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Bryophytes Are Potential Biomass Sources for Alternative Energy

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ABSTRACT
Bryophytes are the oldest land plant on the world. Bryophyte places this group between algae and Pteridophyte. Bryophytes exist in a wide variety of habitats. They can be found growing in a range of temperatures, cold arctics and in hot deserts, in a range of elevations sea-level to hilly land, and moisture dry deserts to wet rainforests. The usefulness of bryophytes is relatively unknown to most people. Bryophytes are used for several proposes such as protection from soil erosion, soil formation, water retention, peat, animal feeds, medical uses and energy. Cultivation of bryophytes should be done in large area that can supply of bryophytes enough for industrial purposes. Bryophyte is renewable biomass, cultivation used minerals from waste stream, high CO_2 *fixation as a mitigation of climate change. Uncoming bryophytes are used as a fuel, according to the composition of bryophytes that have similar to the algae composition that included carbohydrate, protein, lipid, acid and minerals. Hydrothermal Liquefaction can be used to proceed bryophyte into bio-oil. Bryophytes are degradable organic substances in the hydrothermal liquefaction process resulted residual solid is called hydrochar, liquid fraction that contain of bio-oil that can be upgraded into fuel, and gaseous product. Peat mosses have been used as a fuel in many Europe countries.*
Kata kunci: bryophyte, cultivation, energy, HTL, bio-oil, conversion

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I. INTRODUCTION

Bryophytes are the second largest group in the plant kingdom with about 25000 bryophyte species[1] and they can be found in any kind of ecosystems.[2] In comparison with higher plants use of bryophytes for human consumption is negligible due to their low caloric value[3] and poor organoleptic properties. Bryophyte was classified into mosses, liverworts, and hornworts. Among them, mosses and liverworts contribute considerably to the biodiversity of terrestrial ecosystems.[4] Studies conducted to better understanding their chemical composition are limited and scattered.[5]

Bryophytes are amphibian plants, which are found in almost all kinds of habitats world-wide, from dry desert to humid rainforest, form hot tropical area to the cold Arctic and from sea level to alpine peak.[6] Bryophytes show high tolerance against various biotic and abiotic stresses.[7] Bryophytes play a remarkable role in maintaining ecosystems because they provide an important buffer system for other plants.[8]

Liverworts as third generation biofuel feedstock have some distinguishable features, such as high photosynthetic efficiency, rapid growth, high lipid content, high carbon dioxide, mitigation efficiency, non-competition with food crops for farmland and less water demand than croplands. Photosyntetic organisms, liverworts are able to capture solar energy and use water and atmospheric carbon dioxide to accumulate biomass in forms of organic ingredients such as lipids.[9]

Bryophyte has almost neglected exploring it’s potential as a raw materials for energy alternative. Bryophytes are an important group of non-vascular land plants and can be classified into tree sub-divisions such as mosses, liverworts, and hornworts.[4] Bryophytes are the second largest taxonomic group in the plant kingdom, but their chemical composition are limited.[5] Bryophytes have about 25000 species[1] and they can be found in any kind of ecosystems.[2]

Bryophytes are pioneer of the land plants, because they are the first plants to grow and colonize the barren rocks and lands. Bryophyte places this group between Algae and Pteridophyte. Bryophyte exist in a wide variety of habitats. They can be found growing in a range of temperatures, cold arctics and in hot deserts, elevations, sea-level to hilly land, and moisture dry deserts to wet rainforests.

I.1 Bryophyte Cultivation

The smallest and possibly most ancient terrestrial plants, bryophytes are an important part of our environment, but in the tropics, there is still much to learn about them. The world of mosses, liverworts and hornworts, collectively known as bryophytes, form a beautiful miniature forest; nonetheless they are often overlooked, due to their small size and lack of colorful flowers. But it is precisely those characteristicsthat make bryophytes incredibly interesting from an evolutionary standpoint.[10]

Many bryophyte are the first ones to appear on open and often nutrient-poor sites where no other plant is able to grow. Gradually, the bryophytes build up an organic layer that is invaded by microorganisms, resulting in changes in the mineral substratum beneath. This increases nutrient avaibility makes the site suitable for invasion by vascular plants. In this way, bryophyte help in succession of plants on bare rocks by becoming pioneer plant community. Most of these bryophytes are highly tolerant to extended period of desiccation.[10] The mosses are also pioneer species on burnt sites. Every year large areas of grassland, and temperate and tropical forests catch fire. The resulting tracts of land provide habitats for the succession of mosses like *Funaria* and *Polytrichum*. Example bryophyte grown as shown in Fig. 1,2.

