEUTRAL LIPID THEREIN USING SONIC VIBRATION....68

METHOD FOR CULTIVATING MICROALGAE USING SEWAGE AND LIQUEFIED FERTILIZER....68

MICROALGAE CULTIVATION METHOD USING FLASH LIGHT FOR INCREASE OF FATTY ACIDS PRODUCTION AND WASTEWATER TREATMENT....69

STRAIN OF MICROALGAE Desmodesmus sp FOR CONVERSION OF CARBON DIOXIDE FROM INDUSTRIAL WASTE GASES IN RAW MATERIAL FOR PRODUCTION OF BIOFUEL AND FEED ADDITIVES 70

PRODUCTION OF EICOSAPENTAENOIC AND/OR ARACHIDONIC ACID IN MIXOTROPHIC MODE BY EUGLENA 70

METHODS FOR THE SIMULTANEOUS PRODUCTION OF ASTAXANTHIN AND LIPID FROM HAEMATOCOCCUS PLUVIALIS 71

MANUFACTURING METHOD OF LIPID USING MICROALGAE 71

HIGH STARCH AND HIGH LIPID PRODUCING MICROALGAE CHOLORELLA CELL STRAIN ISOLATED FROM ARTIC OCEAN AND USE THEREFOR 72

METHOD OF SELECTING LIPIDES FROM BIOMASS OF MICROWAVES OF THE GENUS Chlorella 73

Method for preparing biodiesel from algae as raw material 74

Preparation and application of microalgae natural dye 74

LAURIC ESTER COMPOSITIONS 75

IMPROVED PRODUCTIVITY AND BIOPRODUCT FORMATION IN PHOTOTROPIN KNOCK/OUT MUTANTS IN MICROALGAE 75

Micro-algal oil production method, and application of alga residues as pollutant adsorbent 77

Method for promoting oil accumulation of microalgae by adding high-concentration organic wastewater into natural seawater 78

Recycle thermal power plant flue gas waste heat and carbon dioxide's device 79

METHOD OF INCREASING FOR BIOMASS AND LIPID CONTENT OF MICROALGAE USING ACORNS 79

Method for producing microalgal oil by using flue gas 80

Method for simultaneously preparing long-chain alkane and arene by taking microalgae oil as raw material 81

Biomass granule fuel taking marine microalgae as main raw material and production method of biomass granule fuel 81

Noticias de interés general: 83

Eventos y Cursos 83

Árbol de categorías 84

Español 84

Inglés 84

En este boletín se presentan las publicaciones, patentes y noticias de interés del primer trimestre del año 2017. Asimismo se listan eventos que tendrán lugar en el transcurso del año 2017.

Para acceder a el vínculo de cada publicación copiar el enlace en su navegador de internet.

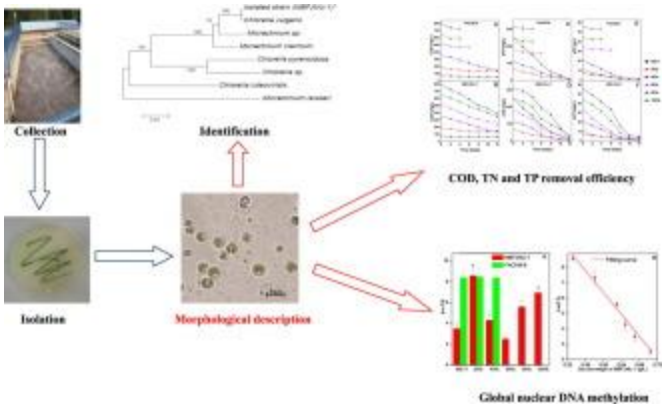
BIOPRODUCTOS

PUBLICACIONES

Isolation of an indigenous Chlorella vulgaris from swine wastewater and characterization of its nutrient removal ability in undiluted sewage

Source: Bioresource Technology, Volume 243
Author(s): Yangmin Wen, Yongjin He, Xiaowei Ji, Shaofeng Li, Ling Chen, Youcai Zhou, Mingzi Wang, Bilian Chen
Bio-treatment of wastewater mediated by microalgae is considered as a promising solution. This work aimed to isolate an indigenous microalgal strain (named MBFJNU-1) from swine wastewater effluent and identify as Chlorella vulgaris. After 12days, the removal efficiencies of total nitrogen (TN) and total phosphorus (TP) in undiluted swine slurry were 90.51% and 91.54%, respectively. Stress tolerance in response to wastewater was verified by cultivating in artificial wastewater containing different levels of chemical oxygen demand (COD), TN and TP. MBFJNU-1 could grow well in undiluted swine slurry and artificial wastewater containing 30,000mg/L COD or 2000mg/L TN. Furthermore, global nuclear DNA methylation (5-mC) of MBFJNU-1 was employed to explore the possible mechanism in response to wastewater stress. The results showed that the level of 5-mC was inversely proportional to the growth of MBFJNU-1 in different diluted swine slurry, helping to understand 5-mC variation in response to stress environment.

Graphical abstract

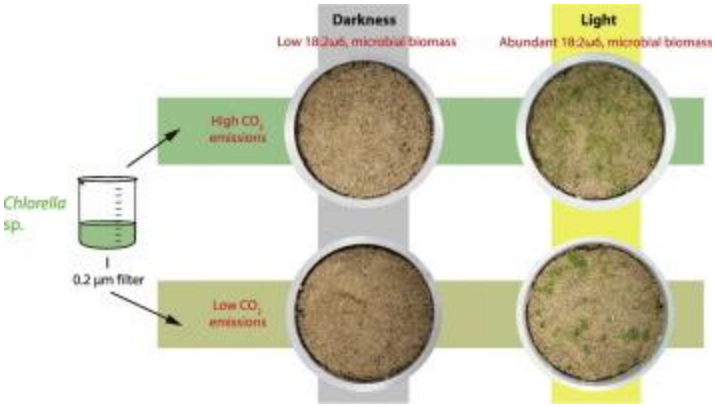


Application of a microalgal slurry to soil stimulates heterotrophic activity and promotes bacterial growth

Source: Science of The Total Environment, Volumes 605–606
Author(s): Evan A.N. Marks, Jorge Miñón, Ana Pascual, Olimpio Montero, Luis Manuel Navas, Carlos Rad

Active microalgae biomass from wastewater treatment may be given added value as a biofertilizer, but little is known about how this may affect soil nutrient dynamics and biology. If the goal is to recycle waste nutrients and matter, live algae applied in a liquid slurry to soil may add both organic carbon and nutrients while providing other benefits such as biological carbon fixation. However, the potential persistence of unicellular green algae after such an application is not known, nor the influence of their photosynthetic activity on soil organic carbon - the aim of the present study was to probe these basic questions. In a controlled laboratory microcosm experiment, suspensions of Chlorella sp. microalga culture and sterile filtrates were applied to an agricultural soil and incubated for 42days, whereas the effect of darkness was also tested to understand the importance of photosynthetic activity of the algae. Autotrophic microorganism development was 3.5 times higher in treatments with algae application as measured by chlorophyll pigment concentration. Against expectations that increased photosynthetic activity would decrease the CO2-C flux, the algal suspension with a photoperiod significantly increased soil respiration compared to culture filtrates without algal cells, with accumulated quantities of 1.8 and 0.7gCO2-Cm^{-2}, respectively. Also, phospholipid fatty acid (PLFA) analyses showed that the suspension accelerated the development of a stable community of eukaryotic and prokaryotic microorganisms in the soil surface, whereas bacterial PLFA biomarkers were significantly associated with eukaryote biomarkers on the study level.

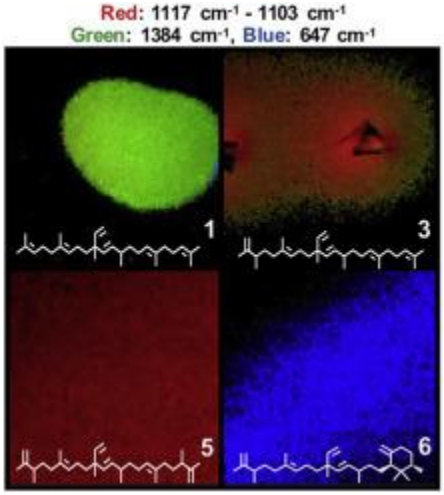
Graphical abstract



Raman spectra and DFT calculations for botryococcene and methylsqualene hydrocarbons from the B race of the green microalga Botryococcus braunii

Source: Journal of Molecular Structure, Volume 1147
Author(s): Mehmet Tatli, Hye Jin Chun, Charles H. Camp, Jingting Li, Marcus T. Cicerone, Wei-Chuan Shih, Jaan Laane, Timothy P. Devarenne
Botryococcus braunii, a green colonial microalga, is a prodigious producer of liquid hydrocarbon oils that can be used as renewable feedstocks for producing combustion engine fuels. The B race of B. braunii mainly produces the triterpene hydrocarbons known as botryococcenes, which have over twenty known structures. Minor hydrocarbons in the B race include the triterpene methylsqualenes. Here we report an examination of the molecular structure for ten botryococcenes and five methylsqualenes using Raman spectroscopy and density functional theory (DFT) calculations in an effort to distinguish between these structurally similar molecules by spectroscopic approaches. The DFT calculations show that these molecules have between 243 and 271 vibrational frequencies. A comparison of the experimental Raman spectroscopy and DFT calculations indicates several spectral regions such as those for ν(CC) stretching, CH2/CH3 bending, and ring bending can be used to distinguish between these molecules. In an extension of this analysis, a broadband coherent anti-Stokes Raman spectroscopy (BCARS) analysis was used to clearly distinguish between several botryococcenes isomers.

Graphical abstract



Effect of salt type and concentration on the growth and lipid content of Chlorella vulgaris in synthetic saline wastewater for biofuel production

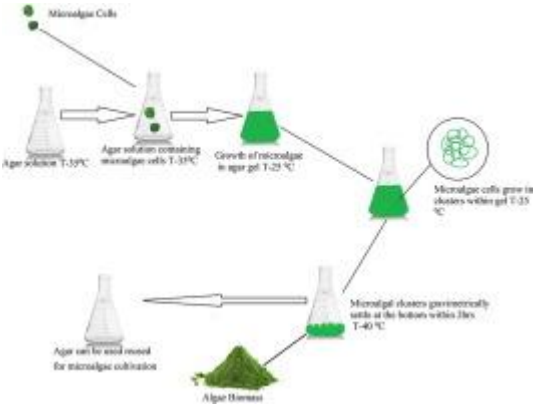
Source: Bioresource Technology, Volume 243
Author(s): Jared Church, Jae-Hoon Hwang, Keug-Tae Kim, Rebecca McLean, You-Kwan Oh, Bora Nam, Jin Chul Joo, Woo Hyoung Lee
Microalgae can offer several benefits for wastewater treatment with their ability to produce large amounts of lipids for biofuel production and the high economic value of harvested biomass for biogas and fertilizer. This study found that salt concentration (~45gL^{-1}) had more of an effect than salt type on metabolisms of Chlorella vulgaris for wastewater treatment and biofuel production. Salinity stress decreased the algal growth rate in wastewater by 0.003day^{-1} permScm^{-1} and slightly reduced nutrient removal rates. However, salinity stress was shown to increase total lipid content from 11.5% to 16.1% while also increasing the saturated portions of fatty acids in C. vulgaris. In addition, salinity increased the algal settling rate from 0.06 to 0.11mday^{-1} which could potentially reduce the cost of harvesting for algal biofuel production. Overall, C. vulgaris makes a suitable candidate for high salinity wastewater cultivation and biofuel production.

Application of agar liquid-gel transition in cultivation and harvesting of microalgae for biodiesel production

Source: Bioresource Technology, Volume 243
Author(s): Vinod Kumar, Manisha Nanda, Monu Verma
In order to increase microalgal biomass productivity efficient cultivation and harvesting methods are needed against the available traditional methods. The present study focuses on the same by harvesting microalgae using agar gel. Agar medium containing bold's basal medium (BBM) undergoes a thermoreversible gel transition. As compared to the traditional

protocols, this gel is used to cultivate microalgae without even affecting the total productivity. To develop the gel for microalgae cultivation, agar was boiled in BBM. Then the agar was cooled to 35°C and microalgae culture was added to it. After seeding the microalgae the temperature of the agar was further decreased by 10°C to induce gelation. Instead of isolated cells microalgae were grown in clusters within the agar gel. Microalgal clusters gravimetrically settle at the bottom within 2h. In this method agar can be reused.

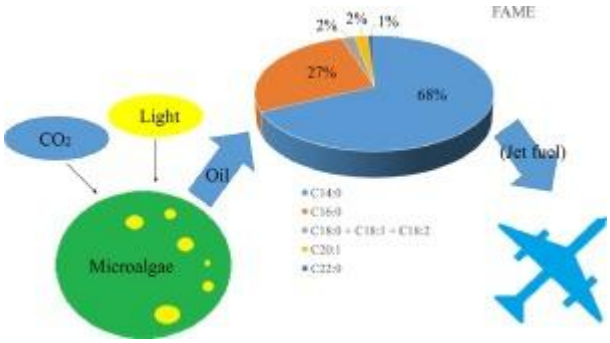
Graphical abstract



Advances in bioconversion of microalgae with high biomass and lipid productivity

Source: Journal of the Taiwan Institute of Chemical Engineers
Author(s): Yu-Tzu Huang, Chung-Wei Lai, Bo-Wei Wu, Kuen-Song Lin, Jeffrey C.S. Wu, Md Shahriar A Hossain, Yusuke Yamauchi, Kevin C.-W. Wu
Biomass energy is considered a clean and sustainable energy source that can reduce the amount of greenhouse gases. Among the different varieties of biomass, the algae can provide a number of different biofuel sources and reduce carbon dioxide (CO2) emissions. Botryococcus braunii is especially rich in lipids, which can be converted into bioenergy, but it typically grows more slowly. The aim of this study was to optimize the cultivation conditions in order to obtain high growth rates, biomass productivity, and lipid productivity. The effects of illumination and CO2 were studied in 21-day intervals. The cultured B. braunii in this work reached the maximum specific growth rate of 0.553d^{-1}, and can tolerate CO2 concentrations of up to 10%. An illumination intensity of 6000lux was identified as the optimum for both biomass and lipid productivities. Compared to the results of other studies, the major components of fatty acid methyl esters (FAMEs) obtained in this study had shorter carbon chains. The percentage of C14:0 and C16:0 in the FAMEs was greater than 70%, indicating potential applications for biojet fuel.

Graphical abstract



Wastewater treatment by microalgae can generate high quality biodiesel feedstock

Source: Journal of Water Process Engineering, Volume 18
Author(s): Francesca Rinna, Silvia Buono, Iago Teles Dominguez Cabanelas, Iracema Andrade Nascimento, Giovanni Sansone, Carmela Maria Assunta Barone
Botryococcus braunii strains are high-lipid producers. Despite this, their use as biodiesel feedstock is limited by their slow growth, which increases production costs. B. braunii wastewater bioremediation power, however, may be able to overcome this problem. This research evaluated the performance of two strains (UTEX-USA and IBL-Brazil) grown in pre-treated (influent) and treated (effluent) wastewater. The goal was to optimize algal-productivity and wastewater treatment in order to provide biomass rich in high-quality oil for biodiesel. The standard CHU-medium was used as control. Phosphorus was 100% removed in all treatments for both strains. Nitrogen removal was higher in wastewater (61–65%) than in CHU medium (48 and 61%), respectively for UTEX and IBL strains. Cultivation in the effluent generated higher biomass and lipid productivity for the UTEX strain, while the influent was the best for the IBL strain. The composition of the fatty-acids produced by Botryococcus was used to estimate the biodiesel quality. Hence, the biodiesels may have good fuel quality (high ignition and combustion efficiency) but limited application at low temperatures. The composition of fatty-acids, however, can be optimized by growing or mixing strategies. Therefore, Botryococcus braunii is a potential source for high quality biodiesel production.

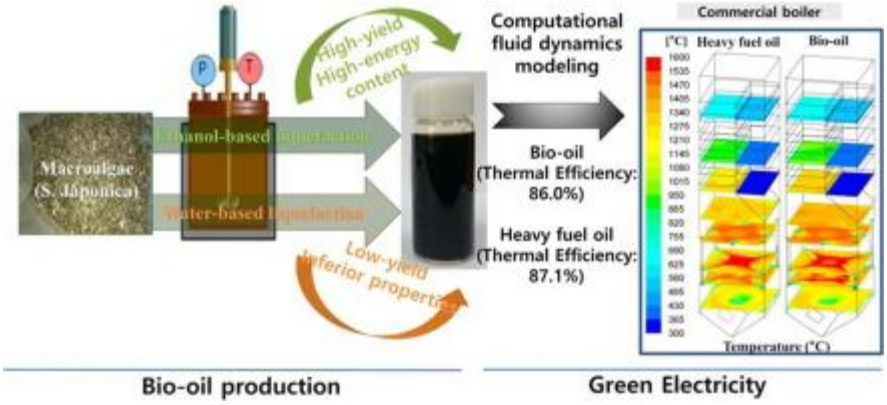
Economic analysis of drying microalgae Chlorella in a conveyor belt dryer with recycled heat from a power plant

Source: Applied Thermal Engineering, Volume 124
Author(s): Hasti Hosseinizand, C. Jim Lim, Erin Webb, Shahab Sokhansanj
The objective of this research is to estimate the cost of drying microalgae chlorella in a conveyor belt dryer using waste heat from an industrial source. The recycling system consists of a run around thermal fluid between two tube heat exchangers. The dryer is mathematically modeled and the mass transport coefficient is obtained from empirical thin-layer kinetic data. The dryer and heat recovery system are designed for the production of 1000kg/h dried microalgae at a moisture content of 10% (wet basis, w.b.). The input moisture content can range from 35 to 75% (wet basis). Depending upon the applied Hand factor, the total cost to dry microalgae from 55% to 10% ranges from $46.13 to $109.64 per ton of dried product. Using natural gas assumed at $6.27/GJ, the drying cost increases to $83.47 per ton (using hand factor equal to 1). The drying cost using a commercial spray dryer is $109.05 per ton of dried product (using hand factor equal to 1). The paper discusses the sensitivity of drying costs to initial moisture content as well. The results show that integrating waste heat recovery with conveyor belt dryer decreases the drying costs of chlorella drying in comparison to two other drying methods.

High-yield bio-oil production from macroalgae (Saccharina japonica) in supercritical ethanol and its combustion behavior

Source: Chemical Engineering Journal, Volume 327
Author(s): Hassan Zeb, Jongkeun Park, Asim Riaz, Changkook Ryu, Jaehoon Kim
The effect of reaction parameters (temperature, time and biomass-to-solvent (BS) ratio) on properties (higher heating value (HHV) and O/C and H/C ratios) and yields of bio-oil produced from macroalgae (Saccharina japonica) liquefaction using supercritical ethanol (scEtOH) as a solvent was investigated. At 400°C using a BS ratio of 1/10 and reaction time of 45min, a high yield of bio-oil (88wt%) with a HHV of 35.0MJkg^{-1}, O/C ratio of 0.14, and H/C ratio of 1.62 was obtained. Compared with water-based liquefaction, (subcritical water at 300°C, bio-oil yield of 43wt%, HHV of 20.7MJkg^{-1}, O/C ratio of 0.48, and H/C ratio of 2.01; supercritical water at 400°C, bio-oil yield of 37wt%, HHV of 29.0MJkg^{-1}, O/C ratio of 0.18, and H/C ratio of 1.76), the yield and energy content of the bio-oil produced using scEtOH were significantly higher. This enhancement was attributed to the reactivity of scEtOH with the intermediates generated from macroalgae. The utility of the generated bio-oil was demonstrated by application in a commercial 100 MWe generation plant. The thermal efficiency of the bio-oil (86.0%) was quite similar to that of heavy fuel oil (HFO) (87.1%), suggesting that the HFO could be fully replaced by the bio-oil.

Graphical abstract



Growth and physiological responses of a marine diatom (Phaeodactylum tricornutum) against two imidazolium-based ionic liquids ([C4mim]BF4 and [C8mim]BF4)

Source: Aquatic Toxicology, Volume 189

Author(s): Xiang-Yuan Deng, Biao Chen, Da Li, Xiao-Li Hu, Jie Cheng, Kun Gao, Chang-Hai Wang

Ionic liquids (ILs) have been considered as “green” substitutes for traditional organic solvents in many existing biological and chemical areas. However, they have high solubility and poor biodegradability in water, suggesting that they could become persistent chemical pollutants in aquatic environment. The ability of two widely used imidazolium-based ILs to affect the growth and physiological characteristics of a marine diatom (Phaeodactylum tricornutum) was investigated in this study. The diatom was exposed to different concentrations of 1-butyl-3-methylimidazolium tetrafluoroborate ([C4mim]BF4) and 1-octyl-3-methylimidazolium tetrafluoroborate ([C8mim]BF4) for 96h within a batch-culture system. Results showed that [C4mim]BF4 and [C8mim]BF4 were very stable in seawater during 96h of exposure, and the compounds significantly inhibited the growth of P. tricornutum with 24, 48, 72 and 96h EC50 values of 30.81, 28.53, 39.92, 45.88mgL^{-1} and 30.17, 23.36, 28.62, 31.37mgL^{-1}, respectively. In addition, the photosynthetic activity and chlorophyll a synthesis of P. tricornutum were inhibited by [C4mim]BF4 and [C8mim]BF4, indicating that the structural integrity of chloroplasts of the diatom may be disrupted or damaged by the two ILs. Compared with that of the controls, reactive oxygen species (ROS) level was increased by 0.65, 1.17, 1.85, 3.13, 2.94 times and 0.55, 1.77, 2.42, 3.45, 3.47 times in 5, 10, 20, 40 and 60mgL^{-1} [C4mim]BF4 and [C8mim]BF4 treatments, respectively. The excessive ROS may cause lipid peroxidation, shortage of metabolic energy and decline of photosynthetic efficiency, which may be the main reason for toxicity of the two ILs to marine diatoms. To withstand the damaging effects of excessive ROS, remarkable physiological and biochemical responses occurred in treatments with the two ILs to protect the cells of P. tricornutum. Parameters such as soluble protein content, soluble sugar content, and superoxide

dismutase (SOD) and peroxidase (POD) activities of the diatom increased significantly with increasing concentrations of the two ILs at 96h of exposure relative to the controls. These findings not only provide strong background for evaluating the ecological risks and toxicity of ILs in marine environment, but also help to unravel the toxic mechanism of the two ILs to marine diatoms.

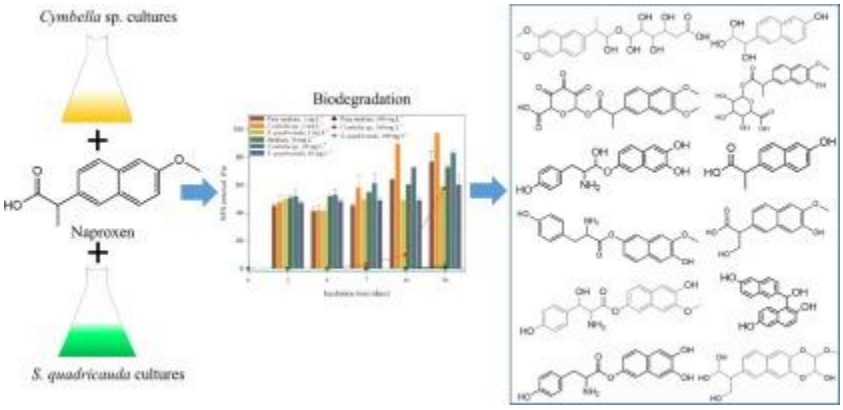
Biodegradation of naproxen by freshwater algae Cymbella sp. and Scenedesmus quadricauda and the comparative toxicity

Source: Bioresource Technology, Volume 238

Author(s): Tengda Ding, Kunde Lin, Bo Yang, Mengting Yang, Juying Li, Wenying Li, Jay Gan

Naproxen is one of the most prevalent pharmaceuticals and of great environment concern. Information about bioremediation of naproxen by algae remains limited and no study has been reported on the degradation mechanism and the toxicity of NPX on algae. In this study, both Cymbella sp. and Scenedesmus quadricauda showed complete growth inhibition (100%) at 100mgL^{-1} within 24h. Biochemical characteristics including chlorophyll a, carotenoid contents and enzyme activities for these two microalgae were affected by NPX at relatively high concentrations after 4d of exposure. Degradation of naproxen was accelerated by both algae species. Cymbella sp. showed a more satisfactive effect in the bioremediation of NPX with higher removal efficiency. A total of 12 metabolites were identified by LC-MS/MS and the degradation pathways of naproxen in two algae were proposed. Hydroxylation, decarboxylation, demethylation, tyrosine conjunction and glucuronidation contributed to naproxen transformation in algal cells.

