POSSIBILITIES OF ALGAE IN BIOMASS ENERGY AND FOOD PRODUCTION THROUGH GAS EMISSION MITIGATION

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Abstract

Global scarcity and territorial inequalities of resources, diminishing stock-type resources are causes for the economy to change to a sustainable operation. Transformation of CO_2 into useful organic compounds promises economically viable way for these goals. Phototrophic CO_2 biofixation of microalgal species is a promising alternative to other CO_2 sequestration approaches, at the same time producing commercially valuable products. This paper rewievs the possibilities of algal technologies in terms of their products and the effect of filtered and flue-gas CO_2 on algal biomass production.

1. Objective

Global scarcity and territorial inequalities of resources, diminishing stock-type resources are causes for the economy to replace present value chains and technologies for renewable ones. As regards emissions, there are several international protocols of global environmental summits stipulating CO_2 mitigation. Novel carbon capture strategies have to be established in order to reach thses goals. Transformation of CO_2 into useful organic compounds via photosynthesis promises economically viable and sustainable way for these goals.

As Ho et al. [24] summarise the history of algal technologies, microalgae and cyanobacteria that are present on the Earth since the very beginnig [43] with well-established traditions of human utilization [47]. Nevertheless, technologies for algae cultivation exist only since a few decades ago [11]. This is due to the rapid increase in global population from the early 1950s on, that made microalgae and cyanobacteria, which have high protein and nutrients content, good candidates for food enhancement. In addition, microalgae and cyanobacteria have considerable potential for other purposes, including food additives, biofuel, cosmetics and pharmaceuticals. Combinations with other technologies such as biomass energy and agricultural production are also promising [2], [20].

This paper aims to rewiev the possibilities of algal technologies in terms of their products and their CO_2-mitigation ability.

2. Possibilities of algae in biomass production for energy, food and other purposes

As highlighted by Bai [5], energy market has a very considerable share within the fossil energy based global economy, which equals 7 trillion USD in 2008, representing 13% within the global GDP. Oil production and consumption in the world reached 5 trillion litres in 2008. This huge amount is, however, environmentally not sustainable, both in terms of resources and emissions. Nevertheless, its infrastructure (from production through transportation, processing, distribution through consumption) represents an incredibly huge value that is almost impossible to replace in the short term. Thus, invading this nearly infinite market by alternative fuels is a giant market possibility and an environmental necessity, although a difficult economic task to solve.

As regards the economic and social-political relations of fuels, the European Union and Hungary share the same problems [7]: the EU's dependency reaches 55% in energy import and 80 % in oil import, and Hungary has even greater dependency, which is ca. 66% in total energy and near 90% in oil products.

Algae-based biofuels as next generation propellants can be compared to an ideal alternative fuel, which is [7] renewable; economic (compared to products from mineral oil, to other alternative fuels and to other uses of their feedstock); potentially able to fully replace oil; at least partly able to utilize the oil-economy's infrastructure (cars, pipelines, stations). If possible, next generation fuels also eliminates the worries raised by first generation biofuels, in general: causing famine partly directly ("food fed in cars"), partly indirectly (through decreasing food- and feed prices); consuming arable land and causing tropical deforestation; using more energy for their production, as gained by their utilization; having adverse environmental and nature protection effect is, due to industrialized production and special species; resulting in few workplaces because of automated technologies. Algae-based biofuels conform many of these characteristics, except that of economy at present level [5]. However, resources and economic sustainability and overall potential advantages over other sources of other biofuels [4] make algae fuels to the ultimate alternative to petro-diesel [44] in the long term. This is the most important usage type of algal energy, though other uses are also prospective [30].

These all imply the prospectivity and the need for further research results, technology, management, economy and policy enhancemenmts, to mention some important areas of development. The existence of algae containing 30–75% of lipid by dry basis (these can be also called oilgae) [17] present good prospects for algae-biodiesel. However, the cultivation and downstream processing technologies have to be carefully rewiewed and further developed for better efficiency and economy [27].