Fig. 1. Species *Dicranum scoparium* [11]

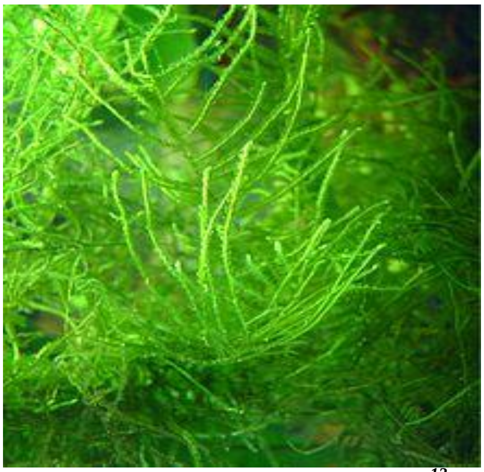

Fig. 2. Spicies *Taxiphyllum barbieri* [12]

The usefulness of bryophytes are relatively unknown to most people.[13] The fisrt used of bryophytes were for environmental benefits, such as ecological uses, horticultural uses, moss industry, household uses, oxygen supply, bryophyte cleaner the atmosfer, and reduce the noise pollution.[14]

1.2 Bryophyte cultivation and harvesting

In vitro cultivation is not only essential for the use of bryophytes in cellular, developmental and molecular research but is also vital to the elucidation of the roles of juvenile stages in reproductive biology. Other important uses include the discovery of new characters for systematics, the conservation of rare taxa and understanding the functional significance of fungal and cyanobacterial association in hepatics and hornworts.[15] The various major objectives necessitating the cultivation of bryophytes in vitro were listed by.[15] The most approapariate condition of culturing were searched concerning mineral nutrition, light and temperature with other invariable conditions.[16]

Bryophytes also play a very important role in the environment: they colonize sterile soils, absorb nutrients and water and release them slowly back into the ecosystem, contributing to the formation of soil for new plants to grow on. As they are not flowering plants, bryophytes reproduce by spores instead of seeds. Deforestation isn't the only human danger. Harvesting of bryophytes for commercial use likewise can endanger the bryophytes.[17] The dispersion capabilities of some species are incredible: their spores even reach other countries and continents.[10]

They are also long thought to be the closest living relatives to the very first terrestrial plants, with ancestors dating as far as half a billion years. However, recent studies tend to present a different hypothesis, although not undermining their evolutionary potential. Bryophytes are harvested, packed, and sold in Mexico City for ornamental use. One family alone (about 10 members) harvested 50 tons (fresh weight) of bryophytes in one collecting season.[17]

The high abundance of large-material forming bryophytes has attracted commercial interests. Bryophytes are traditionally used as ornamentals in family Christmas stalls. A species such as Hylocomium splendens will have a year's growth as a flattish plate and the second year will put up branches which supports another plate. Gradually older plates die off and the living moss will be perhaps three or four years of growth.[18]

TABLE 1. Characteristics of the removed moss packs at the Sierra Chincua sanctuary, Mexico, during the 1996 harvesting season.[19]

	Per day (average)	Per season (29 days)
Number	218.9	6,348.1
Weight (kg)	1,716.1 (7.84)	49,766.9
Volume (m^2)	10.9 (0.05)	316.1
Number of Abies seedlings	383.0 (1.75)	11,109.1

Moss remains the same throughout the year but demand peaks in the spring and early summer for hanging baskets and before Chistmas for festive wreathes. There are two main picking seasons, one from March to June and another from September to Desember.[18]

I.3 Bryophyte Chemical Composition

Further exploration of bryophyte was to explore it's active content such as phenolic acids, flavonoids, triterpenes and alkaloids,[20,21,22] and it's elements content.[5,23] More specifically bryophytes demonstrate antibacteral, antifungal, antiviral activities, antioxidant, antiplatelet, antithrombin, insecticidal, and neurorotective activities.[24]

Table 2. Elemental composition (%) of bryophyte species.[5]