Graphical abstract



Assisting cultivation of photosynthetic microorganisms by microbial fuel cells to enhance nutrients recovery from wastewater

Source: Bioresource Technology, Volume 237
Author(s): Alessandra Colombo, Stefania Marzorati, Giorgio Lucchini, Pierangela Cristiani, Deepak Pant, Andrea Schievano
Spirulina was cultivated in cathodic compartments of photo-microbial fuel cells (P-MFC). Anodic compartments were fed with swine-farming wastewater, enriched with sodium acetate (2.34gCOD L^{-1}). Photosynthetic oxygen generation rates were sufficient to sustain cathodic oxygen reduction, significantly improving P-MFC electrochemical performances, as compared to water-cathode control experiments. Power densities (0.8–1Wm^{-2}) approached those of air-cathode MFCs, run as control. COD was efficiently removed and only negligible fractions leaked to the cathodic chamber. Spirulina growth rates were comparable to those of control (MFC-free) cultures, while pH was significantly (0.5–1unit) higher in P-MFCs, due to cathodic reactions. Alkaliphilic photosynthetic microorganisms like Spirulina might take advantage of these selective conditions. Electro-migration along with diffusion to the cathodic compartment concurred for the recovery of most nutrients. Only P and Mg were retained in the anodic chamber. A deeper look into electro-osmotic mechanisms should be addressed in future studies.

Graphical abstract

Efficacy of Spirulina platensis diet supplements on disease resistance and immune-related gene expression in Cyprinus carpio L. exposed to herbicide atrazine

Source: Fish & Shellfish Immunology, Volume 67
Author(s): Samah R. Khalil, Rasha M. Reda, Ashraf Awad
The present study evaluated the immunotoxicological effects of the herbicide atrazine (ATZ) at sub-lethal concentrations and the potential ameliorative influence of Spirulina platensis (SP) over a sub-chronic exposure period on Cyprinus carpio L., also known as common carp.

Common carp was sampled after a 40-days exposure to ATZ (428 µg/L) and SP (1%), individually or in combination to assess the non-specific immune response, changes in mRNA expression of immune-related genes [lysozyme (LYZ), immunoglobulin M (IgM), and complement component 3 (C3)] in the spleen, and inflammatory cytokines (interleukins IL–1ß and IL–10) in the head kidney using real-time PCR. Additionally, disease resistance to Aeromonas sobria was evaluated. The results revealed that ATZ exposure caused a significant decline in most of the hematological variables, lymphocyte viability, and lysozyme and bactericidal activity. Moreover, ATZ increased the susceptibility to disease, reflected by a significantly lower post-challenge survival rate of the carp. ATZ may induce dysregulated expression of immune-related genes leading to downregulation of mRNA levels of IgM and LYZ in the spleen. However, expression of C3 remained unaffected. Of the cytokine-related genes examined, IL–1B was up-regulated in the head kidney. In contrast, the expression of IL–10 gene was down-regulated in the ATZ-exposed group. The SP supplementation resulted in a significant improvement in most indices; however, these values did not match with that of the controls. These results may conclude that ATZ affects both innate and adaptive immune responses through the negative transcriptional effect on genes involved in immunity and also due to the inflammation of the immune organs. In addition, dietary supplements with SP could be useful for modulation of the immunity in response to ATZ exposure, thereby presenting a promising feed additive for carps in aquaculture.

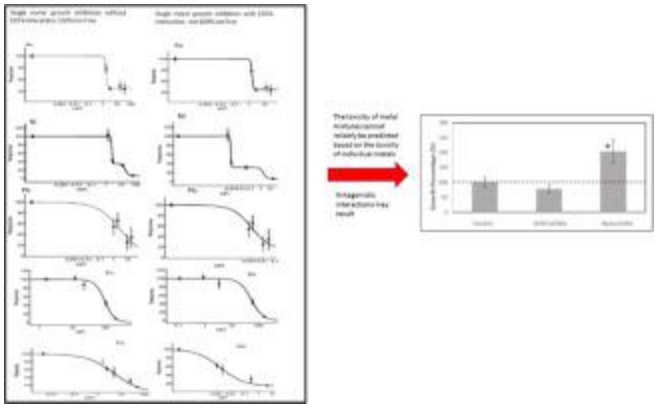
Performance of Raphidocelis subcapitata exposed to heavy metal mixtures

Source: Science of The Total Environment, Volumes 601–602
Author(s): Nora Expósito, Vikas Kumar, Jordi Sierra, Marta Schuhmacher, Gemma Giménez Papiol

Microalgae growth inhibition assays are candidates for referent ecotoxicological assays, and are a fundamental part in the strategy to reduce the use of fish and other animal models in aquatic toxicology. In the present work, the performance of Raphidocelis subcapitata exposed to heavy metals following standardized growth inhibition assays has been assessed in three different scenarios: 1) dilutions of single heavy metals, 2) artificial mixture of heavy metals at similar levels than those found in natural rivers and, 3) natural samples containing known mixtures of contaminants (heavy metals). Chemical speciation of heavy metals has been estimated with Eh-pH diagram and Visual MINTEQ software; heavy metal and free heavy metal ion concentrations were used as input data, together with microalgae growth inhibition, for Dr. Fit software. The final goal was to assess the suitability of the ecotoxicological test based on the growth inhibition of microalgae cultures, and the mathematic models based on these results, for regulatory and decision-making purposes. The toxicity of a given heavy metal is not only determined by its chemical speciation; other chemical and biological interaction play an important role in the final toxicity. Raphidocelis subcapitata 48h-h-EC50 for tested heavy metals (especially Cu and Zn) were in agreement

with previous studies, when ion metal bioavailability was assumed to be 100%. Nevertheless, the calculated growth inhibition was not in agreement with the obtained inhibition when exposed to the artificial mixture of heavy metals or the natural sample. Interactions between heavy metal ions and the compounds of the culture media and/or the natural sample determine heavy metal bioavailability, and eventually their toxicity. More research is needed for facing the challenge posed by pollutant mixtures as they are present in natural environments, and make microalgae-based assays suitable for pollution management and regulatory purposes.

Graphical abstract



Kinetic modelling of starch and lipid formation during mixotrophic, nutrient-limited microalgal growth

Source: Bioresource Technology, Volume 241

Author(s): Gonzalo M. Figueroa-Torres, Jon K. Pittman, Constantinos Theodoropoulos

Microalgal starch and lipids, carbon-based storage molecules, are useful as potential biofuel feedstocks. In this work, cultivation strategies maximising starch and lipid formation were established by developing a multi-parameter kinetic model describing microalgal growth as well as starch and lipid formation, in conjunction with laboratory-scale experiments. Growth dynamics are driven by nitrogen-limited mixotrophic conditions, known to increase cellular starch and lipid contents whilst enhancing biomass growth. Model parameters were computed by fitting model outputs to a range of experimental datasets from batch cultures of Chlamydomonas reinhardtii. Predictive capabilities of the model were established against different experimental data. The model was subsequently used to compute optimal nutrient-based cultivation strategies in terms of initial nitrogen and carbon concentrations. Model-based optimal strategies yielded a significant increase of 261% for starch ($0.065 gCL^{-1}$) and 66% for lipid ($0.08 gCL^{-1}$) production compared to base-case conditions ($0.018 gCL^{-1}$ starch, $0.048 gCL^{-1}$ lipids).

Progress and perspective of biosynthetic platform for higher-order biofuels

Source: Renewable and Sustainable Energy Reviews, Volume 80
Author(s): HaiFeng Su, JiaFu Lin, FuRong Tan
The exploitation of innate microbial capacities and/or the importation of novel diverse biosynthetic pathways have become one of the predominant research directions, with both being used to convert fermentable substrates into higher-order biofuels with long carbon chains (> 6) approximating those of gasoline with rating octane value. However, one of the primary issues has been which microorganic biosynthetic platform is most appropriate for transformation into an efficient cell factory for the production of higher-order biofuels. It is indistinct whether such a microorganism would ultimately be engineered using a native, newly isolated strain, a recombinant strain, or a model organism as the starting host. Different biosynthetic platforms microorganisms naturally have different genetic backgrounds, thus presenting different levels of complexity for metabolic networks, the incorporation of different physiological characteristics, cell structural properties, and/or biological activities. These complexities affect strategic formulations of synthetic biology, optimization designs of systems metabolic engineering, selection of metabolic pathways, and operation process difficulties in the realm of evolutionary engineering at the systems level. Here, we offer a global review of existing research for selected, engineered microorganisms designed to produce higher-order biofuels. Our focus on these microorganisms centers on the optimal production of higher-order biofuels using the construction of novel metabolic pathways and/or the alteration of existing pathways as well as examples of their application in recent years. We also discuss potential candidate microorganic biosynthetic platform and offer insight into the circumstances under which each should be used. Finally, we highlight the perspective that developing microorganisms has great possibility, but has not been extensively explored as a viable platform. In this paper, the review is placed in contrast with Crispr-Cas9 genome editing technology that will play an increasingly important role, which can be used to overcome the complex genetic metabolic background of microorganisms at more advanced levels.

Bio-hythane production from microalgae biomass: Key challenges and potential opportunities for algal bio-refineries

Source: Bioresource Technology, Volume 241
Author(s): Anish Ghimire, Gopalakrishnan Kumar, Periyasamy Sivagurunathan, Sutha Shobana, Ganesh D. Saratale, Hyun Woo Kim, Vincenzo Luongo, Giovanni Esposito, Raul Munoz
The interest in microalgae for wastewater treatment and liquid bio-fuels production (i.e. biodiesel and bioethanol) is steadily increasing due to the energy demand of the ultra-modern technological world. The associated biomass and by-product residues generated from these processes can be utilized as a feedstock in anaerobic fermentation for the

production of gaseous bio-fuels. In this context, dark fermentation coupled with anaerobic digestion can be a potential technology for the production of hydrogen and methane from these residual algal biomasses. The mixture of these gaseous bio-fuels, known as hythane, has superior characteristics and is increasingly regarded as an alternative to fossil fuels. This review provides the current developments achieved in the conversion of algal biomass to bio-hythane (H2 +CH4).

Pre-treated digestate as culture media for producing algal biomass

Source: Ecological Engineering, Volume 105
Author(s): Davide Veronesiv, Giuliana D'Imporzano, Silvia Salati, Fabrizio Adani
An agro-zootechnical ultrafiltered digestate (UF) coming from an anaerobic digester plant was used to grow two strains of microalgae: Chlorella sp. and Phaeodactylum tricornutum, in a comparison with standard substrates. Chlorella sp. and P. tricornutum were able to grow on UF with similar growth rates (μ) to those obtained using standard substrates, i.e. μ of $0.216d^{-1}$ and of $0.200d^{-1}$ for Chlorella sp., and of $0.128d^{-1}$ and $0.126d^{-1}$ for P. tricornutum, on synthetic media and UF, respectively. Algae grown on UF showed similar final biomass composition to those obtained by using synthetic media. Algae were able to remove nitrogen from UF, i.e. 92% and 71%, for Chlorella sp. and P. tricornutum respectively. Microalgae can grow on UF producing good quality final biomass.

Sustainable conversion of light to algal biomass and electricity: A net energy return analysis

Source: Energy, Volume 131
Author(s): Mahdi Shahnazari, Parisa A. Bahri, David Parlevliet, Manickam Minakshi, Navid R. Moheimani
A substantial interest is growing in the cultivation of microalgae as a source of biofuel production, considering their relatively high lipid content, fast growth rates, use of alternative water sources, and growth on non-arable land. This paper conducts an energy life cycle analysis for a novel hypothetical hybrid energy system where the electricity required for microalgae cultivation is generated from semi-transparent PV panels to energise paddle wheels and light emitting diodes installed on raceway ponds. The combined system configuration allows for a full utilisation of the solar spectrum, while enhancing the photosynthetic productivity of microalgae cultivation and reducing the evaporation from raceway ponds. The findings of study for a hypothetical system installed in Western Australia show that the amount of land use substantially decreases by 43%, the productivity of microalgae cultivation increases by 75%, while the net energy return of the system remains significantly higher than one, in comparison with a microalgae cultivation system energised by grid electricity. Among a range of variables affecting the energy performance of the proposed system, the primary energy demand for PV panels and conversion efficiency of LEDs exert the highest impact on energy life cycle of the system.

Potential of fecal waste for the production of biomethane, bioethanol and biodiesel

Source: Journal of Biotechnology, Volume 253

Author(s): Mohamed A. Gomaa, Raeid M.M. Abed

Fecal waste is an environmental burden that requires proper disposal, which ultimately becomes also an economic burden. Because fecal waste is nutrient-rich and contains a diverse methanogenic community, it has been utilized to produce biomethane via anaerobic digestion. Carbohydrates and lipids in fecal waste could reach up to 50% of the dry weight, which also suggests a potential as a feedstock for bioethanol and biodiesel production. We measured biomethane production from fecal waste of cows, chickens, goats and humans and compared the microbial community composition before and after anaerobic digestion. We also compared the fecal waste for cellulase production, saccharification and fermentation to produce bioethanol and for lipid content and fatty acid profiles to produce biodiesel. All fecal waste produced biomethane, with the highest yield of 433.4±77.1ml CH4/g VS from cow fecal waste. Production of bioethanol was achieved from all samples, with chicken fecal waste yielding as high as 1.6±0.25g/l. Sludge samples exhibited the highest extractable portion of lipids (20.9±0.08wt%) and conversion to fatty acid methyl esters (11.94wt%). Utilization of fecal waste for the production of biofuels is environmentally and economically beneficial.

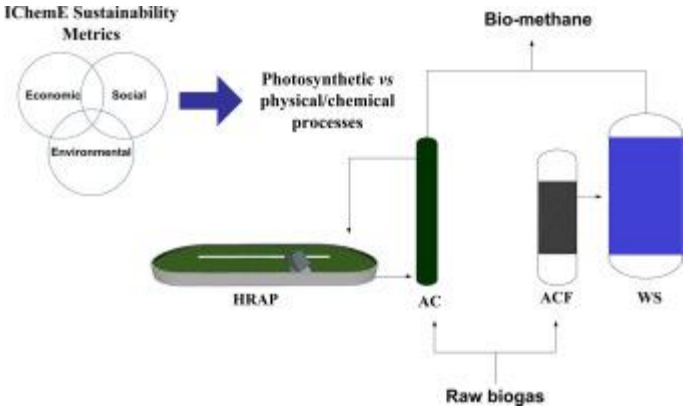
A comparative analysis of biogas upgrading technologies: Photosynthetic vs physical/chemical processes

Source: Algal Research, Volume 25

Author(s): Alma Toledo-Cervantes, José M. Estrada, Raquel Lebrero, Raúl Muñoz

Two biogas upgrading technologies, viz. an innovative algal-bacterial photobioreactor and a conventional activated carbon filter coupled with a water scrubber, were comparatively evaluated in terms of environmental, economic and social performance by using the IChemE Sustainability Metrics. The upgrading of 300Nm^3/h of biogas generated from the anaerobic digestion of mixed sludge in a wastewater treatment plant was used as a model scenario for the comparative analysis. Despite the algal-bacterial photobioreactor entailed 1860 times higher land requirements, the two-stage physical/chemical technology exhibited ×3.8 higher energy consumptions and larger environmental impacts in terms of material and water consumption and greenhouse gas emissions (the latter by a factor of ~45). The investment cost for the algal-bacterial photobioreactor was 1.6 times higher than that of its physical/chemical counterpart due to the biomass drying unit required to produce an algae-based fertilizer. However, the operating cost of the physical/chemical technology was ~7 times higher due to the frequent replacement of the activated carbon. A further analysis of the net present value (NPV 20) revealed that photosynthetic upgrading would yield revenues from year 5 of operation mainly due to the sale of the algal bio-fertilizer produced, even without tax incentives for bio-methane.

Graphical abstract



Performance of mixed LED light wavelengths on nutrient removal and biogas upgrading by different microalgal-based treatment technologies

Source: Energy, Volume 130

Author(s): Yuejin Zhang, Keting Bao, Juan Wang, Yongjun Zhao, Changwei Hu

Micro-algal treatment technologies are an efficient and effective method for simultaneous biogas slurry nutrient removal and biogas upgrade. Three treatment technologies were investigated, utilizing different selected strains (mono-cultivation of microalgae, co-cultivation of microalgae with fungi, and co-cultivation of microalgae with activated sludge). Strains were cultivated by using biogas slurry as a nutrient medium in a photo-bio-reactor at various mixed LED treatments. A red: blue LED ratio of 7:3 and 5:5 was considered optimum for co-cultivation of microalgae with either fungi or activated sludge, to support COD and TP removal, with 65.57%–74.29% and 70.83%–76.69% removed, respectively. The system with co-cultivated microalgae and activated sludge, demonstrated high N removal efficiency at a red: blue LED ratio of 5: 5. The most effective light mixture ratios for biogas upgrade were found to be red: blue = 7: 3 and 5: 5, with the highest performance in the co-cultivated microalgae with fungi system, while the optimum red: blue ratio for both biogas slurry nutrient removal and biogas upgrade was 5:5 for the co-cultivation of microalgae with fungi system. The optimal cultivation times for mono-cultivated microalgae, co-cultivated microalgae with fungi and co-cultivated microalgae with activated sludge, were 7 d, 9 d and 8 d, respectively. These results show the high potential for combined strain systems in nutrient removal and biogas upgrading, with algal-fungal symbiotic systems showing significant promise.

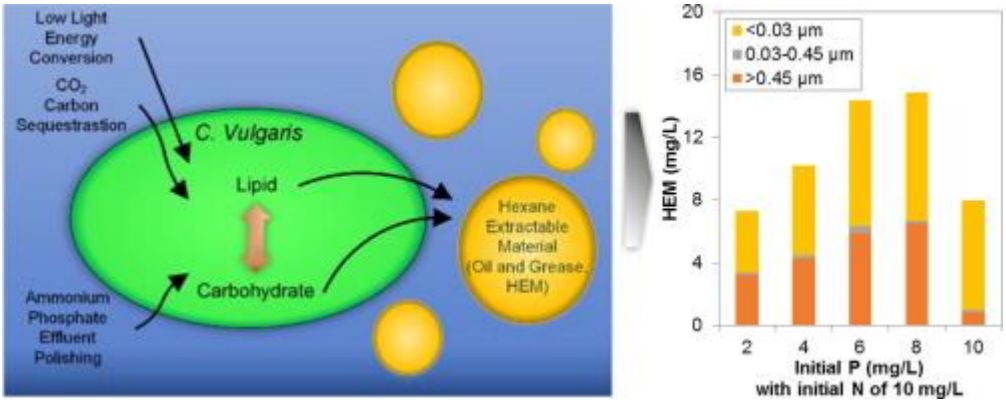
Synechococcus nidulans from a thermoelectric coal power plant as a potential CO2 mitigation in culture medium containing flue gas wastes

Source: Bioresource Technology, Volume 241
Author(s): Jessica Hartwig Duarte, Jorge Alberto Vieira Costa
This study evaluated the intermittent addition of coal flue gas wastes (CO2, SO2, NO and ash) into a Synechococcus nidulans LEB 115 cultivation in terms of growth parameters, CO2 biofixation and biomass characterization. The microalga from a coal thermoelectric plant showed tolerance up to 200ppm SO2 and NO, with a maximum specific growth rate of $0.18\pm0.03 d^{-1}$. The addition of thermal coal ash to the cultivation increased the Synechococcus nidulans LEB 115 maximum cell growth by approximately 1.3 times. The best CO2 biofixation efficiency was obtained with 10% CO2, 60ppm SO2, 100ppm NO and 40ppm ash (55.0±3.1%). The biomass compositions in the assays were similar, with approximately 9.8% carbohydrates, 13.5% lipids and 62.7% proteins.

Polishing of anaerobic secondary effluent by Chlorella vulgaris under low light intensity

Source: Bioresource Technology, Volume 241
Author(s): Tuoyuan Cheng, Chun-Hai Wei, TorOve Leiknes
To investigate anaerobic secondary effluent polishing by microalgae (Chlorella vulgaris) under low light intensity (14μmol/m^2/s), bubbling column reactors were operated in batches of 8 d with initial ammonium nitrogen 10–50mg/L, initial phosphate phosphorus 2–10mg/L and microalgal seed 40mg/L. Maximum microalgal biomass and minimum generation time were 370.9mg/L and 2.5d, respectively. Nitrogen removal (maximum 99.6%) was mainly attributed to microalgal growth rate, while phosphorus removal (maximum 49.8%) was related to microalgal growth rate, cell phosphorus content (maximum 1.5%) and initial nutrients ratio. Dissolved microalgal organics release in terms of chemical oxygen demand (maximum 63.2mg/L) and hexane extractable material (i.e., oil and grease, maximum 8.5mg/L) was firstly reported and mainly affected by nitrogen deficiency and deteriorated effluent quality. Ultrafiltration critical flux (16.6–39.5L/m^2/h) showed negative linear correlation to microalgal biomass. Anaerobic membrane bioreactor effluent polishing showed similar results with slight inhibition to synthetic effluent.

Graphical abstract



The chemical profile and pharmacodynamic properties of extracellular Wollea saccata biopolymer

Source: International Journal of Biological Macromolecules, Volume 103
Author(s): Martina Šutovská, Michaela Kočmálová, Lenka Pappová, Soňa Fraňová, Andrej Chyba, Jiří Kopecký, Jaromír Lukavský, Vladislav Cepák, Peter Capek
Microalgae organisms are of interest for many biotechnology applications due to the production of a wide range of biologically active compounds. Incubation of Wollea saccata in a large scale afforded a mucilaginous, high molecular weight biopolymer composed of carbohydrate, protein and phenolic compounds. Sugar moiety was rich in hexoses (60%) and 6-deoxyhexoses (31%), while only 9% of pentoses was identified. Methylation analysis revealed about 40 types of methylated sugar derivatives, suggesting a very complex structure of Wollea biopolymer. Pharmacological studies revealed new pharmacodynamic properties of cyanobacteria biopolymer, i.e. antitussive and bronchodilatory. Biopolymer was able to suppress the cough reflex induced by chemical tussigen, but its effect was lower than that of codeine, the strongest antitussive agent. The bronchodilatory effect was similar or higher than the effect of salbutamol, a bronchodilatory drug used in a clinical practice. In pharmacological studies, there were no signs of toxicity or side effects in the animals following administration of Wollea biopolymer.

Impact of nutrient starvation on intracellular biochemicals and calorific value of mixed microalgae

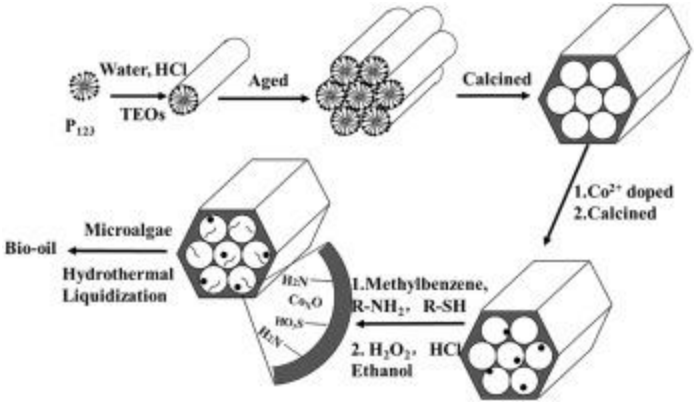
Source: Biochemical Engineering Journal, Volume 125
Author(s): Azadeh Fazeli Danesh, Sirous Ebrahimi, Abolfazl Salehi, Alireza Parsa
A two-stage cultivation strategy was applied to mixed microalgae, which were first cultured in complete nutrient medium then switched to different nutrient-free mediums in order to assess the impact of nutrient starvation on intracellular biochemical components of mixed microalgae. The effects of nitrogen, sulfur and phosphorus starvation on cell counts,

chlorophyll, carotenoid, protein, starch and lipid content of the mixed microalgae are compared in this study. The obtained results revealed that starch, as a dominant storage compound, was the highest in the nitrogen-free medium up to 49% of dry weight (DW). Protein and chlorophyll content declined slightly from 512 to 472.96mgL^{-1} and 29.43 to 26.58mg.L^{-1} only in the case of nitrogen starvation. Nitrogen starvation showed the best result as it ceased cell division immediately whereby in the case of sulfur and phosphorus starvation, cell division was not interrupted as microalgae are a pool of phosphorus and store sulfur. Calculation of starch and lipid energy content on the basis of electron equivalent and J/mg dry weight showed the higher energy content of lipid in compare with that of starch for all nutrients starvation. Nitrogen deprivation condition represents the superlative energy value of storage compounds content with the value of 17.61J/mg dry weight. The finding proves the potential of attractive and economically feasible mixed microalgae cultivation for high percentages of storage compounds production under nitrogen starvation.