Considering gas emission mitigation pruposes of microalgal technologies, they do not necessarily contradict to algae-biodiesel production. Investigations effects of flue gas aeration on lipid production in Chlorella sp. MTF-7 [14] have shown, that lipid content have not increased with flue gas aeration compared with CO_2-enriched gas (25%) aeration, but the lipid production was higher, due to increased biomass production.

Algae-based biomass production has advantages compared to traditional crop production [6], since their reproduction is very fast, which can allow a harvest even every week, involving relatively modest capital need because of a continuous operation of the processing plants. paired with excellent light utiliztaion, algae can poduce more biomass per area than dry-land plants (even 150-300 t/ha), at the same time needing no arable land. Instead of using food production resources, algal by-products of biofuel processing can serve as feedstock for food and feed. Moreover, a proper technology instalment can easily be adjusted to the needs of different species and production purposes, e.g., to switch from energy production to feed production, or to produce any type of energy. The fact that also flue gas can be effictecely and safely used for food biomass production is also promising in terms of economy of technologies and safe food supply. A study has revealed that "extending the flue gas treatment prior to the cultivation unit by a simple granulated activated carbon column led to an efficient absorption of gaseous mercury and to the algal biomass composition compliant with all the foodstuff legislation requirements" [19].

In addition to the products listed in Table 1, microalgae have also represent a possible solution to a number of environmental problems, as well as GHG mitigation as waste treatments. Algal technologies are well suited to waste water management [12], combining nutrient removal with biomass and biofuel production. The composition of liquid pig manure is also favorable to algae production [8]. Based on outdoor experiments, Bai et al. [3]

recommend the adaptation of a 12- to 14-day rotation period. An algae farm operated this way requires a relative modest amount of capital while achieving sludge management and energy porocudtcing purposes. This way, a feasible microalgal-CO_2 mitigation model for commercial use can be facilitated (Ono and Cuello, 2006), not only fixing CO_2 effectively, but also converting biomass to different valuable by-products. These includes such is biodiesel, and also lutein and other pigments for health food applications, pharmaceiuticals, cosmetics, even photoluminescent markers for research applications.

Table 1. Purposes and types of algae technologies

Microalgal species	FOOD AND FEED	ENERGY (biofuels)	OTHER (cosmetics, pharma-ceuticals)
Botryococcus braunii/Chlorophyta		[12], [13]	
Chlorella vulgaris / Chlorophyta	[11], [47], [33]	[12]	[23], [50]
Dunaliella salina / Chlorophyta	[36], [47], [28], [16]		[36], [47]
Haematococcus pluvialis /Chlorophyta	[47], [16]		[47], [16]
Isochrysis galbana /Chlorophyta	[37]; [42]		
Lyngbya majuscule / Cyanobacteria	[46]		[46]
Muriellopsis sp. /Chlorophyta	[10]; [16]		
Nannochloropsis spp./Heterokontophyta	[54]	[12], [13]	
Odontella aurita / Bacillariophyta	[42]		[42]
Phaedactylum tricornutum / Bacillariohyta	[51]; [1]	[51]; [1]	
Porphyridium cruentum / Rhodophyta	[22]		[22]
Spirulina (Arthrospira spp.) /Cyanobacteria)	[47], [49], [9], [33], [15]		[47], [49], [43], [33], [15]

3. Possibilities of algae in CO_2 emission mitigation

Greenhouse gases are the radiatively active gaseous constituents of the atmosphere, which contribute to the phenomena of global warming. According to recent studies, carbon dioxide (CO_2) is the most important of them, while methane (CH_4) and nitrouse oxides (NO_x) represent considerably smaller quantities in the atmosphere [29]. Trapping CO_2 through carbon sequestration strategies is therefore a current global environmental issue.