Species	C	H	N	O	C/H
Aulacomnium palustre	43.51	5.72	0.51	50.25	7.606
Polytrichum commune	43.79	6.06	2.02	48.13	7.226
Polytrichum funiperum	41.99	5.89	1.99	50.14	7.129
Ptilium crista-castrensis	42.25	5.68	1.21	50.87	7.438
Pleurozium schreberi	43.15	5.52	1.12	50.21	7.817
Rhytidiadelphus triquetrus	42.47	5.56	1.12	50.85	7.638
Sphagnum girgensohnii	42.04	5.74	0.85	51.17	7.324
Sphagnum magellanicum	42.21	5.55	0.52	51.72	7.605
Sphagnum capillifolium	40.98	5.58	0.42	53.02	7.344
Sphagnum angustifolium	41.78	5.52	0.43	52.27	7.569
Plagiochila asplenioides	41.97	5.63	0.92	51.48	7.455

Elemental content of bryophyte species was shown in Table 2. The ranges in concentrations of basic elements in the studies bryophytes were C: 40 to 43%, H 5.5 to 6%; N 0.4 to 2%; S 0%; O 48 to 53% and C/N ratio from 7.13 to 7.82. There was high similarity in the basic structural molecules of the bryophytes. More comprehensive statement was by Orlov.[25] Bryophytes are mainly composed of hemicelluloses and pectin (30 to 60%), respectively, cellulose content from (15 to 25%). Bryophytes also contain 5 to 10% proteins, 5 to 10% lipids and phenolic compounds. For comparison the algae mainly composed by protein, fat and carbohydrate, 10.76, 4.17 and 62.21 respectively.[26] Lipids content of microalgae as shown in Table 3.

Tabel 3. Lipid content of some microalgae (% dry matter)[27]

Species	Lipids (%)
1.Scenedesmuobliquus	*11-22/35-55*
2.Scenedesmusdimorphus	*6-7/16-40*
3.Chlorellavulgaris	*14-40/56*
4.Chlorellaemersonii	*63*
5.Chlorellaprotothecoides	*23/55*
6.Chlorellasorokiana	*22*
7.Chlorellaminutissima	*57*
8.Dunaliellabioculata	*8*
9.Dunaliellasalina	*14 – 20*
10.Neochlorisoleoabundans	*35 – 65*
11.Spirulinamaxima	*4 - 9*

II. USED OF BRYOPHYTE

Although bryophyte are among the oldest land plants, their usefulness is relatively unknown to most people. Bryophyte are used in pharmaceutical products, horticulture, for household purposes, and also ecologically important.[14] Medical uses and biologically active substances. [28]

2.1 Protection from soil erosion

Bryophytes, especially mosses, form dense mats over the soil and prevent soil erosion by running water. Bryophytes made a bearing the impact of falling rain drops. Bryophytes are holding much of the falling water and reducing the amount of run-off water.

2.2 Soil formation

Mosses are an important link in plant succession on rocky areas. They take part in binding soil in rock crevices formed by lichens. Growth of Sphagnum ultimately fills ponds and lakes with soil.

2.3 Water retention

Sphagnum can retain 18-26 times more water than its weight. Hence, used by gardeners to protect desiccating of the ending during transportation and used as nursery beds.

2.4 Peat

It is dark spongy fossilized matter of Sphagnum. Peat is dried and cut as cakes for use as fuel. Peat used as good manure. It overcome soil alkalinity and increases its water retention as well as aeration,

2.5 Food

Mosses are good source of animal food in rocky and snow-clad areas. Mosses are used as food by chicks, birds and Alaskan reindeer.

2.6 Medical uses

Bryophyte species actually produce broad-range antibiotics.[1] Their usage in surgical dressings, diapers, and other human medicinal applications is well known. One indication of the presence of unique and potentially important pharmaceutically and anti-feedant chemicals in bryophytes is the presence of unique odors. Some tribal communities of Africa, America, Europe, Argentina, Australia used bryophyte to cure hepatic disorders, skin diseases, cardiovascular diseases, and used antipyretic, antimicrobial, wound healing.[8]

Some bryophytes are used medicinally in various diseases. *Decoction of Polytrichum commune* is used to remove kidney and which in the range gall bladder stones. Decoction prepare by boiling Sphugnum in water for treatment of eye diseases. *Marchantia polymorpha* has been used to cure pulmonary tuberculosis.

III. BRYOPHYTES FOR ALTERNATIVE ENERGY RESOURCES

3.1 **Peat moss**

Peat is spongy material formed by the partial decomposition of organic matter, primarily plant material, including dead bryophyte in wetlands such as swamps, muskegs, bogs, fens, and moors. Peatification is influenced by several factors, including the nature of the plants material deposited, the availability of nutrients to support bacterial lift, the availability of oxygen, the acidity of peat, and temperature.