Catalytic hydrothermal liquefaction of D. tertiolecta over multifunctional mesoporous silica-based catalysts with high stability

Source: Microporous and Mesoporous Materials, Volume 250
Author(s): Qisong Lin, Yu Chen, Yin Tang, Kejing Wu, Mingde Yang, Husheng Hu, Yulong Wu
In this work, multifunctional mesoporous silica-based catalysts containing metal, acid and base were successfully synthesized by doping metal cobalt through the impregnation–precipitation method and grafting amino and sulfonic groups by the silicon alkylation method. The catalytic hydrothermal liquefaction (HTL) of Dunaliella tertiolecta (D. tertiolecta) was performed at 533 K for 30 min. X-ray diffraction (XRD), small angle X-ray diffraction (SXRD), N2 absorption/desorption isotherm analysis, elemental analysis, inductively coupled plasma optical emission spectrometer (ICP-OES), and transmission electron microscopy (TEM) were employed to characterize SBA-15 and multifunctional SBA-15. The hydrothermal testing on the obtained multifunctional SBA-15 were conducted in a stainless steel autoclave at 533 K for 30 min. SXRD, TEM, and N2 absorption/desorption isotherm analysis results showed that Co doping and sulfonic group grafting, but not amino group grafting, could improve the hydrothermal stability of SBA-15. The results of TEM, XRD, and ICP-OES confirmed that Co existed as Co3O4 and entered into the SBA-15 skeleton. Meanwhile, the results of elemental analysis and ICP-OES showed that amino and sulfonic groups were successfully grafted on SBA-15. Gas chromatography–mass spectrometry (GC-MS) and elemental analysis were adopted to identify the composition of the obtained bio-oil. The bio-oil produced by the catalytic HTL of Dunaliella tertiolecta at 533 K for 30 min gained high contents of furfural and its derivatives, as well as low contents of acids, N-containing compounds, and esters, when NH2-SO3H-Co-SBA-15 and SO3H-Co-SBA-15 were used as catalysts. However, fewer conversions and lower bio-oil yields were obtained under the use of such catalysts than under catalyst absence.

Graphical abstract



Comparative life cycle assessment study on environmental impact of oil production from micro-algae and terrestrial oilseed crops

Source: Bioresource Technology, Volume 239

Author(s): S. Jez, D. Spinelli, A. Fierro, A. Dibenedetto, M. Aresta, E. Busi, R. Basosi

In this study the LCA methodology is applied in order to satisfy two goals: i) to evaluate the hot spots in site-specific production chain of biodiesel from terrestrial and micro-algae feedstock; ii) to compare quantitatively, utilizing primary data, the impacts of the first generation in respect to the third generation bio-fuels. Results show that micro-algae are neither competitive yet with traditional oil crops nor with fossil fuel. The use of renewable technologies as photovoltaics and biogas self production might increase the competitiveness of micro-algae oil. Further investigations are however necessary to optimize their production chain and to increase the added value of co-products.

Energy consumption and water-soluble protein release by cell wall disruption of Nannochloropsis gaditana

Source: Bioresource Technology, Volume 239

Author(s): C. Safi, L. Cabas Rodriguez, W.J. Mulder, N. Engelen-Smit, W. Spekking, L.A.M. van den Broek, G. Olivieri, L. Sijtsma

Several cell disruption methods were tested on Nannochloropsis gaditana, to evaluate their efficiency in terms of cell disintegration, energy input and release of soluble proteins. High-pressure homogenization (HPH) and bead milling were the most efficient with >95% cell disintegration, ±50% (w/w) release of total proteins and low energy input (<0.5kWh.kg^{-1} biomass). Enzymatic treatment required low energy input (<0.34kWh.kg^{-1} biomass), but it only released ±35% protein (w/w). Pulsed Electric Field (PEF) was neither energy-efficient (10.44kWh.kg^{-1} biomass) nor successful for protein release (only 10% proteins w/w) and cell disintegration. The release of proteins after applying HPH and bead milling always required

less intensive operating conditions for cell disruption. The energy cost per unit of released protein ranged from 0.15–0.25 €.kgProtein $^{-1}$ in case of HPH, and up to 2–20 €.kgProtein $^{-1}$ in case of PEF.

Effect of temperature, water loading, and Ru/C catalyst on water-insoluble and water-soluble biocrude fractions from hydrothermal liquefaction of algae

Source: Bioresource Technology, Volume 239
Author(s): Donghai Xu, Phillip E. Savage
Hydrothermal liquefaction (HTL) converts algal biomass into a crude bio-oil (biocrude) and aqueous-phase products. The effect of temperature, water loading, and added H2 and/or Ru/C catalyst on the properties of the biocrude that spontaneously separates from the aqueous phase post reaction and also the biocrude that is extractable from the aqueous phase by dichloromethane is explored herein. This report is the first to elucidate how the yields, compositions, heating values, and energy recoveries of the two biocrudes vary with the processing conditions above. Increasing temperature from 350 to 400°C increased the yield of water-insoluble biocrude (38.1–42.5wt%) and its hexane-soluble subfraction (63.7–85.6wt%) while decreasing the yield of extractable, water-soluble biocrude (6.6–2.5wt%). The Ru/C catalyst had the same effect. Reaction temperature and catalysts could be used to manipulate the proportions of water-soluble and water-insoluble biocrude from algae HTL and thereby manipulate biocrude quantity and quality.

Effect of seasonality and Cr(VI) on starch-sucrose partitioning and related enzymes in floating leaves of Salvinia minima

Source: Plant Physiology and Biochemistry, Volume 118
Author(s): Mariana Rosa, Carolina Prado, Silvana Chocobar-Ponce, Eduardo Pagano, Fernando Prado
Effects of seasonality and increasing Cr(VI) concentrations on leaf starch-sucrose partitioning, sucrose- and starch-related enzyme activities, and carbon allocation toward leaf development were analyzed in fronds (floating leaves) of the floating fern Salvinia minima. Carbohydrates and enzyme activities of Cr-exposed fronds showed different patterns in winter and summer. Total soluble sugars, starch, glucose and fructose increased in winter fronds, while sucrose was higher in summer ones. Starch and soluble carbohydrates, except glucose, increased under increasing Cr(VI) concentrations in winter fronds, while in summer ones only sucrose increased under Cr(VI) treatment. In summer fronds starch, total soluble sugars, fructose and glucose practically stayed without changes in all assayed Cr(VI) concentrations. Enzyme activities related to starch and sucrose metabolisms (e.g. ADPGase, SPS, SS and AI) were higher in winter fronds than in summer ones. Total amylase and cFBPase activities were higher in summer fronds. Cr(VI) treatment

increased enzyme activities, except ADPGase, in both winter and summer fronds but no clear pattern changes were observed. Data of this study show clearly that carbohydrate metabolism is differently perturbed by both seasonality and Cr(VI) treatment in summer and winter fronds, which affects leaf starch-sucrose partitioning and specific leaf area (SLA) in terms of carbon investment.

Algae production platforms for Canada's northern climate

Source: Renewable and Sustainable Energy Reviews, Volume 80
Author(s): Stan Pankratz, Adetoyese Olajire Oyedun, Xiaolei Zhang, Amit Kumar
Large resources are being invested globally in algae research in the anticipation that these microorganisms will become the “silver bullets” that lead to economic bio-renewable fuels, new food sources, and a host of high value products and simultaneously mitigate rising atmospheric CO2 levels. A great deal of research has been completed on strains of algae with the potential to produce high lipid yields that make the biomass suitable for biofuel production. Many production systems for algae cultivation continue to be developed for moderate and hot climates (e.g., USA, Europe, and Australia). The largest algae cultivation systems to date use open pond systems. These autotrophic systems, however, have limited applicability in Canada’s northern climatic conditions. There is consensus that closed photobioreactor systems are required to control environmental conditions (including temperature), minimize evaporation and contamination, and augment the limited sunlight available during winter to generate consistent biomass yields for economically sustainable crops. Given the high capital and operating costs, however, many are skeptical that meaningful and economically sustainable algae cultivation can take place in Canada. This paper identifies nine scalable algae photobioreactor cultivation technologies that may suit Canadian northern climates. The information provides insights related to the developing algae industry in Canada as well as highlighting opportunities for further technological development specific to cold climates. Although the review demonstrates that exciting headway has been made, significant technological challenges remain and require that further innovations be developed.

Light enhancement strategies improve microalgal biomass productivity

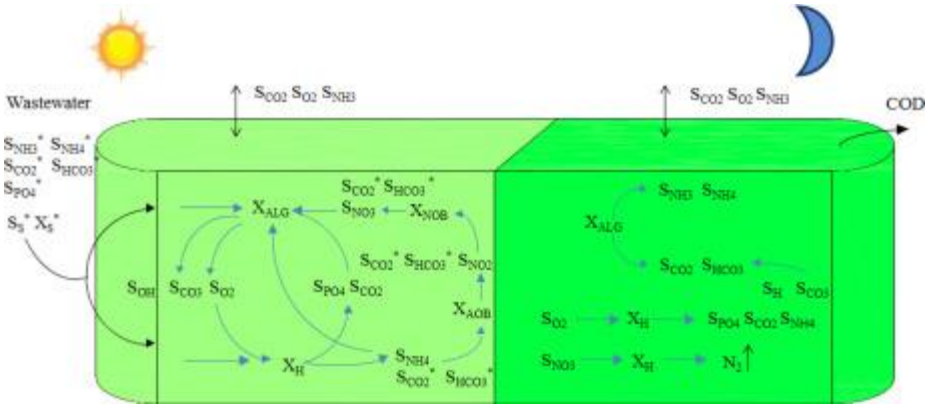
Source: Renewable and Sustainable Energy Reviews, Volume 80
Author(s): Luveshan Ramanna, Ismail Rawat, Faizal Bux
The rapid increase in global energy demand, global warming and climate change have driven the search for alternative renewable sources of energy with lesser environmental impact. Microalgae have immense potential as renewable energy feedstocks. Microalgal biomass can be used to generate a variety of biofuels including biodiesel, bioethanol, bio-hydrogen, bio-methane and syngas. One of the major hurdles to the commercialization of microalgae-based biofuels and products is limited biomass productivity. Considerable amounts of

research have been conducted into enhancing microalgal biomass production due to its potential sustainability and variety of applications. The traditional methods of improving biomass productivity are limited to adaptation of cultivation conditions and more recently genetic engineering. Light is a crucial factor that governs microalgal growth. Research on the adaptation and manipulation of natural light rather than adaptation of microalgae has been very limited. Microalgae utilize only a small fraction of light wavelengths from the wide spectrum of solar radiation for photosynthesis. In order to enhance microalgal biomass, improved photosynthetic efficiency is essential. This can be accomplished by the manipulation of the light spectrum to achieve an optimal balance between photosynthesis and photoprotection. Manipulation of incident irradiance may be viable for increased light harvesting by algae. This not only reduces unused wavelengths but also concentrates the wavelengths in a range utilized by algae. This would allow for a maximum utilization of the light spectrum by microalgae. This review critically analyses different light manipulation techniques that modify the spectrum of light received by the algae to improve biomass productivity.

Integral microalgae-bacteria model (BIO_ALGAE): Application to wastewater high rate algal ponds

Source: Science of The Total Environment, Volumes 601–602
Author(s): Alessandro Solimeno, Lauren Parker, Tryg Lundquist, Joan García
An integral mechanistic model describing the complex interactions in mixed algal-bacterial systems was developed. The model includes crucial physical, chemical and biokinetic processes of microalgae as well as bacteria in wastewater. Carbon-limited microalgae and autotrophic bacteria growth, light attenuation, photorespiration, temperature and pH dependency are some of the new features included. The model named BIO_ALGAE was built using the general formulation and structure of activated sludge models (ASM), and it was implemented in COMSOL Multiphysics™ platform. Calibration and validation were conducted with experimental data from two identical pilot HRAPs receiving real wastewater. The model was able to simulate the dynamics of different components in the ponds, and to predict the relative proportion of microalgae (58–68% in average of total suspended solids (TSS) and bacteria (30–20% in average of TSS). Microalgae growth resulted strongly influenced by the light factor fL(I), decreasing microalgae concentrations from 40 to 60%. Furthermore, reducing the influent organic matter concentration of 50% and 70%, model predictions indicated that microalgae production increased from ($8.7 gTSS m^{-2} d^{-1}$ to $13.5 gTSS m^{-2} d^{-1}$) due to the new distribution of particulate components. The proposed model could be an efficient tool for industry to predict the production of microalgae, as well as to design and optimize HRAPs.

Graphical abstract

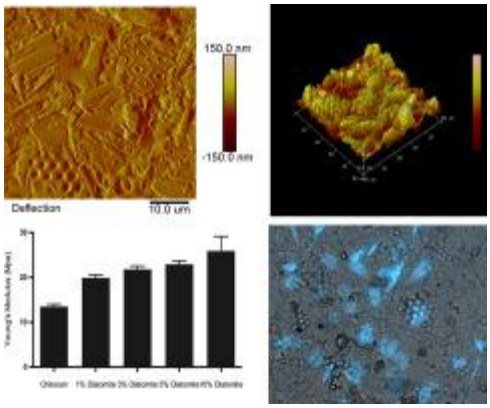


Diatomite reinforced chitosan composite membrane as potential scaffold for guided bone regeneration

Source: Materials Science and Engineering: C, Volume 80
Author(s): Sedef Tamburaci, Funda Tihminlioglu

In this study, natural silica source, diatomite, incorporated novel chitosan based composite membranes were fabricated and characterized for bone tissue engineering applications as possible bone regeneration membrane. The effect of diatomite loading on the mechanical, morphological, chemical, thermal and surface properties, wettability and in vitro cytotoxicity and cell proliferation on of composite membranes were investigated and observed by tensile test, atomic force microscopy (AFM), Fourier transform infrared spectroscopy (FTIR), thermal gravimetric analysis (TGA), protein adsorption assay, air/water contact angle analysis and WST-1 respectively. Swelling studies were also performed by water absorption capacity determination. Results showed that incorporation of diatomite to the chitosan matrix increased the surface roughness, swelling capacity and tensile modulus of membranes. An increase of about 52% in Young's modulus was achieved for 10wt% diatomite composite membranes compared with chitosan membranes. High cell viability results were obtained with indirect extraction method. Besides, in vitro cell proliferation and ALP activity results showed that diatom incorporation significantly increased the ALP activity of Saos-2 cells cultured on chitosan membranes. The novel composite membranes prepared in the present study with tunable properties can be considered as a potential candidate as a scaffold in view of its enhanced physical & chemical properties as well as biological activities for bone tissue engineering applications.

Graphical abstract



Biodiesel production from microalgae: Processes, technologies and recent advancements

Source: Renewable and Sustainable Energy Reviews, Volume 79
Author(s): M. Faried, M. Samer, E. Abdelsalam, R.S. Yousef, Y.A. Attia, A.S. Ali
This literature review discusses several aspects of biodiesel production from microalgae. This paper elucidates the optimal bioenvironmental conditions for microalgae cultivation, process design of algal biodiesel production, physicochemical properties of lipids extracted from microalgae and the properties of the produced biodiesel fuel, and the transesterification process. On the other hand, this paper illustrates the designs of up-to-date full-scale and lab-scale photobioreactors (PBRs). Furthermore, this paper argues different bioengineering aspects of biodiesel production from microalgae. Eventually, the measurements, calculations, design parameters, Life Cycle Analysis (LCA) of the production process are discussed.

Microalgae biodiesel: Current status and future needs for engine performance and emissions

Source: Renewable and Sustainable Energy Reviews, Volume 79
Author(s): Muhammad Aminul Islam, Kirsten Heimann, Richard J. Brown
Microalgae feedstock is recognised as one of the most promising resources for producing triglycerides which is subsequently converted to biodiesel. However, the large-scale technology required to generate biodiesel from microalgae is still in its early stages of development. Microalgae research to date may be placed into four broad categories: (i) growth, (ii) harvesting, (iii) oil extraction and (iv) fuel properties for engine performance and emissions. More than 1000 manuscripts have been published on the first category with progressively less on subsequent groups. Finally, effects of microalgae methyl esters on engine performance have only been reported in 9 scientific articles. This review will place extraction techniques and engine performance of microalgae biodiesel in the context of the preceding two categories and examine the practical problems associated with fuel

properties, engine performance and emissions. Considering energy consumption, toxicity, and time, many of the extraction techniques used in the laboratory show moderate potential for commercial scale. An important finding is that variation of conditions in the first three categories can have a significant effect on biofuel quality which can cause fuel properties to be out of standard and/or adversely affect engine performance and emissions.

A general reaction network and kinetic model of the hydrothermal liquefaction of microalgae Tetraselmis sp.

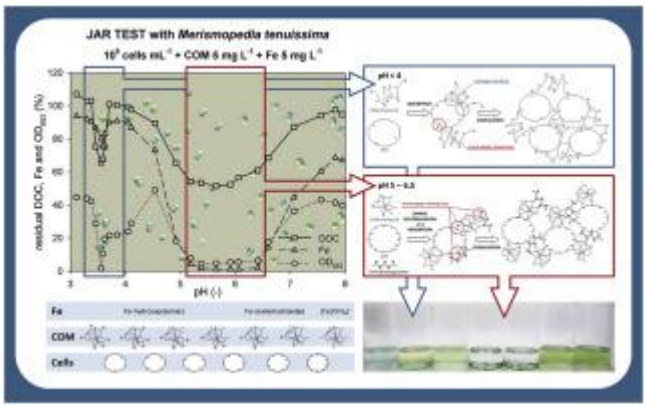
Source: Bioresource Technology, Volume 241
Author(s): The Ky Vo, Seung-Soo Kim, Hoang Vu Ly, Eun Yeol Lee, Choul-Gyun Lee, Jinsoo Kim
In this work, the hydrothermal liquefaction (HTL) of microalgal Tetraselmis sp. was conducted at various reaction temperatures (250–350°C) and reaction times (10–60min). A general reaction network and a quantitative kinetic model were proposed for the HTL of microalgae. In this reaction network, the primary decomposition of lipids, proteins, and carbohydrates generated heavy oil (HO), light oil (LO), and aqueous-phase (AP) products. Then, reversible interconversions and further decomposition of these product fractions to produce gas product were followed. The model accurately captures the trends observed in the experimental data. Analyses of the kinetic parameters (reaction rate constants and activation energies) suggested the dominant reaction pathways as well as the contribution of the biochemical compositions to the bio-oil yield. Finally, the kinetic parameters calculated from the model were utilized to explore the parameter space in order to predict the liquefaction product yields depending on the reaction time and temperature.

An application of cellular organic matter to coagulation of cyanobacterial cells (Merismopedia tenuissima)

Source: Water Research, Volume 122
Author(s): Magdalena Baresova, Martin Pivokonsky, Katerina Novotna, Jana Naceradska, Tomas Branyik
Algae affect the performance of drinking water treatment significantly when they decay and release considerable amounts of cellular organic matter (COM). The study describes the cyanobacterium Merismopedia tenuissima and its COM and investigates the effect of their simultaneous coagulation. As COM is highly complex mixture, we characterised it in terms of hydrophobicity, protein content and molecular weights (MWs). To describe the coagulation mechanisms and molecular interactions in the system, we determined both COM and cell surface charge by means of potentiometric titration and zeta potential analysis, respectively, and performed the jar tests with single components and their mixtures with and without a coagulant (ferric sulphate). The coagulation tests performed with the individual components or with their mixtures proved efficient cell removals (up to 99%) but relatively low COM removals (37 ÷ 57%). This disproportion can be attributed to the prevalence of hydrophilic

compounds and to the high portion of low-MW organics in COM. Coagulation of COM/cell mixtures achieved comparable efficacy with single component tests, using even lower coagulant doses. Furthermore, COM presence substantially deviated the pH optimum for cell removal and thus altered coagulation mechanisms. While single cells interacted prevailingly through adsorption onto Fe-oxide-hydroxides at about neutral pH (6.0–7.7), the COM/cell mixtures succumbed to charge neutralisation by Fe-hydroxopolymers within moderately acidic pH range (5.0–6.5). Moreover, COM initiated cell flocculation also at acidic pH in both the presence (pH 3.4–3.9) and the absence of a coagulant (pH 3.6–4.6). This supportive effect is ascribed to relatively high-MW COM (>10 kDa), serving as a natural flocculant through inter-particle bridging mechanism and exhibiting nearly the same COM/cell removals as ferric sulphate.

Graphical abstract

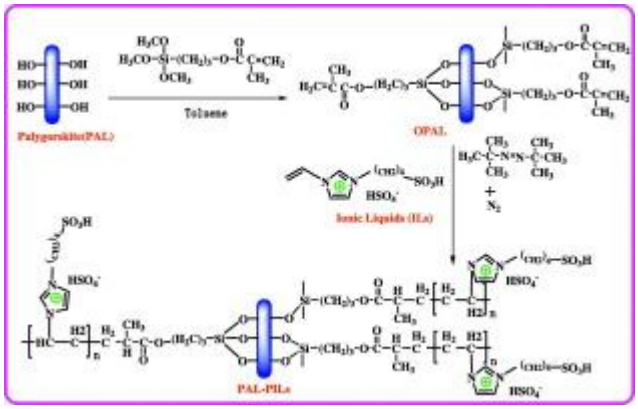


Heterogeneous poly(ionic liquids) catalyst on nanofiber-like palygorskite supports for biodiesel production

Source: Applied Clay Science, Volume 146
Author(s): Wen Zhang, Meisheng Li, Jie Wang, Yijiang Zhao, Shouyong Zhou, Weihong Xing
New heterogeneous poly(ionic liquids) catalysts (PAL-PILs) were successfully prepared by grafting polymerization of acid ionic liquids (ILs) (1-butysulfonate-3-vinylimidazole hydrogen sulfate) onto nanofiber-like palygorskite (PAL) supports that had been, in advance, covalently modified by γ-methacryloxypropyl trimethoxy silane (OPAL). Using the ester yields and PILs grafting degrees as main indexes, the optimized immobilization conditions were that the mass ratio of OPAL to ILs monomer was 1:2, the immobilization temperature and time were 60°C and 30h, the initiator (2,2′-Azobis(2-methylpropionitrile) dosage was about 5wt%, respectively. Then, the esterification between methanol and oleic acid was carried out to investigate the catalytic properties of PAL-PILs. For the homogeneous ILs catalyst, the yield of methyl oleate was about 85%. For the PAL-PILs, on which only about 41% of ILs used in homogeneous catalysis was immobilized, the yield could reach over 69% after reacting only 5h at 75°C at atmospheric pressure, when the molar ratio of methanol to oleic acid is adjusted to 12:1. More importantly, the yield of methyl oleate still maintained at about 22% after 6 recycling experiments. Moreover, the PAL-PILs catalysts exhibited

efficient catalytic properties and could be recycled easily. These results offer great potential for the PAL-PILs in the biodiesel production for further research.

Graphical abstract



A perspective on renewable bioenergy from photosynthetic algae as feedstock for biofuels and bioproducts

Source: Algal Research, Volume 24, Part A

Author(s): Lieve M.L. Laurens, Melodie Chen-Glasser, James D. McMillan

There has been substantial technical progress in developing algae-based bioenergy in recent years and a large part of industry and academic research and deployment projects have pivoted away from a pure biofuels strategy. This letter summarizes the findings of a recently completed, comprehensive report, that represents a collaborative effort of at least 20 co-authors, where we analyzed the prospects for using microalgae and macroalgae as feedstocks for biofuels and bioenergy production. The scope of this report includes a discussion of international activities advancing bioenergy and non-energy bioproducts from algae, progress on the use of macroalgae (both cast and cultivated seaweeds) for biogas applications, distinct biochemical and thermochemical conversion pathways, multi-product biorefining opportunities, as well as a thorough review of process economics and sustainability considerations. It is envisioned that a higher value algal biomass-based bioproducts industry will provide the additional revenue needed to reduce the net cost of producing algae-based biofuels. As such, a biorefinery approach that generates multiple high-value products from algae will be essential to fully valorize algal biomass and enable economically viable coproduction of bioenergy. To accelerate the implementation of algae-based production, minimizing energy, water, nutrients and land use footprints of integrated algae-based operations needs to be a primary objective of larger scale demonstrations and future research and development.

Assessment of potential zooplankton control treatments for wastewater treatment High Rate Algal Ponds

Source: Algal Research, Volume 24, Part A
Author(s): Valerio Montemezzani, Ian C. Duggan, Ian D. Hogg, Rupert J. Craggs
Cladocerans and rotifers rapidly consume beneficial microalgae and reduce the performance of High Rate Algal Ponds (HRAPs) for wastewater treatment and algal production. Potential zooplankton control treatments for HRAPs have been proposed and tested at a laboratory scale including CO2 asphyxiation, biological control using competitor species, filtration, and mechanical disruption using hydrodynamic shear stress. This paper aims to validate these treatments using outdoor mesocosms with physicochemical and operational conditions similar to those of full scale HRAPs. A continuous CO2 concentration of ~100mg/L maintained low pond water zooplankton densities, while a continuous concentration of ~180mg/L killed all microcrustaceans and rotifers present. As biocontrol agents, the cladoceran Moina tenuicornis at ~2000 individuals/L reduced average rotifer densities by 90% while the ostracod Heterocypris incongruens at ~1000 individuals/L removed all rotifers. Mechanical filtration using 300µm and 500µm filters eradicated M. tenuicornis after one and four filtration periods, respectively. Mechanical hydrodynamic stress killed up to 100% of microcrustaceans, and ~50% of larger rotifers. Furthermore, phototaxis-induced migration promoted higher densities of M. tenuicornis in the upper layer of the water column in an $8m^3$ HRAP during periods of low solar radiation, suggesting that mechanical treatments should be performed at night and to the upper layer of the pond water. Overall, CO2 asphyxiation appeared to be the most reliable, versatile, and effective zooplankton control treatment.