According to Ho et al. (2011) [24], CO_2 emissions stem mainly from power plants burning fossil fuels (e.g., coal, oil, and LNG). Major flue gas components are carbon dioxide, SO_x and NO_x [31]. Besides power plants, other large future possibility is to use algae in the mitigation of transportation emissions [21]. Using flue gas to cultivate microalgae is a promising way of mitigating CO_2 emissions [18], [34] but could suffer the problem with the growth inhibitory effects arising from the presence of high concentrations of NO_x and SO_x. Therefore, isolation of high CO_2-tolerant microalgae is the first step toward the development of a feasible microalgae-based system for CO_2 capture from flue gas [52]. For example, Chiu et al. [14] have used Chlorella sp. MTF-7 that was isolated in laboratory by chemical mutagenesis. Scendesmus species are also reported to suit these purpose [25].

Table 2 shows some literature results on how CO_2 affected algal biomass growth in experiments using CO_2-enriched air and and real flue gases.

Table 1. Purposes and types of algae technologies

Microalgal species	CO_2 (%) [a)]	Tempe-rature (°C)	NO_x/SO_x ($mg\ L^{-1}$)[a)]	Specific growth rate (d^{-1})	Biomass productivity ($mg\ L^{-1}\ d^{-1}$)	Reference
Chlorella sp. MTF-7	2	25	0	1,25	250	[14]
Chlorella sp.	2	25	0	1,23	247	[14]
Chlorogleopsis sp.	5	50	N.D	0,65	40	[39]
Chlorella sp. MTF-7	10	25	0	0,75	150	[14]
Chlorella sp.	10	25	0	0,74	148	[14]
Nannochloris sp.	15	25	0/50	N.D	350	[38]
Nannochloropsis sp.	15	25	0/50	N.D	300	[38]
Chlorella sp.	15	25	0/60	N.D	1000	[32]
Hot spring algae	15	50	N.D	3,00	267	[26]
Chlorella sp.	20	40	N.D	5,76	700	[45]
Chlorella sp. MTF-7	25	25	0	0,95	190	[14]
Chlorella sp. MTF-7	25	25	5/12	1,85	370	[14]
Chlorella sp.	25	25	0	0,93	185	[14]
Chlorella sp.	25	25	5/12	1,15	230	[14]
Chlorella sp. MTF-7	25	25	5/12	1,85	370	[14]
Chlorella sp. MTF-7	25	30	5/12	1,95	390	[14]
Chlorella sp. MTF-7	25	35	5/12	1,60	320	[14]
Chlorella sp. MTF-7	25	40	5/12	1,20	240	[14]
Chlorella sp.	25	25	5/12	1,15	230	[14]
Chlorella sp.	25	30	5/12	1,05	210	[14]
Chlorella sp.	25	35	5/12	0,70	140	[14]
Chlorella sp.	25	40	5/12	0,55	110	[14]
Chlorella sp.	50	35	60/20	N.D	950	[35]
Chlorella sp.	50	25	N.D	N.D	386	[48]
Chlorella sp.	50	25	N.D	N.D	500	[53]
Chlorocuccum littorale	50	22	N.D	0,95	44	[40]

a) Chiu et al. (2011)[14]: flue gas from the coke oven of a steel plant contained approximately (20-)25% CO_2, 4% O_2, 80 ppm NO and 90 ppm SO_2. The flue gas was provided at 0.05 vvm.

5. Conclusions

As the above results have shown, phototrophic CO_2 biofixation using fast-growing microalgal species is a very promising alternative to conventional CO_2 sequestration approaches, at the same time producing commercially valuable products [24]. The potential of microalgae as a source of renewable energy, food an non-food ingredients has received considerable interest, but further optimization of mass culture conditions are needed. [12] Future research has many was to develop these technologies in terms of strains, cultivation, processing as well as system economy, so as to establish and spread economic system variatons, to further develop recently not economic systems and to pave the way for future developments of algal technologies.

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