Peat is made up of the remains of dead plants of many kinds. It is the light-brown, dark-brown, or nearly black soil found in wet places, such as bogs, swamps, and margins of ponds and lakes, or in the tundra region, covering the entire surface of the country. After it has been dug and dried, peat may vary from light yellowish brown to nearly black in color and from coarsely fibrous, loose-textured, turfy material to that which is very fine grained or even structureless. [29] It is possible that where the climate is so cold that the ground is always frozen, below a thin surface layer of growing plants.

Within the Europe, there are huge reserves of peat, especially in Finland, Sweden, Estonia and Latvia. In Finland, there are 9.4 million ha of peatland, which is about 30% of the land area. Peat moss has been used as a source of energy in boreal and temperate regions.[9] Presently, most of the harvested peat moss is used for non-fuel application, especially in horticulture as a soil supplement.[30] The main advantages of energy density peat fuel is low cost on unit heating capacity. The logistic scheme of energy dence peat fuel production consists of three level. The first level is peat field. Here the peat raw materials are mining, exposing and collecting in points to storage of raw materials. The second levels are separated, crushed, pressed and is packed. The third is delivering ready fuel to region heat sources.[31]

The preparation of peat for fuel still in use in Ireland, Sweden, and many other parts of Europe where peat is used for domestic purposes.[29] Attempt to briquette peat was made early in the development of the briquetting industry. In this form peat makes an efficient and easily transported fuel and commands a ready sale.

Peat in the form of fine powder, burned under a blast in a specially constructed burner, makes a very efficient fuel. The peat is cut or dug from the bog and, after being left on the surface through the winter to disintegrade, is gathered in a partly air-dried condition. The resulting powder is dark colored, nonabsorbent, and very nearly as heavy as coal.

Attempt to briquette peat was made early in the development of the briquetting industry. In preparing the peat for briquetting, cut peat or pressed peat is air dried to about 40 or 50 per cent of moisture, then ground and screened and artificially dried to about 15 % of moisture; it is then or conveyed to the briquetting press or stored. A step further in the process of increasing the fuel value of peat and of rendering it more transportable is to convert it into coke or charcoal. Energy peat usage will cut down by a rough estimation with 50 to 75 % by volume in all energy peat countries altogether until the end of 2029. [32]

Peat also proceeds by catalytic pyrolysis and get bio-oil.[33] Peat pyrolysis resulted tar and gas.[34] High-temperature microwave pyrolysis of peat obtained liquid and gaseous fuels. [35] Peat produced from Abnali, Barasat north- east in Khulna used Pawer plant about 22-25 MW capacities.[36] Peat moss and miscanthus were hydrothermally carbonized (HTC) to produce hydrochar. The hydrochar was pelletized and can be used as an alternative to coal to produce bioenergy.[37]

3.2 Bryophyte extraction

Plants produce a plethora of natural compounds of medicinal value, included bryophytes.[38] *Leucobryum aduncum* and *Campylopus schmidii* have antioxidant and antibacterial activities. Bodade[39] screening of Bryophyte for antimicrobial activity. Ethanolic, acetone and chloroform are effective solvents to extract all bryophyte.

Seven species of Philippine mosses have potentials of antioxidant.[40] Mosses generate a pleasant sometimes distinct odour in thin fresh state and have been used as traditional medicine for the treatment of broken bones, eczema, eczema, eye diseases, and burns in India and China. [41] Volatile composition of essestial oils of *Polytrichum commune* and *Antitrichia curtipendula* heve antimicrobial and antioxidant activities. [42] The mosses of *Oxytegius tenuirostris, Eurhynchium striatum W.P.Schimper and Rhynchostegium murale Schimp* were extracted with different solvents. Volatiles fraction have antioxidant activities were found.[22] The flavonoid contents of bryophytes have examined in more detail.[21] The results revealed that a range of total flavonoid contents of liverworts were generally higher than those of mosses.

Determine and compare of the chemical composition of bryophytes common in Lavia using analysis to gave better understanding of chemical composition of bryophytes.[5] To evaluate bryophyte's chemical composition and new possible application, to evaluate bryophyte potential usage as a raw food material.[43] The extracts obtained from bryophytes have remarkable antioxidant activity.