Growth of microalgae on undiluted anaerobic digestate of piggery effluent with high ammonium concentrations

Source: Algal Research, Volume 24, Part A
Author(s): Jeremy Miles Ayre, Navid Reza Moheimani, Michael Armin Borowitzka
Anaerobic digestate of piggery effluent (ADPE) is extremely high in ammonia toxic to many microorganisms. Bioprospecting and nutrient enrichment of several freshwater and wastewater samples combined and further acclimation resulted in a mixed culture containing at least three microalgae species capable of growing on undiluted ADPE. Outdoor growth of the mixed culture using raceway ponds showed potential for up to 63.7±12.1mg N-NH 4 + L^{-1} d^{-1} ammonium removal from the ADPE. The microalgal consortium was dominated by Chlorella sp. and was stable at between 800 and 1600mg N-NH 4 + L^{-1}. Regulation of CO2 addition to the ponds to maintain a pH of 8 increased chlorophyll content of the microalgal consortium. Average microalgal biomass productivity of 800mg N-NH 4 + L^{-1} culture conditions during five weeks semicontinuous growth was 18.5mgash-freedryweightL^{-1} d^{-1}. Doubling the ammonium concentration from 800 to 1600mg N-NH 4 +

L^{-1} resulted in a 21% reduction of productivity, however the culture grown at 1600mg N-NH 4 + L^{-1} with the addition of CO2 by keeping pH at pH=8 led to a 17% increase in biomass productivity.

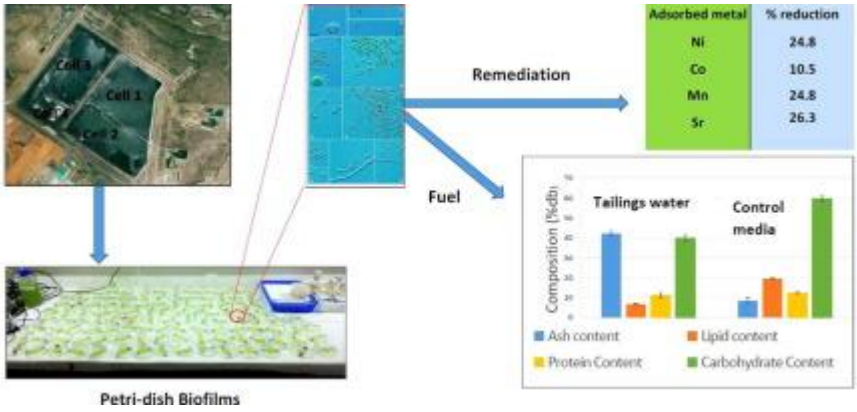
Assessment of microalga biofilms for simultaneous remediation and biofuel generation in mine tailings water

Source: Bioresource Technology, Volume 234

Author(s): H. Palma, E. Killoran, M. Sheehan, F. Berner, K. Heimann

Microalgae crops can generate a biochemical profile of high energy density and may be used for remediation of contaminated waste waters. This manuscript presents a laboratory-scale investigation into the potential for growing endemic microalgae biofilms in phosphorus-enriched nickel refinery tailings water, with an emphasis on product potential and the remediation of heavy metals. The dominant species of the consortia was a Chlorella-like microalga. The growth was monitored over time, with a productivity ($0.77\pm0.07 gAFDW.m^{-2}.day^{-1}$) showing promising potential. The biochemical profile of biomass had a high total carbohydrate yield (40.0%), and a potential for increased lipid yields (6.7–19.5%). Biofilms showed a significant potential for the removal of heavy metals (Ni, Co, Mn, Sr) from the waste water with 24.8%, 10.5%, 24.8% and 26.4% reduction in Ni, Co, Mn and Sr, respectively. Results highlight significant potential for large-scale biofilm biomass production using metal-laden nickel refinery waste waters.

Graphical abstract



Selection and adaptation of microalgae to growth in 100% unfiltered coal-fired flue gas

Source: Bioresource Technology, Volume 233

Author(s): Ambreen Aslam, Skye R. Thomas-Hall, Tahira Aziz Mughal, Peer M. Schenk

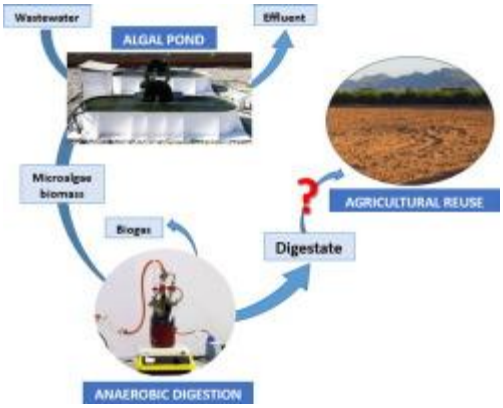
Microalgae have been considered for biological carbon capture and sequestration to offset carbon emissions from fossil fuel combustion. This study shows that mixed biodiverse

microalgal communities can be selected for and adapted to tolerate growth in 100% flue gas from an unfiltered coal-fired power plant that contained 11% CO2. The high SOx and NOx emissions required slow adaptation of microalgae over many months, with step-wise increases from 10% to 100% flue gas supplementation and phosphate buffering at higher concentrations. After a rapid decline in biodiversity over the first few months, community profiling revealed Desmodesmus spp. as the dominant microalgae. To the authors' knowledge this work is the first to demonstrate that up 100% unfiltered flue gas from coal-fired power generation can be used for algae cultivation. Implementation of serial passages over a range of photobioreactors may contribute towards the development of microalgal-mediated carbon capture and sequestration processes.

Assessing the agricultural reuse of the digestate from microalgae anaerobic digestion and co-digestion with sewage sludge

Source: Science of The Total Environment, Volume 586
Author(s): Maria Solé-Bundó, Mirko Cucina, Montserrat Folch, Josefina Tàpias, Giovanni Gigliotti, Marianna Garfí, Ivet Ferrer
Microalgae anaerobic digestion produces biogas along with a digestate that may be reused in agriculture. However, the properties of this digestate for agricultural reuse have yet to be determined. The aim of this study was to characterise digestates from different microalgae anaerobic digestion processes (i.e. digestion of untreated microalgae, thermally pretreated microalgae and thermally pretreated microalgae in co-digestion with primary sludge). The main parameters evaluated were organic matter, macronutrients and heavy metals content, hygenisation, potential phytotoxicity and organic matter stabilisation. According to the results, all microalgae digestates presented suitable organic matter and macronutrients, especially organic and ammonium nitrogen, for agricultural soils amendment. However, the thermally pretreated microalgae digestate was the least stabilised digestate in comparison with untreated microalgae and co-digestion digestates. In vivo bioassays demonstrated that the digestates did not show residual phytotoxicity when properly diluted, being the co-digestion digestate the one which presented less phytotoxicity. Heavy metals contents resulted far below the threshold established by the European legislation on sludge spreading. Moreover, low presence of E. coli was observed in all digestates. Therefore, agricultural reuse of thermally pretreated microalgae and primary sludge co-digestate through irrigation emerges a suitable strategy to recycle nutrients from wastewater.

Graphical abstract



Remediation of a mixture of analgesics in a stirred-tank photobioreactor using microalgal-bacterial consortium coupled with attempt to valorise the harvested biomass

Source: Bioresource Technology, Volume 232

Author(s): Maha M. Ismail, Tamer M. Essam, Yasser M. Ragab, Abo El-khair B. El-Sayed, Fathia E. Mourad

An artificial microalgal-bacterial consortium was used to remediate a mixture of analgesics (ketoprofen, paracetamol and aspirin) in a stirred-tank photobioreactor. A hydraulic retention time (HRT) of 3days supported poor treatment because of the formation of p-aminophenol (paracetamol toxic metabolite). Increasing the HRT to 4days enhanced the bioremediation efficiency. After applying an acclimatization regime, 95% removal of the analgesics mixture, p-aminophenol and COD reduction were achieved. However, shortening the HRT again to 3days neither improved the COD reduction nor ketoprofen removal. Applying continuous illumination achieved the best analgesics removal results. The harvested biomass contained 50% protein, which included almost all essential amino acids. The detected fatty acid profile suggested the harvested biomass to be a good biodiesel-producing candidate. The water-extractable fraction possessed the highest phenolic content and antioxidant capacity. These findings suggest the whole process to be an integrated eco-friendly and cost-efficient strategy for remediating pharmaceutical wastewater.

Batch cultivation of marine microalgae Nannochloropsis oculata and Tetraselmis suecica in treated municipal wastewater toward bioethanol production

Source: Journal of Cleaner Production, Volume 150

Author(s): Zubaidai Reyimu, Didem Özçimen

Algae have come into prominence over the last decade as a commercial biofuel feedstock due to their high production efficiencies compared to first and second feedstocks. However, algal investment is not economically feasible currently due to the operational and capital

cost. There is still need for innovations for both high productivity and green productions. In order to decrease the cost of the algal processes, usage of some wastes as cultivation medium for algal productions and novel biofuel production methods should be considered according to green chemistry principals. In this study, seawater and wastewater supplied from Istanbul Water and Sewerage Administration (ISKI) were used and combined at different ratios to be utilized as a growth medium for Nannochloropsis oculata and Tetraselmis suecica microalgae strain under the same growth conditions, and its effect on cell proliferation and growth kinetics were investigated. It was found that, both N. oculata and T. suecica can tolerate and utilize the wastewater and, the specific growth rate of the cultures can up to 0.5430 d^{-1} (75% of wastewater) for N. oculata and 0.4778 d^{-1} (25% of wastewater) for T. suecica. Different concentrations show different results for the growth of two species due to the effect of higher concentrations of the fundamental sources on growth stage and change of ionic composition of the culture medium. To evaluate bioethanol production performance of these two strains, samples which included maximum carbohydrate content as well as control groups were chosen for further studies. The results showed that T. suecica is much suitable for ethanol production using municipal wastewater as a culture medium.

Cross-study analysis of factors affecting algae cultivation in recycled medium for biofuel production

Source: Algal Research, Volume 24, Part A
Author(s): Sarah E. Loftus, Zackary I. Johnson
Current high costs of commercial-scale algal biofuel production prevent the widespread use of this renewable fuel source. One cost-saving approach is the reuse of algae cultivation water after biomass harvesting, which reduces water pumping and treatment costs. However, dissolved compounds, cell debris, and microorganisms remaining in the water could affect subsequent algae generations. Previous studies demonstrate a variety of effects of recycled medium on algae growth, yet their results have not been collectively analyzed. Here we integrate data across 86 studies to determine the relative importance of different factors influencing algae growth in recycled medium. We found that algae taxa can have the greatest influence, while the harvesting method is less influential on growth outcomes. This meta-analysis identifies favorable taxa and thus provides a tool for algae cultivation decision-making when medium reuse is an important driver. Results can also aid in estimating relative algae yield and growth rates for technoeconomic assessments that incorporate water recycling.

Pulsed Electric Field for protein release of the microalgae Chlorella vulgaris and Neochloris oleoabundans

Source: Algal Research, Volume 24, Part A
Author(s): G.P. 't Lam, P.R. Postma, D.A. Fernandes, R.A.H. Timmermans, M.H. Vermuë, M.J. Barbosa, M.H.M. Eppink, R.H. Wijffels, G. Olivieri
Pulsed Electric Field (PEF) is currently discussed as promising technology for mild and scalable cell disintegration of microalgae. In this study Chlorella vulgaris and Neochloris oleoabundans have been subjected to batch and continuous PEF treatments under a wide range of operating conditions (1–40 pulses, 0.05–5ms pulses, 7.5–30kV cm^{-1}, 0.05–150 $kWhkgDW^{-1}$). In many cases after treatment, both algal species show release of ions, which indicates that PEF treatment resulted in permeabilization of the algal cell. However, the electroporation effect was not sufficient to substantially release intracellular proteins. Even at severe energy input (10 to 100 times higher than bead milling) only up to 13% of proteins released from the cells in comparison to 45–50% after bead milling.

Enhancement of microalgae anaerobic digestion by thermo-alkaline pretreatment with lime (CaO)

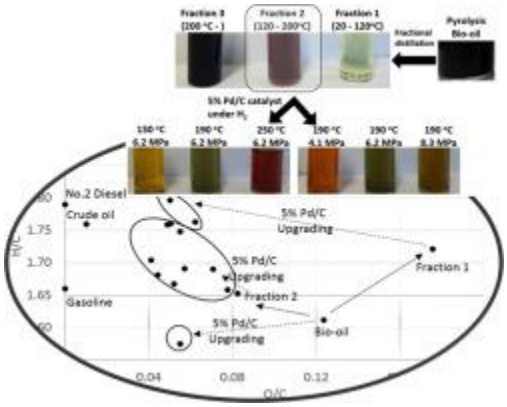
Source: Algal Research, Volume 24, Part A
Author(s): Maria Solé-Bundó, Hélène Carrère, Marianna Garfí, Ivet Ferrer
The aim of this study was to evaluate for the first time the effect of a thermo-alkaline pretreatment with lime (CaO) on microalgae anaerobic digestion. The pretreatment was carried out by adding different CaO doses (4 and 10%) at different temperatures (room temperature (25°C), 55 and 72°C). The exposure time was 4days for pretreatments at 25°C, and 24h for pretreatments at 55 and 72°C. Following, a biochemical methane potential test was conducted with pretreated and untreated microalgae. According to the results, the pretreatment enhanced proteins solubilisation by 32.4% and carbohydrates solubilisation by 31.4% with the highest lime dose and temperature (10% CaO and 72°C). Furthermore, anaerobic digestion kinetics were improved in all cases (from 0.08 to $0.14day^{-1}$ for untreated and pretreated microalgae, respectively). The maximum biochemical methane potential increase (25%) was achieved with 10% CaO at 72°C, in accordance with the highest biomass solubilisation. Thus, lime pretreatment appears as a potential strategy to improve microalgae anaerobic digestion.

Catalytic upgrading of fractionated microalgae bio-oil (Nannochloropsis oculata) using a noble metal (Pd/C) catalyst

Source: Algal Research, Volume 24, Part A
Author(s): Hyungseok Nam, Changkyu Kim, Sergio C. Capareda, Sushil Adhikari
Pyrolytic bio-oil was chemically upgraded after physically distilled upgrades to meet the petroleum transportation fuel substitute. A Pd/C catalyst was used to upgrade the

microalgae pyrolytic bio-oil to determine the effect of different distillation fractions and catalytic upgrading conditions on the yields and properties. The middle distillation fraction (F2) was upgraded under various temperature (130 to 250°C) and pressure (4.1 to 8.3MPa) conditions based on response surface methodology (RSM). The light distillation fraction (F1) and raw bio-oil were also catalytically upgraded for the comparison. The distillation step prior to catalytic upgrading led to a better quality of upgraded bio-oil compared to the direct bio-oil upgrades. Both the oxygen and hydrogen contents of light and middle fraction upgrades were improved, while the upgraded raw bio-oil showed limited improvement. The other properties of HHV and TAN with the middle fraction upgrades were improved to 42.9MJ/kg and 1.09mgKOH/g, respectively, at the severe condition as most of the ketones in upgrades were removed. Also, paraffin and aromatic chemical groups were significantly produced at the expense of the olefin groups through hydrogenation and hydrodeoxygenation. Thus, the catalytic upgrading after a distillation stage enhanced the quality of biofuel that can be a petroleum fuels substitute or additives.

Graphical abstract



A comparative study on biochemical methane potential of algal substrates: Implications of biomass pre-treatment and product extraction

Source: Bioresource Technology, Volume 234

Author(s): Faiz Ahmad Ansari, Shantanu Wahal, Sanjay Kumar Gupta, Ismail Rawat, Faizal Bux

Dried powdered algae (SDPA), heat treated algae (MHTA), lipid extracted algae (LEA) and protein extracted algae (PEA) were digested to determine biomethane potential. The average CH4 production rate was ~2.5-times higher for protein and lipid extracted algae than for whole algae (SDPA and MHTA) whilst the cumulative CH4 production was higher for pre-treated algae. Highest cumulative CH4 production (318.7mlCH4 g^{-1} VS) was observed for MHTA followed by SDPA (307.4mlCH4 g^{-1} VS). CH4/CO2 ratios of 1.5 and 0.7 were observed for MHTA and LEA respectively. Pre-treatment processes disrupted the algal cell wall, exposing intracellular material which remained intact as opposed to product extraction processes which broke down the intracellular compounds resulting in changes in elemental

composition and decreases the cumulative gas yield and CH4/CO2 ratio. Comparative analysis determined that the most profitable route of biomass utilisation was protein extraction followed by biogas production giving ~2.5-times higher return on investment.

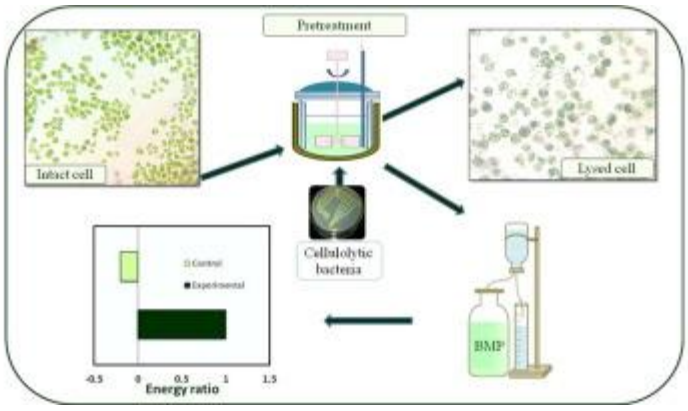
Enhancement of biogas production from microalgal biomass through cellulolytic bacterial pretreatment

Source: Bioresource Technology, Volume 233

Author(s): S. Kavitha, P. Subbulakshmi, J. Rajesh Banu, Muthukaruppan Gobi, Ick Tae Yeom

Generation of bioenergy from microalgal biomass has been a focus of interest in recent years. The recalcitrant nature of microalgal biomass owing to its high cellulose content limits methane generation. Thus, the present study investigates the effect of bacterial-based biological pretreatment on liquefaction of the microalga Chlorella vulgaris prior to anaerobic biodegradation to gain insights into energy efficient biomethanation. Liquefaction of microalgae resulted in a higher biomass stress index of about 18% in the experimental (pretreated with cellulose-secreting bacteria) vs. 11.8% in the control (non-pretreated) group. Mathematical modelling of the biomethanation studies implied that bacterial pretreatment had a greater influence on sustainable methane recovery, with a methane yield of about 0.08 (g Chemical Oxygen Demand/g Chemical Oxygen Demand), than did control pretreatment, with a yield of 0.04 (g Chemical Oxygen Demand/g Chemical Oxygen Demand). Energetic analysis of the proposed method of pretreatment showed a positive energy ratio of 1.04.

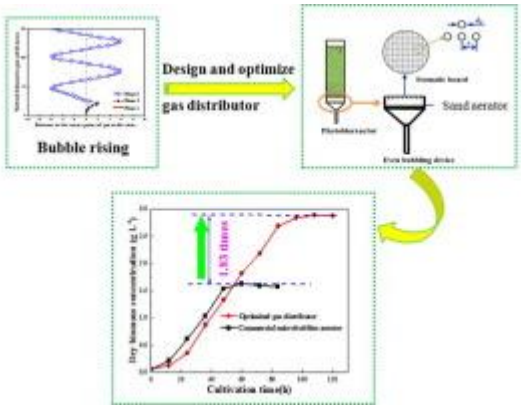
Graphical abstract



Optimizing the gas distributor based on CO2 bubble dynamic behaviors to improve microalgal biomass production in an air-lift photo-bioreactor

Source: Bioresource Technology, Volume 233
Author(s): Yun Huang, Sha Zhao, Yu-dong Ding, Qiang Liao, Yong Huang, Xun Zhu
Dynamic behavior of bubbles would significantly affect CO2 mass transfer and may cause microalgae cells uneven distribution due to the bubble carrying effect. To improve microalgae growth, the gas distributor and aeration conditions was optimized according to the bubble rising behavior. The CO2 bubble rising trajectory is similar to a Zigzag. The amplitude and wavelength of the Zigzag, which reflected the influenced zone of microalgae suspension in horizontal direction and disturbance intensity on culture, respectively, was controlled by the structure of gas distributor and aeration conditions. An optimized round gas distributor that full of holes with an inner diameter of 0.5mm and spacing of 1.5mm was designed. When cultivated with the optimized gas distributor aerating 5% CO2 gas at 0.250vvm, the maximum biomass concentration of Chlorella pyrenoidosa achieved 2.88gL^{-1}, increased by 83.44% compared to that of 1.57gL^{-1}cultivated with the commercial micro-bubbles aerator.

Graphical abstract

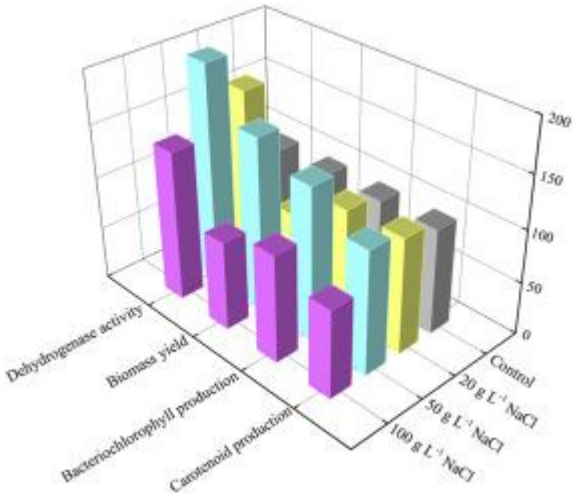


Enhancement of carotenoid and bacteriochlorophyll by high salinity stress in photosynthetic bacteria

Source: International Biodeterioration & Biodegradation, Volume 121
Author(s): Hangyao Wang, Anqi Yang, Guangming Zhang, Boyuan Ma, Fan Meng, Meng Peng, Hongchen Wang
The variation of carotenoid and bacteriochlorophyll in photosynthetic bacteria (PSB) by high salinity stress (20–100 g L^{-1}) was investigated. Results showed that PSB could grow in high salinity wastewater and the productions of two pigments were affected by the salinity significantly. Suitable salinity stress could enhance their productions while excessive salinity would impede the productions. When the NaCl concentration was 50 g L^{-1}, the PSB were stimulated continuously during the whole culture period, and the productions of carotenoid

and bacteriochlorophyll were 1.17 and 1.45-fold of the control group. The variation of dehydrogenase activity indicated that high salinity changed the metabolic activity greatly, and the highest level of dehydrogenase activity appeared at 50 g L^{-1} NaCl condition. Mechanisms analysis showed that the variations of pigments and dehydrogenase were related to self-protection. At the same time, pollutants in high salinity wastewater were removed by PSB. The COD and NH3-N removals under 20–100 g L^{-1} NaCl concentration were around 33.5–66.1%. The biomass yields were over 0.2 mg-biomass (mg-COD-reduction)$^{-1}$ under all situations and salinity benefitted the biomass yield.

Graphical abstract



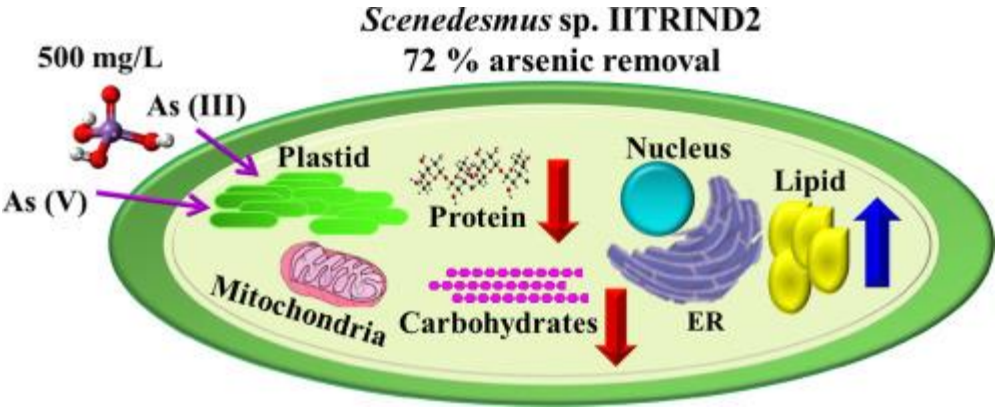
A hybrid approach integrating arsenic detoxification with biodiesel production using oleaginous microalgae

Source: Algal Research, Volume 24, Part A
Author(s): Neha Arora, Khushboo Gulati, Alok Patel, Parul A. Pruthi, Krishna Mohan Poluri, Vikas Pruthi

A novel combinatorial approach integrating toxic and carcinogenic heavy metal arsenic (III, V) mitigation coupled to biodiesel production using oleaginous microalgae grown in synthetic soft water (SSW) was undertaken in this investigation. Among the four prospective microalgal species tested, Chorella minutissima and Scenedesmus sp. IITRIND2 were able to tolerate 500mgL^{-1} of both the forms of As (III) and As (V) with a high metal bioconcentration factor (BCF) indicating that these strains can be categorized as hyper bioaccumulators of arsenic. These arsenic spiked microalgae showed a significant enhancement in the lipid production by accumulating large lipid droplets with minimal morphological changes. The biochemical composition analysis of these microalgal cells showed apparent decline in the protein, carbohydrate and photosynthetic pigments suggesting that the arsenic intake by the cells has remodeled its cellular composition in order to cope up with the heavy metal induced stress. The biodiesel derived from the microalgae was amenable and comparable to plant oil methyl esters with a high cetane number, oxidative stability and low cold flow

plugging properties. This salient approach exhibits two fold advantages, which include safe removal of carcinogenic metal arsenic from potable water sources as well as high yield of lipid production. This novel integrative innovative technology has a strong prospective path for verdurous environment and renewable fuels resulting in socioeconomic welfare.