Bryophytes contain a high number of biological active compounds, its result come from extraction of secondary metabolite. Microwave-assisted extraction showed the most promising approach to obtain highest yields of extractives.[44]

Research activities to convert bryophyte into bio-oil as an alternative energy was pioneer by Sirohi,[45] the technology used is stil to extract lipid from a species of bryophyte. For instance 0.044 g of lipid was extracted from 8 gram of the bryophyte. By extraction of lipid, just lipid content in the bryophyte will converting into bio-fuel.

3.3 **Hydrothermal Liquefaction**

Exploration alternative energy to substitute fossil energy was very attractive, because of the rapid shortage of fossil energy and the rapid growing of demand. People has a big worry by the supply of energy in the future. There are three categories of biofuels, The first generation was converted edible feedstocks, for example soya beans, wheat corn, rape seed, sugar cane, molasses and carbohydrate into ethanol. Because those materials compete with human needs, the raw material supply will unsafe. The second generation was used lignocellulosic waste to convert into ethanol, but the cost was significantly increase. The third generation was used algae to convert into fuels,[46] while bryophytes have less attention. Recent research shows that mosses contain remarkable and unique substances with high biological activity.[47]

Hydrothermal conversion is a thermo-chemical conversion technique which uses liquid sub- and supercritical water as a reaction medium for conversion of wet biomass and waste stream. Hydrothermal carbonization (HTC) is a thermo-chemical pretreatment process is treated under hot compressed water to produce hydrochar. Hydrochar is a stable, hydrophobic, friable solid produc,[48] aqueous and gas phases.[49] The mechanism for this process mainly decarboxylation, dehydration and polymerization.[50]

Hydrothermal liquefaction (HTL) process is used hot compressed water as the reaction medium, and HTL technology is totally environmentally friendly. HTL can proceed any biomass with high water content directly, without drying and extraction process. Not just extracted lipid, all content of bryophyte such protein, lipid and carbohydrate will distructed in the HTL process into bio-oil. The difference between HTC to HTL just the temperature of operation, HTC operated at temperature in the range of 180 – 280 ^{o}C,[51] while HTL operated temperature of 300-400 ^{o}C.[52]

Biomass can be converted into smaller molecules in the grade of fuels using thermo-chemical processes. The basic reaction mechanisms of biomass liquefaction can be described: (i) depolimerization of the biomass; (ii) decomposition of the biomass monomers by cleavage, dehydration, decarboxylation and deamination; (iii) recombination of the reactive fragments through condensation, cyclization, and polymerization to form new compounds.[53] In the first step cellulose is converted into glucose, hemi-cellulose into xylose, and lignin into polyols.[54]

The degradation of biomass cannot be described by detailed chemical reaction pathways with well-defined single reaction steps. The reason is that biomass is a combination of cellulose, hemicelluloses, and lignin, and these components interact each other, leading to very complex chemistry.[55] The analysis of complex reactions which occur in the liquefaction of biomass, is important to the description of the reactions behavior and to the optimization of the operating conditions.

Sasaki [56] reported that the hydrolysis of cellulose was faster in supercritical or near-supercritical region in which cellulose mainly converted into aqueous oligomers (cellubiose, cellotriose, cellotetraose, cellopentaose, and cellohexaose) and monomers (glucose , fructose). Decomposition and deoxygenation are major reactions, which produce final products containing acids, aldehydes, and aromatic compounds. Further fragmentations and dehydrations lead to the formation of a variety of low molecular weight compounds such as formic acid, acetic acid, lactic acid, acrylic acid, 2-furaldehyde, and also aromatic compounds such as 1,2,4-benzenetriol. [57]

Kabyemela [58] discussed the mechanism of degradation of cellobiose in sub- and supercritical water. Cellobiose was decomposed and hydrolyzed simultaneously resulted glucose fructose as the major intermediates hydrolysis. Glucose and fructose intermediates were further decomposed into pyruvaldehyde, erythrose, 1,6-anhydroglucose and acids, and also oligomers.[59] Yin [60] analyzed that hydrolysis of cellulose in strong alkaline mainly resulted carboxylic acids. For weak alkaline the main product is 5-HMF, In medium alkaline both products of carboxylic acid and 5-HMF occurs

In the whole process, the substances of biomass are first hydrolyzed to small molecule compounds, then further reaction of repolimerization, decomposition and condensation of the intermediates from the different phase may be favored with the increment of reaction temperature and residence time. [61] Carbohydrate is hydrolyzed to produce reduced sugar and non-reduced sugar. Glucose itself reversibly isomerizes into fructose, this is an important reaction since a number studies have confirmed that fructose is more reactive than glucose.[62]