Graphical abstract



Effect of sulfate ions on growth and pollutants removal of self-flocculating microalga Chlorococcum sp. GD in synthetic municipal wastewater

Source: Bioresource Technology, Volume 234

Author(s): Junping Lv, Junyan Guo, Jia Feng, Qi Liu, Shulian Xie

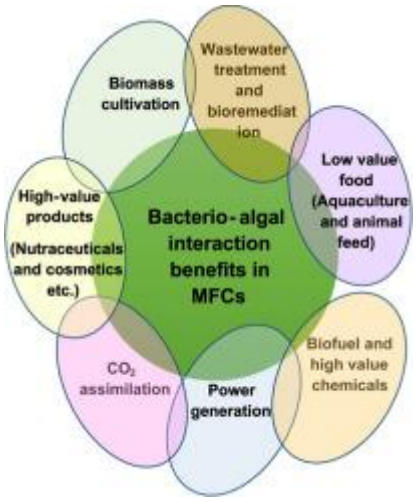
Sulfate is a primary sulfur source and can be available in wastewaters. Nevertheless, effect of sulfate ions on growth and pollutants removal of microalgae seems to be less investigated. At the present study, self-flocculating microalga Chlorococcum sp. GD was grown in synthetic municipal wastewater with different sulfate concentrations. Results indicated that Chlorococcum sp. GD grew better in synthetic municipal wastewater with 18, 45, 77, 136 and 271mg/L $SO4^{2-}$ than in wastewater without $SO4^{2-}$. Chlorococcum sp. GD had also excellent removal efficiencies of nitrogen and phosphorus and effectively flocculated in sulfate wastewater. Sulfate deprivation weakened the growth, pollutants removal and self-flocculation of Chlorococcum sp. GD in wastewater. Antioxidative enzymes activity significantly increased and photosynthetic activity significantly decreased when Chlorococcum sp. GD was cultivated in sulfate-free wastewater. Sulfate deprivation probably reduced cell activity of growth, pollutants removal and flocculation via inducing the over-accumulation of reactive oxygen species (ROS).

Sustainable power generation from bacterio-algal microbial fuel cells (MFCs): An overview

Source: Renewable and Sustainable Energy Reviews, Volume 73
Author(s): Beenish Saba, Ann D. Christy, Zhongtang Yu, Anne C. Co

Microbial fuel cells (MFCs) are bioelectrochemical devices that allow the harvesting of electricity generated during anaerobic respiration of selected bacterial species. This technology shows promise in both wastewater treatment and sustainable bioenergy conversion applications. Bacterial respiration occurs in the anaerobic anode compartment of the MFC, and is electrochemically coupled with electron acceptors in the MFC's aerobic cathode compartment. This paper summarizes the published results of bacterio-algal MFCs. The use of microalgae in MFCs has gained interest primarily due to algae's ability to photosynthesize atmospheric CO2, producing both biomass and oxygen and thereby facilitating the cathodic reaction. These phototrophic microorganisms can serve as biocatholytes in MFCs because the oxygen produced is an electron acceptor for the electrons harvested from the anode compartment. The bacterio-algal MFC can provide multiple benefits including 1) power generation, 2) wastewater treatment, 3) algal biomass cultivation and pigment production, 4) carbon dioxide assimilation, and 5) oxygen production. This review article summarizes not only successful published results of bacterio-algal fuel cells but also highlights critical operational parameters and their effect on power generation and output efficiency.

Graphical abstract

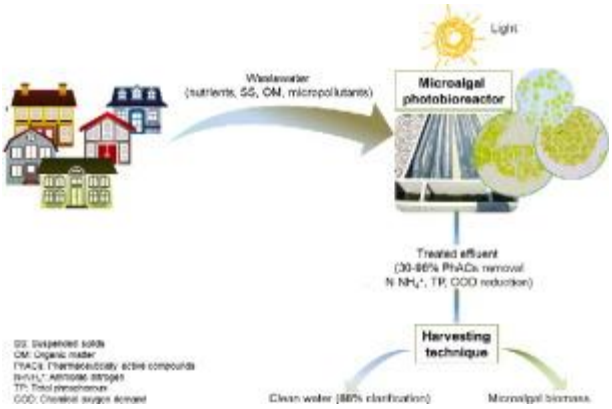


Performance of a microalgal photobioreactor treating toilet wastewater: Pharmaceutically active compound removal and biomass harvesting

Source: Science of The Total Environment, Volume 592
Author(s): Andrea Hom-Diaz, Adrián Jaén-Gil, Iris Bello-Laserna, Sara Rodríguez-Mozaz, Teresa Vicent, Damià Barceló, Paqui Blánquez

In this study, a 1200L outdoor pilot scale microalgal photobioreactor (PBR) was used for toilet wastewater (WW) treatment and evaluate its ability to remove pharmaceutically active compounds (PhACs). The PBR was operated at two different hydraulic retention times (HRTs), which were 8 and 12days, during Period I (September–October) and Period II (October–December), respectively. Algal biomass concentrations varied by operating period because of seasonal changes. Nutrients (ammonia, nitrogen and total phosphorous) and chemical oxygen demand (COD) were monitored and efficiently removed in both periods (>80%), attaining the legislation limits. At the theoretical hydraulic steady state in both periods, pharmaceutical removal reached high levels (>48%). Two harvesting techniques were applied to the PBR microalgae effluent. Gravity sedimentation was efficient for biomass removal (>99% in 7min) in Period I when large particles, flocs and aggregates were present. In contrast, a longer sedimentation time was required when biomass was mainly composed of single cells (88% clarification in a 24h in Period II). The second harvesting technique investigated was the co-pelletization of algal biomass with the ligninolytic fungus Trametes versicolor, attaining >98% clarification for Period II biomass once pellets were formed. The novel technology of co-pelletization enabled the complete harvesting of single algae cells from the liquid medium in a sustainable way, which benefits the subsequent use of both biomass and the clarified effluent.

Graphical abstract



Occurrence forms of key ash-forming elements in defatted microalgal biomass

Source: Fuel, Volume 200

Author(s): Yinglong He, Xiangpeng Gao, Yu Qiao, Minghou Xu

This study reports occurrence forms of key ash-forming elements in a defatted microalga, and for comparison, its corresponding raw microalga. Freeze-dried powders of a marine microalga (Nannochloropsis oceanica) were sieved to a size fraction of <75μm and used as raw microalga. The raw microalga was then extracted with hexane to remove crude lipids and prepare a defatted microalga. The raw and defatted microalgae were subjected to chemical fractionation analysis, i.e., sequential leaching in H2O, 1.0M ammonium acetate (NH4Ac), and 1.0M hydrochloric (HCl) acid. The results demonstrate that, whereas the contents of Fe and Al in the raw and defatted microalgae are extremely low, those of other ash-forming elements follow a sequence of Cl>K>P>Mg>Na>Ca. Chemical fractionation results suggest that virtually all of the Na, K, and Cl in the raw and defatted microalgae are water-soluble. While majority of P in the two fuels are water-soluble and acid-soluble, most of Mg and Ca are leached in water and NH4Ac solution. As determined via chemical fractionation analysis, lipid extraction leads to the content of water-soluble Ca in the defatted microalga being ~69.6% higher than that in the raw microalga counterpart, which is accompanied by a reduction in the amount of Ca leached in NH4Ac solution. Similar trend is also observed for Mg, but to a lesser extent.

Heterogeneous-catalysed direct transformation of microalga biomass into Biodiesel-Grade FAMEs

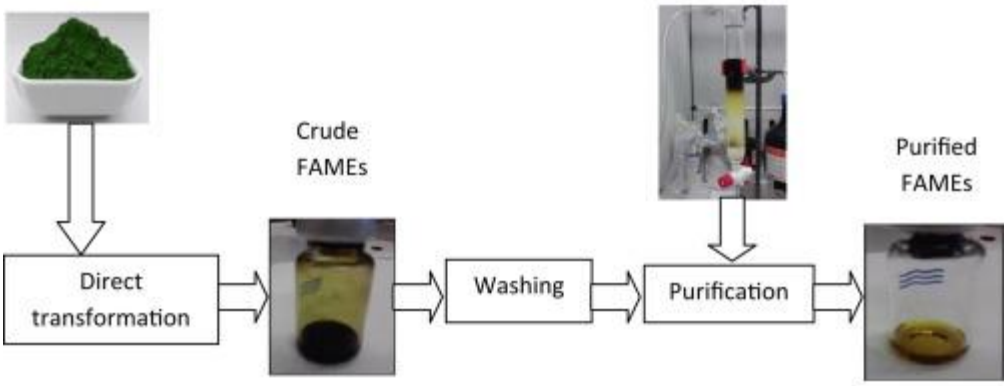
Source: Fuel, Volume 200

Author(s): Gemma Vicente, Alicia Carrero, Rosalía Rodríguez, Gonzalo L. del Peso

The production of biodiesel using microbial lipids is attractive as oleaginous microorganisms can accumulate significant amounts of lipids (>20%) and they do not compete with food production. However, the poor economic viability of the production process involving cell harvest, microalga oil extraction, lipid transesterification and esterification reactions as well as biodiesel purification leads to a non-viable biodiesel production process. Thus, lipid transesterification and esterification optimization in addition to biodiesel purification, are important limiting factors for this process. The present research is focused on the optimization of the reaction conditions in order to obtain a high conversion to FAMEs in the direct biodiesel production from the microalgae N. gaditana using the CT-269 ion-exchange resin. The process was analysed by following the factorial design and response surface methodology concluding that optimum values of the variables are a temperature of 95°C, a mass ratio of catalyst to microalga of 0.52/1, and a mass ratio of methanol to microalga of 33/1. Besides, the properties of the crude biodiesel were evaluated according to EN 14214 and ASTM D6751 standards, indicating that it is necessary an additional downstream purification step to remove all components that defile the final biodiesel. After an a two-

step purification method that combined wet and dry treatments, ASTM D6751 biodiesel grade-FAMEs were obtained for the properties evaluated. The biodiesel also met all the properties determined according to EN 14214 except for the content of polyunsaturated FAMEs, the iodine value, oxidation stability and the cetane number.

Graphical abstract



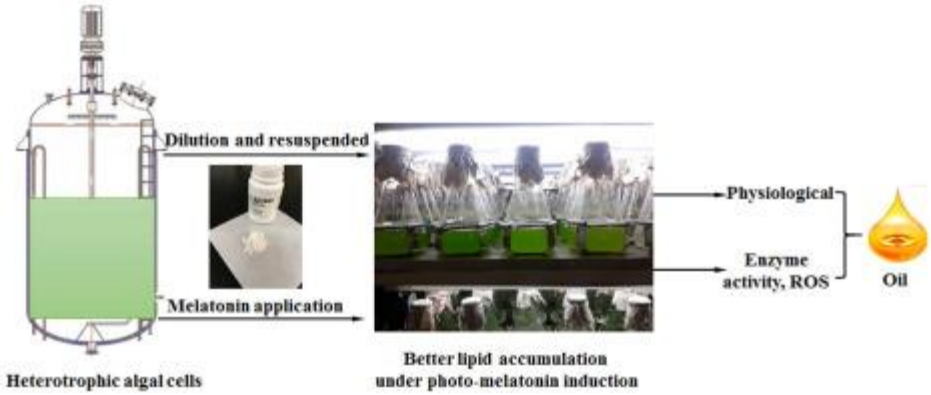
A strategy for promoting lipid production in green microalgae Monoraphidium sp. QLY-1 by combined melatonin and photoinduction

Source: Bioresource Technology, Volume 235

Author(s): Dafei Li, Yongteng Zhao, Wei Ding, Peng Zhao, Jun-Wei Xu, Tao Li, Huixian Ma, Xuya Yu

Microalgae lipids are potential candidates for the production of renewable biodiesel. The combination of plant hormones and two-step cultivation regulates lipid production in microalgae. A strategy for promoting lipid accumulation in Monoraphidium sp. QLY-1 by combining exogenous melatonin (MT) and photoinduction was developed. The effects of melatonin on the lipid content, reactive oxygen species (ROS), and activities of three key fatty acid biosynthetic enzyme in Monoraphidium sp. QLY-1 were investigated. The lipid content increased by 1.32-fold under 1μM melatonin treatment. The maximum lipid content achieved was 49.6%. However, the protein and carbohydrate contents decreased rapidly from 57.21% to 47.96% and from 53.4% to 37.71%, respectively. Biochemical and physiological analyses suggested that the ROS and lipid biosynthesis-related enzyme activities correlated with increased lipid accumulation under photo-melatonin induction conditions.

Graphical abstract



Effects of butanol on high value product production in Schizochytrium limacinum B4D1

Source: Enzyme and Microbial Technology, Volume 102
Author(s): Ke Zhang, Limei Chen, Jianmin Liu, Feng Gao, Ronglin He, Wuxi Chen, Wei Guo, Shulin Chen, Demao Li

Schizochytrium is a microalgae-like fungus and is widely used for producing docosahexaenoic acid (DHA). It is also a promising source of squalene and carotenoids. However, few fermentation strategies are available in enhancing squalene and carotenoid content in Schizochytrium. This study showed that butanol addition had multiple effects on Schizochytrium limacinum B4D1. First, butanol addition altered the lipid content of cells. Second, 6g/L of butanol decreased the proportion of DHA by nearly 40%. Third, the squalene content increased 31-fold in the presence of 6g/L butanol. Finally, cells accumulated more carotenoids upon butanol addition. Specifically, when cells were treated with 8g/L butanol, the astaxanthin content increased to 245 times than that of the untreated control. These results are helpful for the commercial exploitation of Schizochytrium in producing squalene and carotenoids.

Molecular challenges in microalgae towards cost-effective production of quality biodiesel

Source: Renewable and Sustainable Energy Reviews, Volume 74
Author(s): Young-Soo Chung, Jin-Woo Lee, Chung-Han Chung

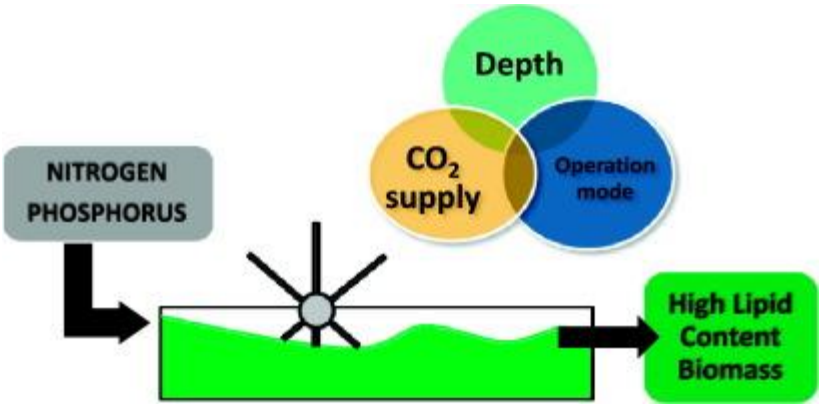
Based on their environmental benefits, microalgae are currently the most favorable renewable biofeedstock materials for biodiesel production. However, the possibility of an economically viable production system using microalgae is still technology-driven, not yet market-driven due to its higher production cost. Accordingly, to establish industrial manufacturing systems for microalgal biodiesel, it is critical to develop technology for its cost-effective production. Here, we propose some novel molecular strategies, which have

not been attempted for microalgal biodiesel production and are conducive to cost-effective production of biodiesel from microalgae. These include genetic manipulation strategies for higher biomass yield and extracellular production of free fatty acids, triacylglycerol, and fatty acid ethyl ester (biodiesel) with high quality, which could be exploited as a breakthrough technology for the cost-efficient production of microalgal biodiesel.

Optimization of pilot high rate algal ponds for simultaneous nutrient removal and lipids production

Source: Science of The Total Environment, Volume 589
Author(s): Zouhayr Arbib, Ignacio de Godos, Jesús Ruiz, José A. Perales
Special attention is required to the removal of nitrogen and phosphorous in treated wastewaters. Although, there are a wide range of techniques commercially available for nutrient up-take, these processes entail high investment and operational costs. In the other hand, microalgae growth can simultaneously remove inorganic constituents of wastewater and produce energy rich biomass. Among all the cultivation technologies, High Rate Algae Ponds (HRAPs), are accepted as the most appropriate system. However, the optimization of the operation that maximizes the productivity, nutrient removal and lipid content in the biomass generated has not been established. In this study, the effect of two levels of depth and the addition of CO2 were evaluated. Batch essays were used for the calculation of the kinetic parameters of microbial growth that determine the optimum conditions for continuous operation. Nutrient removal and lipid content of the biomass generated were analyzed. The best conditions were found at depth of 0.3m with CO2 addition (biomass productivity of 26.2gTSSm^{-2} d^{-1} and a lipid productivity of 6.0glipidsm^{-2} d^{-1}) in continuous mode. The concentration of nutrients was in all cases below discharge limits established by the most restrictive regulation for wastewater discharge.

Graphical abstract



Enzymes produced by biomass-degrading bacteria can efficiently hydrolyze algal cell walls and facilitate lipid extraction

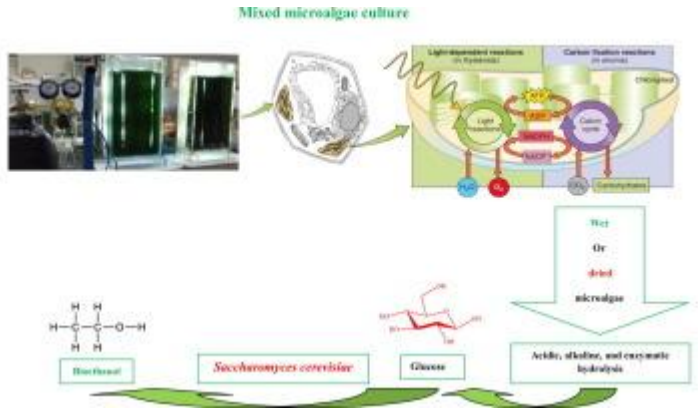
Source: Renewable Energy, Volume 109
Author(s): Haipeng Guo, Houming Chen, Lu Fan, Andrew Linklater, Bingsong Zheng, Dean Jiang, Wensheng Qin
The toughness of microalgal cell walls makes lipid extraction and large-scale biodiesel production difficult. This study investigated the enzymatic hydrolysis of algal cell walls, in which the enzymes were produced by eight biomass-degrading bacterial strains. The bacteria were first cultured in mineral salt medium containing 5% (w/v) wheat bran and various lignocellulolytic enzymes, including exoglucanases (CMCase), endoglucanases (FPase), xylanase, and laccase were monitored in order to obtain an enzymatic extract. All the strains showed marked CMCase activity, with a range of 3.0–6.9 U ml^{-1} after incubation for 2–5 d. Some strains also produced FPase, xylanase, and laccase. The enzymatic extract was directly added to fresh algae culture at a ratio of 1:3 (v/v) for 48 h. All the bacterial enzymatic extracts significantly disrupted algal cell walls, according to the enhancement of reducing sugar content in the culture. The lipid extraction yield was markedly increased by 10.4–43.9%, depending on the bacteria strains used. Due to its high reducing sugar production and lipid extraction efficiency, Bacillus sp. K1 was selected for a time-course experiment. Maximum lipid yield was obtained after 24 h of incubation at the room temperature, with about 40% of the cells were disrupted. These results showed that enzymes produced by biomass-degrading bacteria can weaken and disrupt cell walls and components of algae and facilitate the release of lipids from algae.

Bioethanol production from acidic and enzymatic hydrolysates of mixed microalgae culture

Source: Fuel, Volume 200
Author(s): Hanieh Shokrkar, Sirous Ebrahimi, Mehdi Zamani
Mixed microalgae cultures are considered as an attractive research area compared to traditional pure culture to dominate cultivation contamination risk and enhance economic feasibility of large-scale biofuel production. However, pre-treatment and bioethanol production from mixed microalgae culture has not been reported yet. Therefore, this study was aimed to evaluate the effect of different pre-treatment strategies including acidic, alkaline, and enzymatic hydrolysis on the sugar extraction from mixed microalgae. Besides, the effects of MgSO4 and CaCl2 as lewis acids in acidic pre-treatment on reducing sugar yield were studied. Results showed that the mixture of dilute sulfuric acid and MgSO4 exhibited a higher sugar yield than dilute acid. Among all pre-treatments used, the enzymatic treatment with thermostable enzymes showed the highest recovery of 0.951g extracted glucose/g total sugar. Moreover, the enzymatic pre-treatment of wet microalgae was compared with dried

ones at identical operational conditions and dried biomass concentration of 50g/l, similar sugar yields were achieved which would be advantageous to reduce the need for drying of the microalgae biomass. Fermentation of the acidic and enzymatic treated samples to ethanol using Saccharomyces cerevisiae showed yield of 0.38 and 0.46g/g glucose, corresponding to 76% and 92% of the theoretical values, respectively. The obtained results revealed that bioethanol yield after enzymatic hydrolysis of mixed microalgae culture are higher than those of acid hydrolysis.

Graphical abstract



Life cycle assessment of microalgae based biodiesel production to evaluate the impact of biomass productivity and energy source

Source: Resources, Conservation and Recycling, Volume 122

Author(s): Sarat Chandra Togarcheti, Maneesh kumar Mediboyina, Vikas Singh Chauhan, Suparna Mukherji, Sarada Ravi, Sandeep Narayan Mudliar

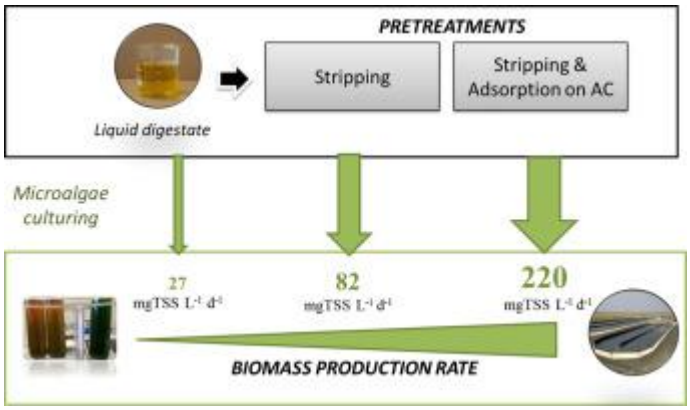
In the present study the life cycle assessment (LCA) of three scenarios for biodiesel production from Scenedesmus dimorphus, a freshwater microalgae, cultivated in open raceway ponds using primary and secondary data was investigated. The main differences in the scenarios were related to biomass productivity, mode of culture mixing and type of energy source. The process steps included algal cultivation in open raceway ponds, harvesting by chemical flocculation, dewatering by mechanical drying option (MDO)/Spray Drying (SD) followed by extraction, reaction, and purification. Supplementation of the cultivation process with electricity derived from defatted algal biomass waste was also analyzed. The scenarios were evaluated for energy demand and environmental impacts amongst the boundary conditions based on a “cradle-to-gate” inventory. The results revealed that among all the scenarios, cultivation in raceway pond was ascertained to be the most energy intensive process with the mode of culture mixing and biomass productivity being the principal determinants. The impacts were found to be directly linked to energy demand and had an inverse relationship with biomass productivity. The geographic location of the energy sources affected the environmental implications of a given process. The integration of defatted algal biomass waste derived electricity with the cultivation system showed a minor reduction in the overall energy demand.