HTL process with bryophyte as a raw materials have conversion into liquid, gas and residual solid.[50] Increase the temperature increased the liquid products, and increased degradation rate of solid. It was similar to the HTL that microalgae as raw material.[63]

Hydrothermal liquefaction of bryophyte was conducted by Sarwono [64] Increase in temperature resulted residual solid decreased from 70.82% to 52.65%, liquid product increased from 16.34 to 27.44%, and gaseous product increased from 12.84 to 19.11%. Increase of substrate load resulted the decreased of the degradation rate. Residual solid increased from 53.37% to 64.27%, liquid products decreased from 15.77 % to 9.07%, and gaseous prouct decreased from 30.86 to 26.66%. The optimum operation condition lies on the temperature of 350 ^oC, resident time of 3 hr, substrate loading rate of 4%.

HTL process to proceed microalgae to produce bio-oil was conducted by many researchers. HTL process to convert *Phaeodactylum tricornutum* on the reaction time of 5 and 15 minutes, temperatures of 275 – 420 ^oC, resulted the highest bio-oil yield 39% was obtained at 350 ^oC and reaction time of 15 minutes.[65] Another researchers have proceeded microalgae in difference operation condition into bio-oil, as shown on Table 4.

IV. CONCLUSION

Bryophytes are olders plants in the planet, they found in any kind of ecosystems. Bryophyte was classified into mosses, liverwort and hornworts.

Bryophytes play a remarkable role in maintaining ecosystems because they provide an important buffer system for other plants. Bryophyte composition is similar to algae that contain elemental C/H ratio around 7. Its consists of organic materials such as carbohydrate, cellulose, hemi-cellulose, protein and oil that are long chain of molecules. Bryophytes used as fuel can be derived from deadly bryophyte as peat mosses. Peat moss was digging from the bog, air dried resulted powder is dark colored, ground and screened and then conveyed to briquetting press and stored. Another proceeds that peat also catalytic pyrolysis to get bio-oil. Bryophytes were extracted into bio-oil. Hydrothermal liquefaction of bryophyte to produce bio-oil, bio-oil is further degradation process or upgrading process thus bio-oil will be degraded into smaller molecule of C_1- C_8 which in the range of fuels.

Table 4. HTL process resulted of bio-oil from different algae spicies and operation conditions

Algae spicies	Operation condition, Temp. (^oC) resident time(τ, min), biomass load (%), catalyst (%)	Optimum condition	Optimum Bio-oil (%)	Ref.
Phaeodactylum tricornutum	275-420, 5-15, None, none	T = 350 ^oC τ= 15	39 wt%	65
Enteromorpha prolifera	220 – 320, 30, -Na_2CO_3	T= 300^oC, τ=30	23 wt%	

		C=5wt% Na_2CO_3		66
Nannochloropsis sp	250 – 400, 10-90, 5-35%, -	250 - 400	36 – 46 wt%	67
Nannochloropsis sp	300-600, 1-5	600 ºC	84%	68
Spirulina	300, 30		32,6%	69
Chlorella pyrenoidosa and spirulina platensis	200 – 320, -	280 - 320	35-40 %	61
Chlorella pyrenoidosa	200 – 350, 10-90, 10-30, -	300 ºC, 60 min	20 wt %	62
Nannochloropsis gaditana and Scenedesmus almeriensis	300 – 375, 5 - 15	-		70
Duckweed	270-380, 10-120, 0-50, K_2CO_3	350-380, 10-20 load.25%, cat,0-5%	20%	71
Chlorella pyrenoidosa	280, 120, 30, ethanol-water	280, 120 min	57,3 wt %	72
Chlorella vulgaris	250-370, 15,water, NiMo/Al_2O3	350, 15	36.2	73
Nannochloropsis sp	400, 1-8 h, 5-80 wt%, 5% Pd/C	400, 4 h, -, 20%	83%	74
Chlorella pyrenoidosa	400, 1 h, - Pt/ϒ-Al_2O_3 0-40 wt%,	400, 1h, 1% cat.	70 wt% treated oil	75
Nannochloropsis sp *Pavlova*	250-350, 60, 14 wt%	350	48.67 wt% 47.05 wt%	76
Tetraselmis sp.	310-370, 5-60, 16% w/w	350, 5	65 wt%	77

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