A novel option for reducing the optical density of liquid digestate to achieve a more productive microalgal culturing

Source: Algal Research, Volume 24, Part A
Author(s): F. Marazzi, C. Sambusiti, F. Monlau, S.E. Cecere, D. Scaglione, A. Barakat, V. Mezzanotte, E. Ficara

The liquid fraction of digestate produced by agricultural biogas plants is rich in macro and micronutrients that are valuable for the culturing of microalgae. Nonetheless, the high ammonium concentration may cause toxicity and the high optical density may reduce light penetration, negatively affecting the biomass production rate. Dilution with fresh water has been frequently suggested as a mean for improving the digestate characteristics in view of microalgal culturing. In this paper, the feasibility of culturing microalgae on undiluted raw digestate or on digestate after pretreatment by stripping and adsorption was investigated. First, adsorption tests were performed using commercial activated carbon from wood in order to identify appropriate conditions for optical density (OD) reduction. Up to 88% reduction was obtained by dosing 40gL^{-1} after 24h of contact time. Then, culturing tests were performed on a microalgal inoculum including mainly Chlorella spp. and Scenedesmus spp. under controlled temperature and light conditions during 6–14weeks. Raw, stripped, and stripped and adsorbed digestate samples were tested. The biomass production rate increased from 27±13mgTSSL^{-1} d^{-1} on raw digestate, to 82±18mgTSSL^{-1} d^{-1} by using stripped digestate, and to 220±78mgTSSL^{-1} d^{-1} by using the stripped and adsorbed digestate. Moreover, nitrification was constantly suppressed when using the stripped and adsorbed digestate, while relevant nitrite built-up was observed when using raw and stripped digestate. These results suggest that microalgae are able to grow on the raw digestate, provided that long hydraulic retention times are applied. A much faster growth (up to 10 times) can be obtained by pretreating the liquid fraction of digestate by stripping and adsorption, which may be an effective means of improving the areal productivity of microalgal culturing on digestates.

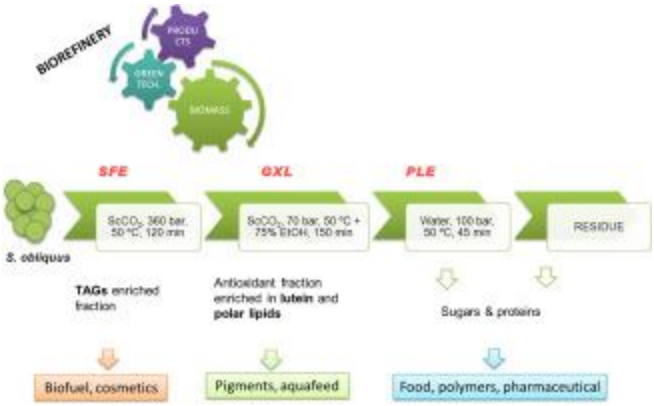
Graphical abstract



Green compressed fluid technologies for downstream processing of Scenedesmus obliquus in a biorefinery approach

Source: Algal Research, Volume 24, Part A
Author(s): Bienvenida Gilbert-López, José A. Mendiola, Lambertus A.M. van den Broek, Bwee Houweling-Tan, Lolke Sijtsma, Alejandro Cifuentes, Miguel Herrero, Elena Ibáñez
The fractionation of algae biomass in several high-value compounds that can be used as ingredients in other applications sets the basis of the algae biorefinery approach. The present study aimed at the extraction and fractionation of bioactive compounds from the microalga Scenedesmus obliquus, by means of applying a sequential process without the manipulation of the biomass in the extraction cell. This integrated platform of compressed fluid extraction technologies of low-environmental impact was designed in order to produce increases of solvent polarity using non-toxic solvents. The process involved the following steps:(1) supercritical fluid extraction (SFE) using supercritical carbon dioxide (ScCO2); (2) gas expanded liquids (GXL) using 75% ethanol and 25% ScCO2 (v/v) and; (3) pressurized liquid extraction (PLE) using water. Extraction conditions were optimized using response surface methodology (RSM) and kinetic studies. Extraction yield, antioxidant activity as well as contents of total phenols, carotenoids, proteins and sugars were the studied response variables. High performance liquid chromatography coupled to evaporative light-scattering detector (HPLC-ELSD) analyses of the fractions revealed that triacylglycerols were mainly extracted by SFE. Lutein and β-carotene were the main pigments identified in the extracts by HPLC coupled to diode array and mass spectrometry detectors (HPLC-DAD-MS/MS), which were preferentially extracted in the GXL step. Polar compounds such as proteins and sugars remained predominantly in the residue. Therefore, the green downstream platform developed in this study for valorization of the microalgae biomass, is able to produce different fractions with potential application in the food, pharmaceutical and cosmetic industries.

Graphical abstract



Effects of CO2 sequestration on lipid and biomass productivity in microalgal biomass production

Source: Applied Energy, Volume 195
Author(s): Andrew C. Eloka-Eboka, Freddie L. Inambao
The study is focused on the technology and manipulation of production strategies for the cultivation of biomass from four strains of microalgae. Species of microalgae studied are: Chlorella vulgaris, Dunaliella, Scenedesmus quadricauda and Synechococcus spp. The effects of the rate and amount of CO2 removal from the atmosphere and sequestration with dissolved oxygen on lipid production from accumulated biomass were studied. Also, the rate of sequestration of both total and dissolved carbon was investigated. Daily measurements of total, organic and inorganic carbon sequestrated, optical densities, proximate analysis and kinetic parameters of the growing and cultivated microalga were monitored and carried out during the two phases of cultivation: dark and light phases. The values of maximum rate of carbon (IV) oxide removed, rmax varied from 11.73mgL^{-1} min^{-1} to 18.84mgL^{-1} min^{-1} from Chlorella vulgaris to Synechoccocus spp. Important parameters such as biomass productivity, maximum pH values obtained at cultivation, lipid content of the produced biomass and the hydraulic detection time for all four strains of microalgae were considered and presented in comparison and with their individual and collective effects. The ratios of the rate of CO2 absorption constant and the constant for the CO2 desorption rate (k1/k2) occurred highest in Dunaliella suggesting that with a high uptake of CO2, the algal strain is more effective in CO2 sequestration. The best biomass producer in this study was the C. vulgaris (Xmax =5400mgL^{-1} and Px=35.1mgLh^{-1}) where biomass productivity is Px and the maximum cellular concentration is Xmax. C. vulgaris has the highest lipids productivity of 27% while Synechoccocus has the least (11.72%). In general, biomass productivity may be inversely related; this fact may be explained by greater metabolic involvement of lipid biosynthesis. This pioneer study may be advanced further to developing models for strategic manipulation and optimisation approach in micro algal biomass cultivation.

Biological CO2 mitigation from coal power plant by Chlorella fusca and Spirulina sp.

Source: Bioresource Technology, Volume 234
Author(s): Jessica Hartwig Duarte, Etiele Greque de Morais, Elisângela Martha Radmann, Jorge Alberto Vieira Costa
CO2 biofixation by microalgae and cyanobacteria is an environmentally sustainable way to mitigate coal burn gas emissions. In this work the microalga Chlorella fusca LEB 111 and the cyanobacteria Spirulina sp. LEB 18 were cultivated using CO2 from coal flue gas as a carbon source. The intermittent flue gas injection in the cultures enable the cells growth and CO2 biofixation by these microorganisms. The Chlorella fusca isolated from a coal power plant could fix 2.6 times more CO2 than Spirulina sp. The maximum daily CO2 from coal flue gas

biofixation was obtained with Chlorella fusca (360.12±0.27mgL^{-1} d^{-1}), showing a specific growth rate of 0.17±<0.01d^{-1}. The results demonstrated the Chlorella fusca LEB 111 and Spirulina sp. LEB 18 potential to fix CO2 from coal flue gas, and sequential biomass production with different biotechnological destinations.

Comparison of red microalgae (Porphyridium cruentum) culture conditions for bioethanol production

Source: Bioresource Technology, Volume 233
Author(s): Ho Myeong Kim, Chi Hoon Oh, Hyeun-Jong Bae
Microalgae biomass are useful resources in biofuel production. The objective of this study was to evaluate bioethanol production in response to Porphyridium cruemtum culture conditions. Enzymatic hydrolysis of seawater P. cruemtum (SPC) and freshwater P. cruemtum (FPC, 1% substrate loading, w/v) resulted in glucose conversion yields of 89.8 and 85.3%, respectively, without any pretreatment. However, FPC hydrolysate was more efficiently converted to ethanol about 7.1% than SPC hydrolysate. The comparison of separate hydrolysis and fermentation (SHF) and simultaneous saccharification and fermentation (SSF) showed that SSF processing is a superior method for bioethanol production from both SPC and FPC. Though SSF processing (5% substrate loading, w/v) in a 500-mL twin-neck round bottom flask, we achieved ethanol conversion yields of 65.4 and 70.3% from SPC and FPC, respectively, after 9h. These findings indicate that P. cruemtum can grow in freshwater conditions and is an efficient candidate for bioethanol production.

Potential of biofuels from algae: Comparison with fossil fuels, ethanol and biodiesel in Europe and Brazil through life cycle assessment (LCA)

Source: Renewable and Sustainable Energy Reviews, Volume 73
Author(s): Maria Luisa N.M. Carneiro, Florian Pradelle, Sergio L. Braga, Marcos Sebastião P. Gomes, Ana Rosa F.A. Martins, Franck Turkovics, Renata N.C. Pradelle
Despite a substantial literature using life cycle assessment (LCA) approach, the extent to which second and third generation biofuels are more sustainable than the first generation remains a subject of debate. Although the existence of limitations due to LCA variability and uncertainty, this paper intends to determine global tendencies based on a statistic and critical interpretation of previously published study results, reviewing 61 recent papers addressing an environmental evaluation of microalgae biofuels. Such information is compared to the same impact indicators for fossil fuels and for ethanol and biodiesel from terrestrial crops in Europe and Brazil. For each case, the system boundaries and the methodological choices were precisely described. The sustainability potential of all biofuels was evaluated by the Global Warming Potential (GWP), the Energy Ratio (ER) and the Land Use (LU), allowing a broad estimation of the biofuels' contribution to climate change mitigation, their net energy efficiency and their competiveness with food production chain. The results highlight that algae-derived biodiesel is, by far, the most efficient alternative in

terms of land use compared to other biofuels, avoiding competition with food crops. Some biodiesel pathways can also satisfactorily perform in terms of greenhouse gases emissions reduction, but some others can be even worst than fossil diesel. Nevertheless, in terms of energy efficiency, algae biofuels cannot compete with other biofuels or fossil fuels. They present very low performances, even demanding more energy for its production then the energy they can deliver. Moreover, no pathway can be conclusively selected as preferable between the two main technologies available for microalgae biodiesel due to high uncertainties. However, open raceway pounds technology seems to be preferable as it looks less GHG intensive, requiring lower energy input and land use. Energetic and GWP performances can be improved if production pathways are carefully chosen and optimized.

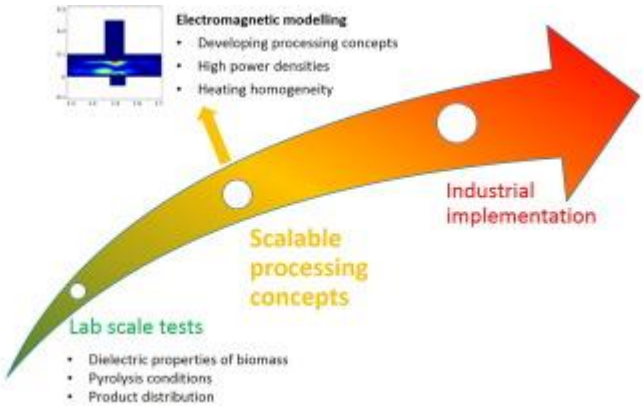
Microwave pyrolysis of biomass for bio-oil production: Scalable processing concepts

Source: Chemical Engineering Journal, Volume 316

Author(s): D. Beneroso, T. Monti, E.T. Kostas, J. Robinson

The pursuit of sustainable hydrocarbon alternatives to fossil fuels has prompted an acceleration in the development of new technologies for biomass processing. Microwave pyrolysis of biomass has long been recognised to provide better quality bio-products in shorter timescales compared to conventional pyrolysis. Although this topic has been widely assessed and many investigations are currently ongoing, this article gives an overview beyond the physico-chemical pyrolysis process and covers engineering aspects and the limitations of microwave heating technology. Herein, we provide innovative scalable concepts to perform the microwave pyrolysis of biomass on a large scale, including essential energy and material handling requirements. Furthermore, some of the possible socio-economic and environmental implications derived from the use of this technology in our society are discussed. Such potential concepts are expected to assist the needs of the industrial bioenergy community to move this largely studied process upwards in scale.

Graphical abstract



Cylindrospermopsin induced changes in growth, toxin production and antioxidant response of Acutodesmus acuminatus and Microcystis aeruginosa under differing light and nitrogen conditions

Source: Ecotoxicology and Environmental Safety, Volume 142
Author(s): Mathias Ahii Chia, Micheline Kézia Cordeiro-Araújo, Adriana Sturion Lorenzi, Maria do Carmo Bittencourt-Oliveira
Growing evidence suggests that some bioactive metabolites (e.g. cyanotoxins) produced by cyanobacteria have allelopathic potential, due to their inhibitory or stimulatory effects on competing species. Although a number of studies have shown that the cyanotoxin cylindrospermopsin (CYN) has variable effects on phytoplankton species, the impact of changing physicochemical conditions on its allelopathic potential is yet to be investigated. We investigated the physiological response of Microcystis aeruginosa (Cyanobacteria) and Acutodesmus acuminatus (Chlorophyta) to CYN under varying nitrogen and light conditions. At 24h, higher microcystins content of M. aeruginosa was recorded under limited light in the presence of CYN, while at 120h the lower levels of the toxins were observed in the presence of CYN under optimum light. Total MCs concentration was significantly (p<0.05) lowered by CYN after 120h of exposure under limited and optimum nitrogen conditions. On the other hand, there were no significant (p>0.05) changes in total MCs concentrations after exposure to CYN under high nitrogen conditions. As expected, limited light and limited nitrogen conditions resulted in lower cell density of both species, while CYN only significantly (p<0.05) inhibited the growth of M. aeruginosa. Regardless of the light or nitrogen condition, the presence of CYN increased internal H2O2 content of both species, which resulted in significant (p<0.05) changes in antioxidant enzyme (catalase, peroxidase, superoxide dismutase and glutathione S-transferase) activities. The oxidative stress caused by CYN was higher under limited light and limited nitrogen. These results showed that M. aeruginosa and A. acuminatus have variable response to CYN under changing light and nitrogen conditions, and demonstrate that need to consider changes in physicochemical conditions during ecotoxicological and ecophysiological investigations.

Biogas from microalgae: Review on microalgae's cultivation, harvesting and pretreatment for anaerobic digestion

Source: Renewable and Sustainable Energy Reviews, Volume 75
Author(s): Ewelina Jankowska, Ashish K. Sahu, Piotr Oleskowicz-Popiel
The goal of this work was to give a comprehensive review on biogas production from microalgae biomass. Different process parameters were summarized in tables which could become comprehensive compendium of operation conditions of microalgae preparation for biogas production. Further,, the limitations of the process implementation and commercialization (e.g. high costs of implementation and maintenance, low biomass productivity, limited methane yield due to specific structure of microalgae cell wall) were

discussed. It was concluded that the microalgae anaerobic digestion should be incorporated with production of other bioproducts such as biodiesel, bioethanol or volatile fatty acids. Such a biorefinery would open possibility to improve both wastewater treatment and generate valuable products from waste streams.

Nutrient recovery and biogas generation from the anaerobic digestion of waste biomass from algal biofuel production

Source: Renewable Energy, Volume 108
Author(s): Pedro Ayala-Parra, Yuanzhe Liu, Jim A. Field, Reyes Sierra-Alvarez
Microalgae are gaining popularity as a source of biodiesel. Recycling fertilizer nutrients is critical to sustain large-scale biodiesel production because the global supply of surplus fertilizer is limited. This study demonstrates that anaerobic digestion of residual algal biomass from biodiesel production can provide additional nutrients and energy. Anaerobic digestion of Chlorella sorokiniana 1412 whole cell algae (WCA), sonicated algae (SA), and SA subjected to lipid extraction (LEA) in bench-scale batch reactors operated at 30 ± 2 °C for 42 days released a considerable amount of the nitrogen and phosphorus in the algal cells. Digestion of WCA, SA, LEA released 48.1, 77.4, and 61.5% of the total algal nitrogen as NH_4^+-N, and 87.7, 99.4, and 93.6% of the total algal P as soluble P, respectively. The energy recovery from algae biomass was quantified through the methane yield. The biochemical methane potential of WCA, SA and LEA was 0.298, 0.388 and 0.253 L methane per gram algal volatile solids, respectively. The conversion of LEA and WCA biomass to methane was very similar (38 and 41% on a COD basis, respectively), indicating that the energy yield was not significantly lowered by extraction of the lipid fraction (which accounted for 9% of algal dry weight). Sonication improved the access of hydrolytic enzymes to algal biopolymers (compensating in part for the energy lost due to lipid extraction). The results taken as a whole indicate that anaerobic digestion of LEA can provide considerable yields of methane and soluble nutrients.

Harvesting of microalgae Chlorella vulgaris using electro-coagulation-flocculation in the batch mode

Source: Algal Research, Volume 25
Author(s): Nidal Fayad, Tania Yehya, Fabrice Audonnet, Christophe Vial
The aim of this study was to evaluate the harvesting of microalgae Chlorella vulgaris by electro-coagulation-flocculation (ECF) using aluminum and iron electrodes, assess the mechanisms responsible for microalgae recovery, quantify the metal contamination in the effluent and biomass, analyze power requirements, and investigate the effect of ECF on lipid and pigment content in the biomass. The influence of six operating parameters (electrode material, sedimentation time, current density, stirring speed, initial pH (pHi) and inter-electrode distance) on the harvesting efficiency was tested. A specific strategy involving flotation and pH-controlled ECF experiments was developed to identify the prevailing

mechanism of harvesting: adhesion on flocs was shown to be negligible; flotation contributed to a maximum of 36.6% of microalgae recovery; zeta potential highlighted that the main mechanism responsible for microalgae recovery was charge neutralization at pHi 4 and 6, and sweep flocculation at pHi 8. The most energy saving conditions for the harvesting of Chlorella vulgaris involved aluminum electrodes, and 60min electrolysis with a current density of 2.9mA/cm^2, pHi 4, stirring speed 250rpm and an inter-electrode distance of 1cm. Economic and competitive energy input (1kWh/kg microalgae) could be achieved by adding 1.5g/L NaCl. In addition, ECF did not affect significantly the amount of microalgal lipids and pigments.

Global optimization of microalgae-to-biodiesel chains with integrated cogasification combined cycle systems based on greenhouse gas emissions reductions

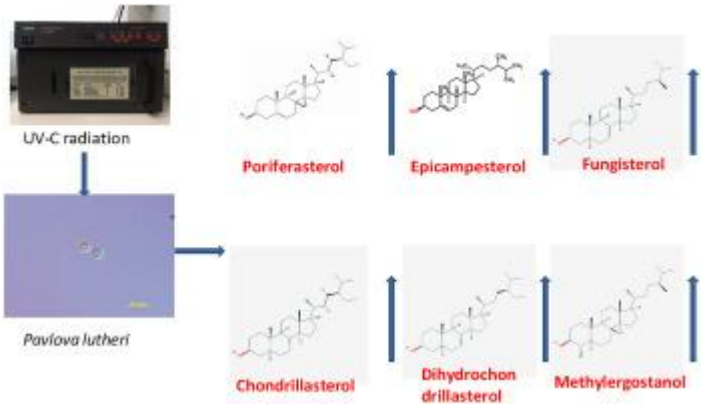
Source: Applied Energy, Volume 197
Author(s): Wei Wu, Po-Han Wang, Duu-Jong Lee, Jo-Shu Chang
A microalgae-based energy system, which is a combination of different microalgae-to-biodiesel chains and an integrated cogasification combined cycle (ICGCC) system, is presented. To address the low environmental impacts, the electricity is generated from ICGCC to meet the load demand from the microalgae-to-biodiesel chains and the flue gas exits from ICGCC to meet the demand of growing algal culture. To achieve the microalgae-based energy system with minimum life cycle greenhouse gas (GHG) emissions, the first step is to develop the superstructure model based on GAMS, the second step is to use the optimal heat exchanger network to maximize the heat recovery of ICGCC, and the third step is to find the optimal combination of the microalgae-to-biodiesel chain and optimal operating conditions of ICGCC by solving the global optimization of nonconvex mixed-integer nonlinear programming (MINLP) problem. For the scope of well-to-tank (WTT), the optimal microalgae-based energy system reduces 16.80% greenhouse gas (GHG) emissions compared to the other reported microalgae-to-biodiesel chains. For the scope of well-to-wheel (WTW), the optimal microalgae-based energy system reduces 45.77% GHG emissions compared to the conventional diesel process.

UV–C radiation increases sterol production in the microalga Pavlova lutheri

Source: Phytochemistry, Volume 139
Author(s): Faruq Ahmed, Peer M. Schenk
Plant sterols have become well-known to promote cardiovascular health through the reduction of low density lipoprotein cholesterol in the blood. Plant sterols also have anti-inflammatory, anti-cancer, anti-oxidative and anti-atherogenicity activities. Microalgae have

the potential to become a useful alternative source of plant sterols with several species reported to have higher concentrations than current commercial ones. In order to increase phytosterol production and optimise culture conditions, the high sterol producer Pavlova lutheri was treated in different dosages (50–250 mJ m^{-2}) of UV–C radiation and several concentrations (1–500 µmol/L) of hydrogen peroxide (H2O2) and the sterol contents were quantified for two days after the treatments. The contents of malondialdehyde (MDA) superoxide dismutase (SOD) as indications of cell membrane damage by lipid peroxidation and repair of oxidative stress, respectively, were measured. Higher activities of SOD and MDA were observed in the treated biomass when compared to the controls. Total sterols increased in P. lutheri due to UV–C radiation (at 100 mJ m^{-2}) but not in response to H2O2 treatment. Among the nineteen sterol compounds identified in P. lutheri, poriferasterol, epicampesterol, methylergostenol, fungisterol, dihydrochondrillasterol, and chondrillasterol increased due to UV–C radiation. Therefore, UV–C radiation can be a useful tool to boost industrial phytosterol production from P. lutheri.

Graphical abstract



PATENTES

Method for synchronously enhancing yields of lutein and carbohydrates of autotrophic microalgae

Inventor(s):	XIE YOUPING; YANG XUQIU; CHEN JIANFENG; SHEN YING; ZHENG XIANGNAN + (XIE YOUPING, ; YANG XUQIU, ; CHEN JIANFENG, ; SHEN YING, ; ZHENG XIANGNAN)
Applicant(s):	UNIV FUZHOU + (FUZHOU UNIVERSITY)
Application number:	CN201611030118 20161122 Global Dossier

Priority number(s): CN201611030118 20161122

The invention relates to a method for synchronously enhancing yields of lutein and carbohydrates of autotrophic microalgae. The method comprises the following steps: inoculating alga seeds into a seed culture medium, culturing to obtain a seed solution, inoculating the seed solution into a photobiological reactor filled with a fermentation culture medium, and culturing. In the culturing process, the initial illumination intensity is controlled at 60-300 mu mol/m<2>/s, and the illumination intensity is enhanced by 50-150 mu mol/m<2>/s every 12 hours until the fermentation finishes; and meanwhile, when the initial nitrogen source concentration starts exhaustion, a nitrogen source with the nitrogen concentration of 2-14 g/L is fed at the constant speed of 1-10 mg/L/h, and the fermentation period is 4-6 days. The biomass concentration of the microalgae cultured by the method can reach 4-9 g/L, the yield of lutein is 20-60 mg/L, and the yield of carbohydrates is 1.4-3.3 g/L. The method has the advantages of short fermentation period, simple production technique and low production cost, and can obviously widen the industrialization prospects for simultaneously producing lutein and biofuels by using microalgae.

PRODUCTION OF DOCOSAHEXAENOIC ACID AND/OR EICOSAPENTAENOIC ACID AND/OR CAROTENOIDS IN MIXOTROPHIC MODE BY NITZSCHIA

Inventor(s): ROMARI KHADIDJA [FR]; GODART FRANÇOIS [FR]; CALLEJA PIERRE [FR] + (ROMARI Khadidja, ; GODART François, ; CALLEJA Pierre)

Applicant(s): FERMENTALG [FR] + (FERMENTALG)

Classification:
- **international:** ***C12N1/12***; ***C12N13/00***; ***C12P23/00***; ***C12P7/64***; *C12R1/89*
- **cooperative:** **C12N1/12**; **C12N13/00**; **C12P23/00**; **C12P7/6427**; **C12P7/6472**; **C12R1/89**

Application number: US201715405559 20170113 Global Dossier

Priority number(s): US201715405559 20170113 ; FR20120052378 20120316 ; FR20120057843 20120816 ; US201414385502 20140916 ; WO2013FR50542 20130315

New strains of microalgae belonging to the Nitzschia genus allow high-yield production of lipids such as docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), and/or carotenoids such as fucoxanthin. Biomass containing the microalgae can be charged with fucoxanthin representing more than 0.2% by weight of the dry matter.

Production of lutein in mixotrophic mode by Scenedesmus

Inventor(s):	ROMARI KHADIDJA [FR]; GODART FRANCOIS [FR]; CALLEJA PIERRE [FR] + (ROMARI Khadidja, ; GODART Francois, ; CALLEJA Pierre)
Applicant(s):	FERMENTALG [FR] + (FERMENTALG)
Classification:	**- international:** *C12R1/89* **- cooperative:** **C12N1/12**; **C12P23/00**; **C12R1/89**
Application number:	US201615374241 20161209 Global Dossier
Priority number(s):	US201615374241 20161209 ; FR20120052381 20120316 ; US201414385305 20140915 ; WO2013FR50544 20130315
Also published as:	EP2844734 (A1) FR2988101 (A1) FR2988101 (B1) JP2015510763 (A) US2015037839 (A1) more

Strains of microalgae belonging to the Scenedesmus genus grown in mixotrophic mode enable the production of lipids, in particular lutein. Methods for selecting and culturing the microalgae strains using variable and/or discontinuous supply of light, in particular in the form of flashes, are provided.

NOVEL MICROALGAE AND METHODS FOR PRODUCING BIOFUEL USING THE SAME

Inventor(s):	MIYAZAKI TATSUO; KANEMOTO KAZUYO + (MIYAZAKI TATSUO, ; KANEMOTO KAZUYO)
Applicant(s):	ALGAE GLOBAL CENTER PTE LTD + (ALGAE GLOBAL CENTER PTE LTD)
Classification:	**- international:** ***C12N1/12***; ***C12P7/64*** **- cooperative:** **C12N1/12**; **C12P7/6409**; **C12P7/649**; **C12R1/89**; C10L1/02; Y02E50/13
Application number:	JP20150056752 20150319 Global Dossier
Priority number(s):	JP20150056752 20150319

PROBLEM TO BE SOLVED: To provide novel microalgae with rapid growth, resistance to contamination with other microalgae, high lipid content, and at least a lipid composition suitable for biofuel production, and methods for producing biofuel using the microorganisms.SOLUTION: The microalgae belonging to the genus Desmodesmus have spiny projections and form two-cell colonies, and are characterized in that 80% or more of the fatty acids contained in the microalgae are composed of Cand Cfatty acids.

Method for culturing microalgae by adding anaerobic digestion liquid of kitchen waste to natural seawater

Inventor(s):	PEI HAIYAN; ZHANG LIJIE; HU WENRONG; JIANG LIQUN; HAN FEI; CHENG JUAN + (Pei Haiyan, ; Zhang Lijie, ; Hu Wenrong, ; Jiang Liqun, ; Han Fei, ; Cheng Juan)
Applicant(s):	UNIV SHANDONG + (Shandong University)
Classification:	**- international:** ***C02F3/32***; ***C12N1/12***; *C12R1/89* **- cooperative:**
Application number:	CN20161323024 20160513 Global Dossier
Priority number(s):	CN20161323024 20160513

The invention discloses a method for culturing microalgae by adding an anaerobic digestion liquid of kitchen waste into natural seawater, aims to find out the best proportion, and belongs to the technical field of the microalgae. According to the invention, the digestion liquid is added to natural seawater according to the ratio of (1:10)-(1:50) to be taken as an experimental group culture medium, BG11, natural seawater and the digestion liquid are taken as a control group, the experimental group culture medium is cultured under the condition of continuous light until the microalgae stops to grow, and centrifugal separation is carried out to obtain the microalgae. The result shows that the growth rate of the microalgae added with the digestion liquid and cultured in natural seawater is obviously higher than that of the microalgae cultured in the BG 11 and pure seawater, furthermore, natural seawater added with the digestion liquid is taken as the culture medium to improve the lipid yield of the microalgae and lower the cultivation cost of the microalgae, so that the method for culturing the microalgae by adding the anaerobic digestion liquid of the kitchen waste to natural seawater is worthy of being popularized and applied.

A fermentation process

Inventor(s):	SIMPSON SEAN DENNIS; BERNASEK SEBASTIAN MICHAL + (SIMPSON SEAN DENNIS, ; BERNASEK SEBASTIAN MICHAL)
Applicant(s):	LANZATECH NEW ZEALAND LTD + (LANZATECH NEW ZEALAND LTD)
Classification:	**- international:** ***C12P7/64*** **C12P7/54**; **C12P7/6463**; **C12P7/649**; **G01N33/92**; Y02E50/13 more **- cooperative:** **default** **C12P7/54**; **C12P7/6463**; **C12P7/649**; **G01N33/92**; Y02E50/13 **CPCNO** **C12P7/54**; **C12P7/6463**; **C12P7/649** less
Application number:	CN2013857205 20131129 Global Dossier
Priority	WO2013US72475 20131129 ; US201261731623P 20121130

number(s):

Also published as: EP2925874 (A1) EP2925874 (A4) US2014154755 (A1) WO2014085756 (A1)

The invention provides methods and systems for the production of lipid products from a gaseous substrate using a two stage fermentation process. The method comprises providing a gaseous substrate comprising CO or CO2 and H2 or mixtures thereof, to a first bioreactor containing a culture or one or more microorganisms, and fermenting the substrate to produce acetate. The acetate from the first bioreactor is then provided to a second bioreactor, where it is used as a substrate for fermentation to lipids by one or more microalgae

MANIPULATION OF MICROALGAL LIPID METABOLIC PATHWAY BY ALTERING CAMP SIGNALING PATHWAYS

Inventor(s): CHOI YOON E [KR]; LEE CHANG SU [KR]; YANG JI WON [KR] + (CHOI, YOON E, ; LEE, CHANG SU, ; YANG, JI WON)

Applicant(s): NAT UNIV CHONBUK IND COOP FOUN [KR] + (INDUSTRIAL COOPERATION FOUNDATION CHONBUK NATIONAL UNIVERSITY)

Classification:
- **international:** ***C12N1/12***; ***C12N1/38*** **C12N1/04**; **C12N1/12**; **C12N1/38** more
- **cooperative:** **default** **CPCNO** **C12N1/04**; **C12N1/12**; **C12N1/38** less

Application number: KR20130138833 20131115 Global Dossier

Priority number(s): KR20130138833 20131115

Also published as: KR101524803 (B1)

The present invention relates to a method for adjusting the microalgae lipid metabolism by treating the chemical substance called 3-isobutyl-1-methylxanthine (IBMX) which affects the cAMP signaling. The present invention adjusts the cAMP signaling process through the IBMX treatment to up-regulate the microalgae lipid metabolism. The signaling can be applied to various types of microalgae instead of one type of strains. The cAMP signaling system adjusting method enables the products of the microalgae lipid metabolism to be industrially useful.

METHOD FOR PROMOTING CELL GROWTH OF MICROALGAE AND ACCUMULATION OF NEUTRAL LIPID THEREIN USING SONIC VIBRATION

Inventor(s): JEON NOO LI [US]; PARK JAE WOO [KR]; KANG MYEONG WOO [KR]; NA SANG CHEOL [KR] + (JEON NOO LI, ; PARK, JAE WOO, ; KANG, MYEONG WOO, ; NA, SANG CHEOL)

Applicant(s): SNU R&DB FOUNDATION [KR] + (SNU R&DB FOUNDATION)

Classification:
- **international:** ***C12N1/12***; ***C12N13/00***
  C12N1/12; **C12N13/00**; **C12P7/649**; Y02E50/13 more
- **cooperative:** **default**
  CPCNO **C12N1/12**; **C12N13/00**; **C12P7/649**; Y02E50/13 less

Application number: KR20130137072 20131112 Global Dossier

Priority number(s): KR20130137072 20131112

The present invention discloses a method for fostering the growth of microalgae and lipid generation by using vibration. The present invention can foster the lipid generation without suppressing the cell growth of the microalgae to be utilized to produce bio-energy fuels such as biodiesel.

METHOD FOR CULTIVATING MICROALGAE USING SEWAGE AND LIQUEFIED FERTILIZER

Inventor(s): LEE TAE HO [KR]; PARK SEONG HWAN [KR]; KIM JEONG MI [KR] + (LEE, TAE HO, ; PARK, SEONG HWAN, ; KIM, JEONG MI)

Applicant(s): PUSAN NAT UNIV IND COOP FOUND [KR] + (PUSAN NATIONAL UNIVERSITY INDUSTRY-UNIVERSITY COOPERATION FOUNDATION)

Classification:
- **international:** ***C12N1/12***; *C12R1/89*
  C12N1/12; Y02E50/10 more
- **cooperative:** **default**
  CPCNO **C12N1/12**; Y02E50/10 less

Application number: KR20130134450 20131106 Global Dossier

Priority number(s): KR20130134450 20131106

Also published as: KR101637628 (B1)

The present invention relate to a composition comprising sewage and a liquid fertilizer as active ingredients for culturing microalgae, and a culture method of microalgae using the same. The culture method of microalgae according to the present invention is economically feasible in terms of using sewage and a liquid fertilizer to culture microalgae and has an effect of remarkably improving lipid productivity as well as the growth rate of Micractinium inermum NLP-F014 microalgae. Further, the Micractinium inermum NLP-F014 strain has a high content of C16 to C18 fatty acids, thus being suitable for use in a biofuel composition.

MICROALGAE CULTIVATION METHOD USING FLASH LIGHT FOR INCREASE OF FATTY ACIDS PRODUCTION AND WASTEWATER TREATMENT

Inventor(s): KIM HYUNG JOO [KR]; CHOI YONG KEUN [KR]; KIM HAN SOO [KR]; JEON JONG MIN [KR]; LEE SANG HYUN [KR]; YANG YUNG HUN [KR]; JEON HYEON JIN [KR]; KIM HYUN KYUNG [KR] + (KIM, HYUNG JOO, ; CHOI, YONG KEUN, ; KIM, HAN SOO, ; JEON, JONG MIN, ; LEE, SANG HYUN, ; YANG, YUNG HUN, ; JEON, HYEON JIN, ; KIM, HYUN KYUNG)

Applicant(s): UNIV KONKUK IND COOP CORP [KR] + (KONKUK UNIVERSITY INDUSTRIAL COOPERATION CORP)

Classification:

- **international:** ***C02F3/32***; ***C12M3/00***; ***C12N1/12***; ***C12P7/64***

C02F3/32; **C12M3/00**; **C12N1/00**; **C12N1/12**; **C12P7/64**; Y02W10/37 more

- **cooperative:** **default** Y02W10/37

CPCNO **C02F3/32**; **C12M3/00**; **C12N1/00**; **C12N1/12**; **C12P7/64** less

Application number: KR20130108516 20130910 Global Dossier

Priority number(s): KR20130108516 20130910

Also published as: KR101579222 (B1)

The present invention relates to a method and an apparatus for improving lipid production of microalgae using a flash light, and to a method and an apparatus for improving wastewater treatment ability using the same. According to the present invention, a flash light type photostress of microalgae is caused by periodically and intermittently supplying light needed in growth of the microalgae, thereby having an effect of improving lipid production and improving function of removing nitrogen and phosphorous.

STRAIN OF MICROALGAE Desmodesmus sp FOR CONVERSION OF CARBON DIOXIDE FROM INDUSTRIAL WASTE GASES IN RAW MATERIAL FOR PRODUCTION OF BIOFUEL AND FEED ADDITIVES

Inventor(s):	LOBAKOVA ELENA SERGEEVNA, ; GORELOVA OL'GA ANDREEVNA, ; BAULINA OL'GA IVANOVNA, ; SOLOVCHENKO ALEKSEJ EVGEN'EVICH, ; KIRPICHNIKOV MIKHAIL PETROVICH
Applicant(s):	FEDERAL'NOE GOSUDARSTVENNOE BJUDZHETNOE OBRAZOVATEL'NOE UCHREZHDENIE VYSSHEGO OBRAZOVANIJA "MOSKOVSKIJ GOSUDARSTVENNYJ UNIVERSITET IMENI M.V. LOMONOSOVA" (MGU)
Classification:	**- international:** ***C02F3/34***; ***C12N1/12***; *C12R1/01* **- cooperative:**
Application number:	RU20130137676 20130812
Priority number(s):	RU20130137676 20130812

FIELD: biotechnology.SUBSTANCE: strain of microalgae Desmodesmus sp. 3Dp86E-1 has high rate of COfixation and tolerance to high concentrations of COin the cultivation medium, and the high ability to accumulate lipids enriched with polyunsaturated fatty acids. The strain is deposited in the Collection of microalgae cultures of the Institute of Plant Physiology n.a. K.A. Timiryazev RAS (IPPAS) under the registration number Desmodesmus sp. IPPAS S-2014 and can be used for conversion of carbon dioxide from industrial waste gases in the raw material for production of biofuel and feed additives.EFFECT: invention enables to improve the rate of fixation of COin air-gas mixture.4 dwg, 1 tbl.

PRODUCTION OF EICOSAPENTAENOIC AND/OR ARACHIDONIC ACID IN MIXOTROPHIC MODE BY EUGLENA

Inventor(s):	ROMARI KHADIDJA [FR]; CALLEJA PIERRE [FR] + (ROMARI KHADIDJA, ; CALLEJA PIERRE)
Applicant(s):	FERMENTALG [FR] + (FERMENTALG)
Classification:	**- international:** ***C12P7/64***; *C12R1/89* **- cooperative:** **C12N1/12**; **C12P7/6427**; **C12P7/6472**; **C12R1/89**
Application number:	US201314385507 20130315 Global Dossier
Priority number(s):	FR20120052376 20120316 ; WO2013FR50540 20130315

New strains of microalgae belonging to the Euglena genus, allow production of lipids, in particular of EPA and/or ARA, in mixotrophic mode, and a method for selecting and culturing such strains, using a variable and/or discontinuous light source, in particular a flashing light.

METHODS FOR THE SIMULTANEOUS PRODUCTION OF ASTAXANTHIN AND LIPID FROM HAEMATOCOCCUS PLUVIALIS

Inventor(s):	CHUE KUCK TACK [KR]; OH YOU KWAN [KR]; KIM DEOG KEUN [KR] + (CHUE, KUCK TACK, ; OH, YOU KWAN, ; KIM, DEOG KEUN)
Applicant(s):	KOREA ENERGY RESEARCH INST [KR] + (KOREA INSTITUTE OF ENERGY RESEARCH)
Classification:	**- international:** ***B01J19/10***; ***C07C49/603***; ***C12P23/00***; ***C12P7/64*** **- cooperative:**
Application number:	KR20130043344 20130419 Global Dossier
Priority number(s):	KR20130043344 20130419

The present invention relates to a method for simultaneously manufacturing astaxanthin and lipid from haematococcus pluvialis. More particularly, the present invention relates to a method for simultaneously manufacturing astaxanthin, which is a highly functional active substance, and lipid, which is to be used as the raw material of a biofuel, by chemically destroying the cell walls of haematococcus pluvialis, which is microalgae, by the aqueous solution of a surface active agent, applying ultrasonic waves to the treated microalgae and a single polar organic solvent or a mixed polar organic solvent in a batch extractor while churning the mixture, thereby extracting ketocarotenoid and lipid, which is the raw material of a biofuel, into the organic solvent, inputting a non-polar organic solvent and ultrapure water into the extract, thereby separating ketocarotenoid,; which is a functional active substance, and lipid which is the raw material of a biofuel via layer separation, supplying the polar organic solvent, in which ketocarotenoid is condensed, and an aqueous solution layer to a non-polar polymer adsorber, thereby manufacturing high-concentration astaxanthin.

MANUFACTURING METHOD OF LIPID USING MICROALGAE

Inventor(s):	FUJII KATSUHIKO + (FUJII KATSUHIKO)
Applicant(s):	UNIV YAMAGUCHI + (YAMAGUCHI UNIV)
Classification:	**- international:** ***A23K1/16***; ***C12N1/12***; ***C12P7/64*** **- cooperative:**
Application number:	JP20130041706 20130304 Global Dossier
Priority number(s):	JP20130041706 20130304

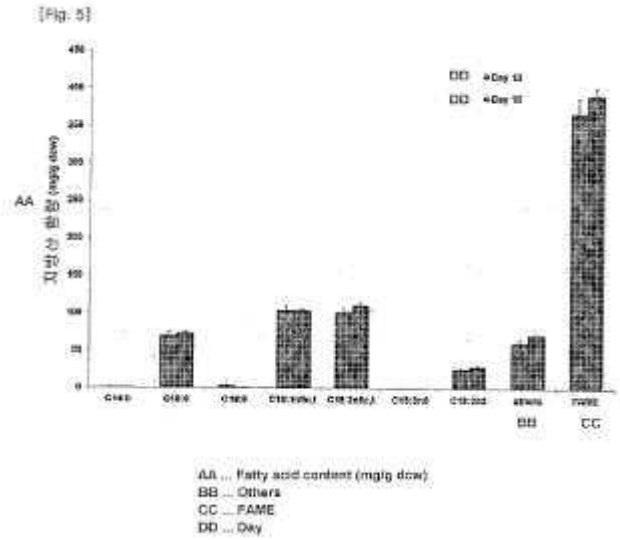
PROBLEM TO BE SOLVED: To provide microalgae with high production volume of lipid on inorganic salt medium, and a manufacturing method of lipid using the microalgae.SOLUTION: Production volume of lipid when cultured in an inorganic salt medium under the condition of pH 6.8, temperature at 25°C, illuminance on medium surface at 6000 lux is 50 mg/L/day or more, Oogamochlamys zimbabwiensis symbiotic with genus Acidovorax bacteria is cultured, lipid is extracted from the cultured Oogamochlamys zimbabwiensis symbiotic with genus Acidovorax bacteria. It is possible to manufacture lipid

derived from microalgae at low cost by the manufacturing method of lipid. Further, since the manufacture lipid contains much unsaturated fatty acid, it is useful as lipid which has low freezing point and is usable in cold climate.

HIGH STARCH AND HIGH LIPID PRODUCING MICROALGAE CHOLORELLA CELL STRAIN ISOLATED FROM ARTIC OCEAN AND USE THEREFOR

Inventor(s):	JEONG WON JOONG [KR]; AHN JOON WOO [KR]; LIU JANG RYOL [KR]; CHOI HAN GU [KR]; PARK YOUN IL [KR] + (JEONG, WON JOONG, ; AHN, JOON WOO, ; LIU, JANG RYOL, ; CHOI, HAN GU, ; PARK, YOUN IL)
Applicant(s):	KOREA RES INST OF BIOSCIENCE [KR]; KOREA INST OCEAN SCI & TECH [KR]; IAC IN NAT UNIV CHUNGNAM [KR] + (KOREA RESEARCH INSTITUTE OF BIOSCIENCE AND BIOTECHNOLOGY, ; KOREA INSTITUTE OF OCEAN SCIENCE & TECHNOLOGY, ; THE INDUSTRY & ACADEMIC COOPERATION IN CHUNGNAM NATIONAL UNIVERSITY)
Classification:	**- international:** ***C10G3/00***; ***C10L1/04***; ***C12N1/12***; ***C12P7/64***
	- cooperative: **C10L1/026**; **C12P19/04**; **C12P7/20**; **C12P7/6463**; **C12P7/649**; **C12R1/89**; Y02E50/13; Y02P30/20
Application number:	WO2013KR04441 20130521 Global Dossier
Priority number(s):	KR20130002313 20130109

The present invention relates to a new microalgae Chlorella sp. for accumulating a functional starch and lipid at high concentrations. The cell strain Chlorella sp. ArM29B according to the present invention has been confirmed to be a cell strain for accumulating starch and lipid at high concentrations during culturing, is enabled to be cultured in various temperature conditions, and has been confirmed to accumulate lipids at a high concentration by nile red analysis, in which a neutral oil drop can be specifically dyed in a cell, thereby enabling the cell strain to be used as a material for a biodiesel and functional lipid production. In addition, the cell strain Chlorella sp. ArM29B is suitable as a microalgae for a biodiesel use since lipids are accumulated at a high concentration during culturing, does not need a special temperature condition during culturing since the cell strain grows well at at least freezing temperature, and can be cultivated and produced throughout the year because the cell strain grows well in all of spring, summer, autumn, and winter.



METHOD OF SELECTING LIPIDES FROM BIOMASS OF MICROWAVES OF THE GENUS Chlorella

Inventor(s): BORGOLOV ARTEM VIKTOROVICH [RU]; VASILOV RAIF GAYANOVICH [RU]; GORIN KIRILL VIKTOROVICH [RU]; GOTOVTSEV PAVEL MIKHAJLOVICH [RU]; KOMOVA ANASTASIYA VIKTOROVNA [RU]; SERGEEVA YANA EDUARDOVNA [RU] + (Borgolov Artem Viktorovich, ; Vasilov Raif Gayanovich, ; Gorin Kirill Viktorovich, ; Gotovtsev Pavel Mikhajlovich, ; Komova Anastasiya Viktorovna, ; Sergeeva Yana Eduardovna)

Applicant(s): FED GOSUDARSTVENNOE BYUDZHETNOE UCHREZHDENIE NATSIONALNYJ ISSLEDOVATELSKIJ TSENTR KURCHATOVSKIJ INST [RU] + (Federalnoe gosudarstvennoe byudzhetnoe uchrezhdenie "Natsionalnyj issledovatelskij tsentr "Kurchatovskij institut")

Classification:
- **international:** ***C12N1/12***; ***C12P1/00***; *C12R1/89*
- **cooperative:**

Application number: RU20150155974 20151225

Priority number(s): RU20150155974 20151225

FIELD: biotechnology.SUBSTANCE: proposed method of isolating lipids for biodiesel from microalgae biomass of genus Chlorella. The method comprises homogenizing the dry biomass of microalgae grinding processing with organic solvent mixture chloroform-methanol and chloroform-ethanol in the ratio 1:2-2:1. The suspension of biomass is subjected to sonication at a frequency of 30-50 kHz for 5-20 minutes and separated lipids.EFFECT: target product yield enhancement.4 cl, 3 tbl, ex 10.

Method for preparing biodiesel from algae as raw material

Inventor(s):	HUANG JIANJUN + (HUANG JIANJUN)
Applicant(s):	NANNING OVERSEAS CHINESE INVEST ZONE ZHENGSUN TRADE CO LTD + (NANNING OVERSEAS CHINESE INVESTMENT ZONE ZHENGSUN TRADE CO., LTD)
Classification:	- international: *C10L1/02*; *C11B1/04*; *C11B1/10*; *C11C1/08*; *C11C1/10*; *C11C3/10* - cooperative:
Application number:	CN20161772842 20160830 Global Dossier
Priority number(s):	CN20161772842 20160830

The invention discloses a method for preparing biodiesel from algae as a raw material. The method comprises the following steps: a medium is inoculated with cylindrotheca, the cylindrotheca is irradiated with red and blue LED light supplement lamps for 20-24 h/day and cultured at a temperature of 24-27 DEG C for 5-8 days, and cylindrotheca cells can be collected; the collected cylindrotheca cells are subjected to wall breaking by ultrasonic waves and then extracted with an organic solvent, microalgal oil is prepared, the microalgal oil, methanol and a zeolite molecular sieve catalyst are then added to a reactor for an esterification reaction in a mass ratio of 1:(4-6):(0.02-0.04), an esterification product is obtained and then is separated and purified, and biodiesel can be obtained. According to the method, the cylindrotheca which is short in production cycle, widely distributed, high in photosynthesis and high in oil content is adopted as the raw material, and the problem of plant oil raw materials in biodiesel development is solved. Meanwhile, the method has the advantages of simple preparation process, high catalytic efficiency, high oil extraction rate, high product yield and the like, and good basis is provided for industrialization and scale production of the biodiesel.

Preparation and application of microalgae natural dye

Inventor(s):	YU DAOYONG; SONG QI; LI QUAN; GE BAOSHENG; HUANG FANG + (YU DAOYONG, ; SONG QI, ; LI QUAN, ; GE BAOSHENG, ; HUANG FANG)
Applicant(s):	CHINA UNIV OF PETROLEUM (EAST CHINA) + (CHINA UNIVERSITY OF PETROLEUM (EAST CHINA))
Classification:	- international: *C11B1/00*; *C11B1/10*; *H01G9/20* - cooperative:
Application number:	CN20161674927 20160815 Global Dossier
Priority number(s):	CN20161674927 20160815

The invention provides a method for inducing microalgae to generate oil with natural dye, and discloses a preparation method of natural dye suitable for inducing microalgae to

generate oil and a production technology of microalgae natural dye for dye-sensitized solar cells. The method includes the steps that with fast-growing microalgae as the raw material and end application as the guide, natural dye chlorophyllin and a chlorophyllin-copper compound are extracted from fresh microalgae, and then are used for sensitizing TiO2-assmebled solar cells and inducing Chlamydomonas reinhardtii to generate oil. Through cooperation of the microalgae oil generation inducer sodium copper chlorophyllin and the assistant sodium ascorbate, oil generation of Chlamydomonas reinhardtii is promoted; the natural dye prepared with the method is used for sensitizing TiO2-assmebled solar cells, and the photoelectric conversion efficiency reaches 3.1%-4.4%.

LAURIC ESTER COMPOSITIONS

Inventor(s):	DUMMER TIMOTHY [US]; BOND RISHA [US] + (Dummer Timothy, ; Bond Risha)
Applicant(s):	TERRAVIA HOLDINGS INC [US] + (TerraVia Holdings, Inc)
Classification:	- international: ***A61K8/37***; ***C09D9/00***; ***C09K3/00***; ***C09K8/52***; ***C11C3/00***; ***C11D3/18***; ***C11D3/20***; ***C11D7/24***; ***C11D7/26***
	- cooperative: **A61K8/37**; **C07C67/03**; **C09D9/005**; **C09K3/00**; **C09K8/52**; **C11C3/00**; **C11C3/08**; **C11D3/188**; **C11D3/2093**; **C11D7/248**; **C11D7/266**; **C12P7/6436**; A61Q19/10
Application number:	US201615184992 20160616 Global Dossier
Priority number(s):	US201615184992 20160616 ; US201514671894 20150327 ; US201461972026P 20140328

Provided are compositions containing alkyl esters derived from triglyceride oils produced from genetically engineered microalgae. Specific embodiments relate to esters derived from oils with high C10-C12 fatty acid profile. Compositions comprising the esters include cleaning products, completion fluids, work-over fluids, drilling fluids, metal working fluids, lubricants, paints, and inks.

IMPROVED PRODUCTIVITY AND BIOPRODUCT FORMATION IN PHOTOTROPIN KNOCK/OUT MUTANTS IN MICROALGAE

Inventor(s):	NEGI SANGEETA [US]; SAYRE RICHARD THOMAS [US]; STARKENBURG SHAWN ROBERT [US] + (NEGI, Sangeeta, ; SAYRE, Richard, Thomas, ; STARKENBURG, Shawn, Robert)
Applicant(s):	NMC INC [US]; LOS ALAMOS NAT SECURITY LLC [US] + (NMC, INC, ; LOS ALAMOS NATIONAL SECURITY, LLC)
Classification:	- international: ***C12N1/13***; ***C12P19/04***
	- cooperative: **C07K14/405**; **C12N1/12**; **C12N9/1205**; **C12P19/04**; **C12P23/00**; **C12P7/64**
Application	WO2016US36077 20160606 Global Dossier

number:

Priority number(s): US201562171176P 20150604

Phototropin is a blue light receptor, which mediates a variety of blue-light elicited physiological processes in plants and algae. In higher plants these processes include phototropism, chloroplast movement and stomatal opening. In the green alga Chlamydomonas reinhardtii, phototropin plays a vital role in progression of the sexual life cycle and in the control of the eye spot size and light sensitivity. Phototropin is also involved in blue-light mediated changes in the synthesis of chlorophylls, carotenoids, chlorophyll binding proteins. We compared the transcriptome of phototropin knock out (PHOT KO) mutant and wild-type parent to analyze differences in gene expression in high light grown cultures {500 µmol photons m-2 s-1). Our results indicate the up-regulation of genes involved in photosynthetic electron transport chain, carbon fixation pathway, starch, lipid, and cell cycle control genes. With respect to photosynthetic electron transport genes, genes encoding proteins of the cytochrome b6f and ATP synthase complex were up regulated potentially facilitating proton-coupled electron transfer. In addition genes involved in limiting steps in the Calvin cycle Ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO), Sidoheptulose 1,7 bisphosphatase (SBPase), Glyceraldehyde-3-phosphate dehydrogenase (3PGDH) and that mediate cell-cycle control (CDK) were also up regulated along with starch synthase and fatty acid biosynthesis genes involved in starch and lipid synthesis. In addition, transmission electron micrographs show increased accumulation of starch granules in PHOT mutant compared to wild type, which is consistent with the higher expression of starch synthase genes. Collectively, the altered patterns of gene expression in the PHOT mutants were associated with a two-fold increase in growth and biomass accumulation compared to wild type when grown in environmental photobioreactors (Phenometrics) that simulate a pond environment. In conclusion, our studies suggest that phototropin may be a master gene regulator that suppresses rapid cell growth and promotes gametogenesis and sexual recombination in wild type strains.

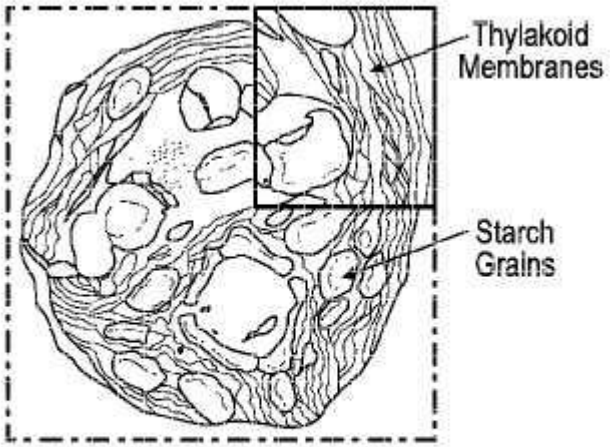


FIG. 11A

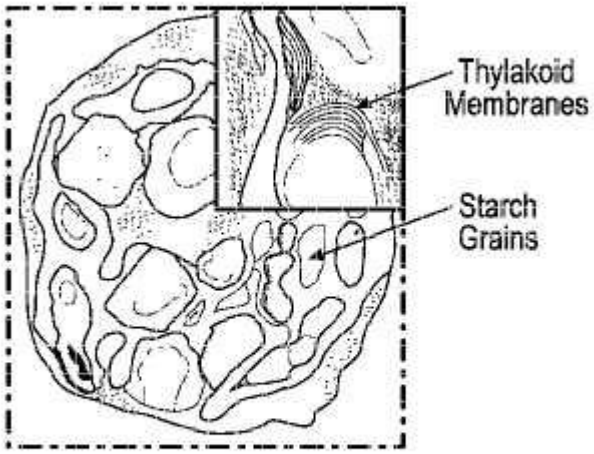


FIG. 11B

Micro-algal oil production method, and application of alga residues as pollutant adsorbent

Inventor(s): GUO WANQIAN; ZHENG HESHAN; LI SHUO; FENG XIAOCHI; REN NANQI + (GUO WANQIAN, ; ZHENG HESHAN, ; LI SHUO, ; FENG XIAOCHI, ; REN NANQI)

Applicant(s): HARBIN INSTITUTE TECHNOLOGY + (HARBIN INSTITUTE OF TECHNOLOGY)

Classification: - *B01J20/24*; *B01J20/30*; *C02F1/28*; *C12P7/64*;

	international: *C02F101/20*; *C12R1/89* **- cooperative:**
Application number:	CN20161656378 20160811 Global Dossier
Priority number(s):	CN20161656378 20160811

The invention discloses a micro-algal oil production method, and an application of alga residues as a pollutant adsorbent, and belongs to the fields of biomass recovery and functional material exploitation and utilization. The problems of low output of oil producing microalgae and low adsorption ability of adsorbents are solved in the invention. The micro-algal oil production method comprises the following steps: 1, carrying out activating culture on the oil producing microalgae; 2, carrying out amplified culture on the above obtained activated algal liquid in a visible light illumination reactor under controlled growth environment illumination intensity, carbon dioxide concentration and growth temperature; and 3, crushing freeze-dried micro-alga powder, extracting oil, and centrifuging the extracted oil to recover alga residues in order to complete micro-algal oil extraction. The freeze-dried alga residue powder is applied as the pollutant adsorbent in water. The micro-algal biological oil with the dry alga weight of 30-50% can be generated through the oil production method, and the alga residue adsorbent can be used to adsorb and remove metals, antibiotics and other pollutants, and has a good adsorption and removal effect.

Method for promoting oil accumulation of microalgae by adding high-concentration organic wastewater into natural seawater

Inventor(s):	PEI HAIYAN; ZHANG LIJIE; HU WENRONG; JIANG LIQUN; HAN FEI; CHENG JUAN + (PEI HAIYAN, ; ZHANG LIJIE, ; HU WENRONG, ; JIANG LIQUN, ; HAN FEI, ; CHENG JUAN)
Applicant(s):	UNIV SHANDONG + (SHANDONG UNIVERSITY)
Classification:	**- international:** ***C02F3/32***; ***C12N1/12***; *C02F101/30*; *C12R1/89* **- cooperative:**
Application number:	CN20161322867 20160513 Global Dossier
Priority number(s):	CN20161322867 20160513

The invention discloses a method for promoting oil accumulation of microalgae by adding high-concentration organic wastewater into natural seawater, belonging to the technical field of microalga biology. The method comprises the following steps: by using natural seawater with 1-10% of high-concentration organic wastewater as a culture medium of the experimental group, carrying out culture under continuous illumination conditions until the microalgae stop growing, and carrying out centrifugal separation to collect the algae. The result indicates that the oil yield of the microalgae cultured in the natural seawater with high-concentration organic wastewater is obviously enhanced, so the method lowers the culture cost of microalgae and is worthy of popularization and use.

Recycle thermal power plant flue gas waste heat and carbon dioxide's device

Inventor(s):	FANG HUI; TAN XIAOGANG; WEN LU; WANG HUAN; LI WEICHENG; SUN DENGKE; NIE LI + (FANG HUI, ; TAN XIAOGANG, ; WEN LU, ; WANG HUAN, ; LI WEICHENG, ; SUN DENGKE, ; NIE LI)
Applicant(s):	DONGFANG BOILER GROUP CO LTD OF DONGFANG ELECTRIC CORP + (DONGFANG BOILER GROUP CO., LTD. OF DONGFANG ELECTRIC CORPORATION)
Classification:	**- international:** ***B01D53/62***; ***B01D53/84***; ***C02F9/14***; ***C10G1/00***; ***C11B1/00***; ***C12M1/00***; ***C12M1/12***
	- cooperative: Y02P20/59; Y02W10/37
Application number:	CN20162138828U 20160224
Priority number(s):	CN20162138828U 20160224

The utility model relates to a circular economy technical field of comprehensive utilization of waste materials, the green production of energy saving and emission reduction, the purpose provides a recycle thermal power plant flue gas waste heat and carbon dioxide's device, including the hydrothermal liquefaction unit of the microalgal culture unit that is arranged in absorbing flue gas carbon dioxide, the algae hydrothermal that will decline liquefaction system oil, waste water degradation unit and the flue gas waste heat utilization unit that the waste water that will liquefy degradation was handled, microalgal culture unit, hydrothermal liquefaction unit, waste water degradation unit loop through the tube coupling, the flue gas coil pipe sets up in photosynthetic bacteria cultivation ware, and the tube coupling is passed through with fan, microalgal culture unit respectively in both ends. The utility model discloses realized simultaneously that flue gas waste heat utilization, carbon dioxide emission reduction, the solid carbon of little algae seal carbon cycle, little algae preparation liquid fuel and wastewater resource and utilizes, can protect the environment, alleviate resource energy shortage, accorded with human sustainable development's demand.

METHOD OF INCREASING FOR BIOMASS AND LIPID CONTENT OF MICROALGAE USING ACORNS

Inventor(s):	CHOI HEE JEONG [KR] + (CHOI, HEE JEONG)
Applicant(s):	CATHOLIC KWANDONG UNIVERSITY INDUSTRY FOUNDATION [KR] + (CATHOLIC KWANDONG UNIVERSITY INDUSTRY FOUNDATION)
Classification:	**- international:** ***C12N1/12***; ***C12P7/64***
	- cooperative: **C12N1/12**; **C12N1/38**; **C12P7/64**; **C12P7/649**; C12N2523/00 more
	default less

CPCNO	**C12N1/12**; **C12N1/38**; **C12P7/64**; **C12P7/649**; C12N2523/00
Application number:	KR20150002697 20150108 Global Dossier
Priority number(s):	KR20150002697 20150108

The purpose of the present invention is to provide a method for increasing biomass and lipid contents in microalgae by using acorn, which massively propagates microalgae using acorn and can further enhance lipid contents in obtained microalgae. According to the present invention, microalgae are produced using acorn so the production of microalgae can be increased. Furthermore, microalgae are produced using acorn so lipid contents in microalgae are enhanced. Accordingly, the production efficiency of biomass can be increased. The method for increasing biomass and lipid contents in microalgae by using acorn comprises the following steps: cultivating microalgae in a nutrient medium; injecting 2-10 g/L of an acorn extract into the cultivated microalgae to grow the microalgae; collecting biomass from the grown microalgae; and extracting a lipid component from the biomass.

Method for producing microalgal oil by using flue gas

Inventor(s):	SHI WENJING; LIAO SHA; GAO DACHENG; SUN QIMEI; LI XIAOSHU; YAO XINWU; FAN YACHAO; WANG LINGMIN + (SHI WENJING, ; LIAO SHA, ; GAO DACHENG, ; SUN QIMEI, ; LI XIAOSHU, ; YAO XINWU, ; FAN YACHAO, ; WANG LINGMIN)
Applicant(s):	CHINA PETROLEUM & CHEM CORP; SINOPEC DALIAN RES INST PETROLEUM & PETROCHEMICALS + (CHINA PETROLEUM & CHEMICAL CORPORATION, ; SINOPEC DALIAN RESEARCH INSTITUTE OF PETROLEUM AND PETROCHEMICALS)
Classification:	**- international:** ***C12P39/00***; ***C12P7/64***; *C12R1/89* **- cooperative:**
Application number:	CN20141730719 20141205 Global Dossier
Priority number(s):	CN20141730719 20141205

The invention discloses a method for producing microalgal oil by using flue gas, wherein the method includes the steps: (1) adding a microalgae culture medium and a scenedesmus obliquus FSH-Y2 seed liquid into a photobioreactor, regulating the pH of the culture system to 10-12, introducing flue gas with the CO2 volume content of 1 v%-5 v%, and culturing for 2-5 days; and (2) regulating the pH value of the culture system to 8-10, inoculating with monoraphidium sp. SS-B1 and ankistrodesmus sp. SS-B7 seed liquids, carrying out mixed culture, introducing flue gas with the CO2 volume content of 5 v%-45 v%, culturing to a stable stage under continuous illumination, and harvesting microalgae cells, wherein the scenedesmus obliquus FSH-Y2, the monoraphidium sp. SS-B1 and the ankistrodesmus sp. SS-B7 are respectively preserved in China General Microbiological Culture Collection Center on

September 11, 2012 and on April 15, 2013 respectively and have the preservation numbers of CGMCC No.6551, CGMCC No.7479 and CGMCC No.7478 respectively. The method improves the tolerance and the solubility of the microalgae culture system on high-concentration CO2, improves the carbon sequestration efficiency, obviously increases the yield of the microalgal oil, and can realize purification of the flue gas.

Method for simultaneously preparing long-chain alkane and arene by taking microalgae oil as raw material

Inventor(s): FU JIE; TIAN QIURONG; LYU XIUYANG; OUYANG PINGKAI + (FU JIE, ; TIAN QIURONG, ; LYU XIUYANG, ; OUYANG PINGKAI)

Applicant(s): UNIV ZHEJIANG + (ZHEJIANG UNIVERSITY)

Classification:
- **international:** ***C10G3/00***
- **cooperative:** Y02P30/20

Application number: CN20161124800 20160304 Global Dossier

Priority number(s): CN20161124800 20160304

The invention relates to a method for simultaneously preparing long-chain alkane and arene by taking microalgae oil as a raw material. The method comprises the following steps: (1) mixing the microalgae oil with water, then, heating for hydrolysis reaction, and performing treatment to obtain C10-C22 fatty acid; (2) adding the C10-C22 fatty acid and a catalyst into a high-temperature and high-pressure reactor together, heating to 280 to 380 DEG C for decarboxylation aromatization reaction for 1 to 7 hours, wherein the catalyst is Pt/C; (3) cooling a reaction product, dissolving with an organic solvent, and filtering to obtain a liquid product and a solid catalyst. According to the method disclosed by the invention, without adding any hydrogen source or solvent, high-yield long-chain alkane and arene, i.e., an important component of aircraft fuel, hard to obtain through other hydrodeoxygenation or Fischer-Tropsch synthesis are obtained from the microalgae oil, and the long-chain alkane and the arene separately reach more than 71.6 percent and 23.1 percent in yield.

Biomass granule fuel taking marine microalgae as main raw material and production method of biomass granule fuel

Inventor(s): WANG PEILEI + (WANG PEILEI)

Applicant(s): LINYI UNIV + (LINYI UNIVERSITY)

Classification:
- **international:** ***A01N65/46***; ***A01P1/00***; ***B01J2/22***; ***C10L5/44***
- **cooperative:** Y02E50/10; Y02E50/30

Application number: CN20161123807 20160307 Global Dossier

Priority number(s): CN20161123807 20160307

The invention discloses biomass granule fuel taking marine microalgae as a main raw material and a production method of the biomass granule fuel and belongs to the field of biomass fuel. The biomass granule fuel comprises Botryococcus braunii, Nannochloropisis oculata, Phaeodactylum tricornutum Bohlin, porphyridium, dried donkey dung, distillers' grains, gutter oil, cotton straw, bean straw, sesame straw, larch sawdust, peanut shells, Jerusalem artichoke straw, sodium carboxymethylcellulose and MgCO3. The biomass granule fuel is simple in technology, low in cost, clean, efficient and easy to ignite, can replace fossil fuel such as coal and the like to be applied to civil fields of heating, cooking and the like or industrial fields of power generating and the like, and has the greater development potential, raw materials are easy to obtain, and nearly zero emission of carbon dioxide is realized.

Noticias de interés general:

Astaxanthin Market Worth 814.1 Million USD by 2022
http://www.prnewswire.com/news-releases/astaxanthin-market-worth-8141-million-usd-by-2022-622074783.html

Eventos y Cursos

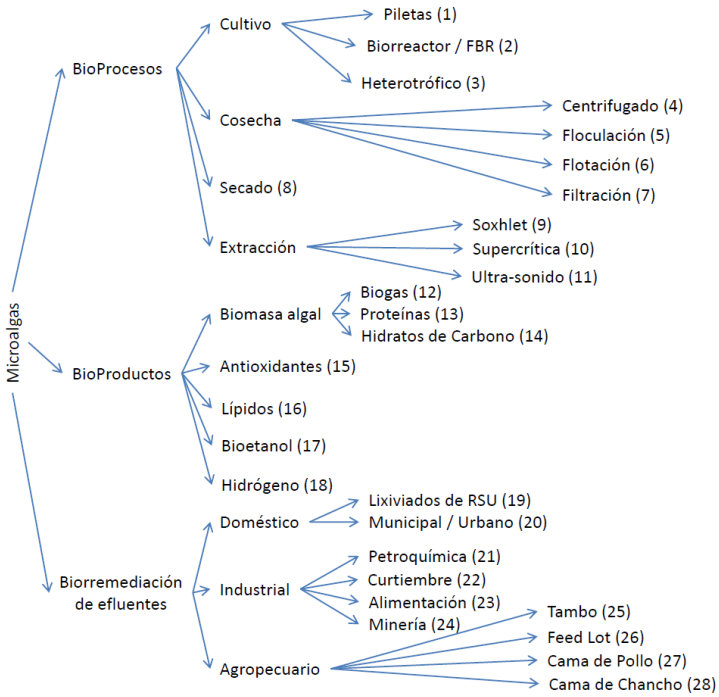
X CONGRESO DE MICRO Y MACROALGAS
Coquimbo, Chile.
19 al 21 de julio de 2017

2017 Algae Biomass Summit
Salt Lake City, Utah, EEUU.
29 de octubre al 1 de noviembre de 2017

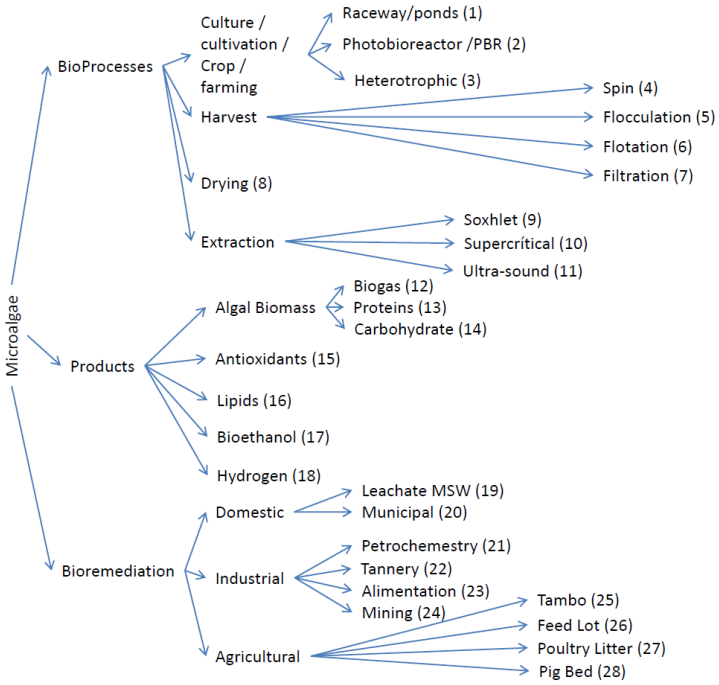
XI CONGRESO DE FICOLOGÍA DE LATINOAMÉRICA Y EL CARIBE y IX REUNIÓN IBEROAMERICANA DE FICOLOGÍA
Santiago de Cali, Colombia.
5 al 10 de noviembre de 2017

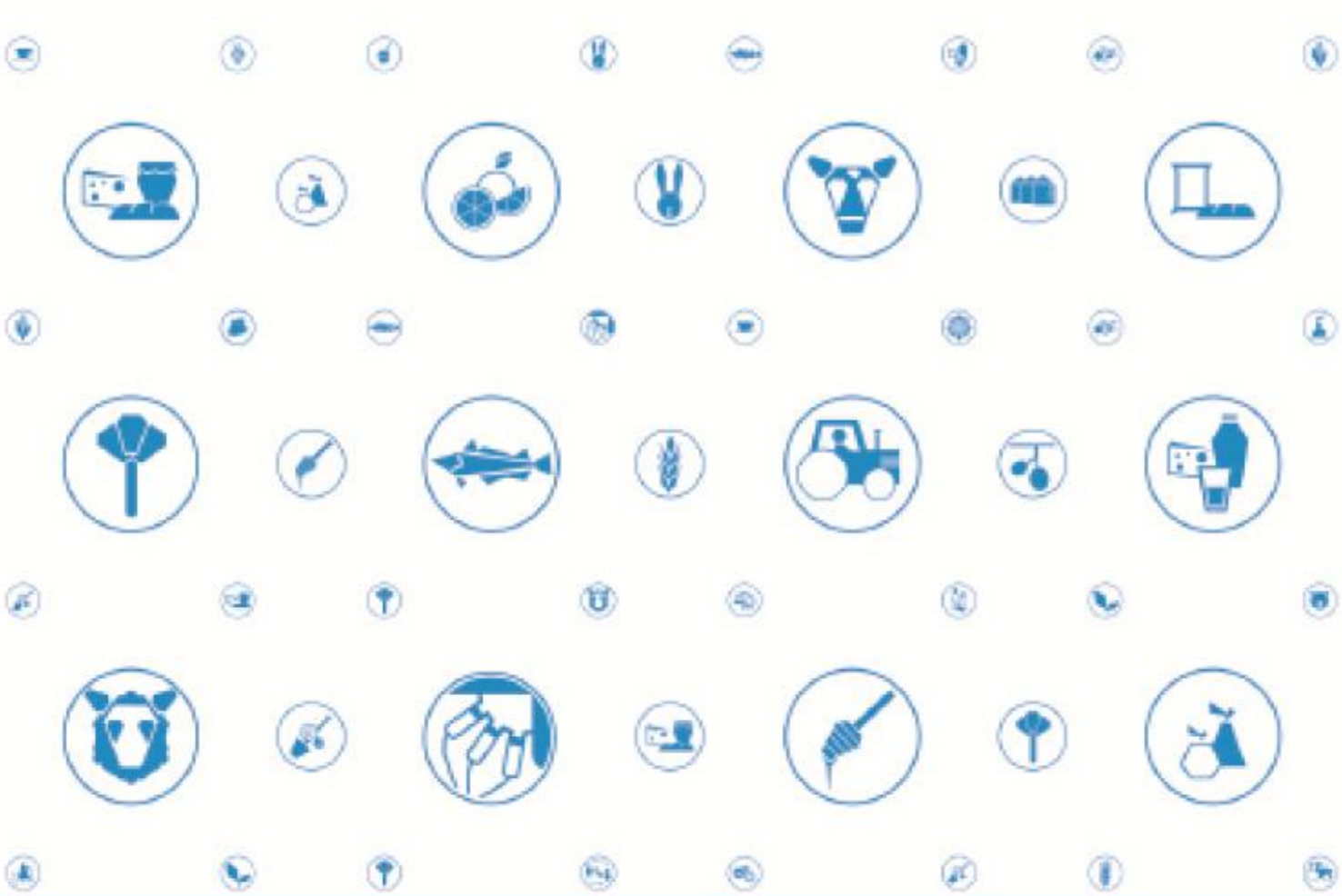
Árbol de categorías

Español



Inglés





TITULO

SUBTITULO