Bioresource Technology 135 (2013) 142–149

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Biorefinery of microalgae for food and fuel

Marieke Vanthoor-Koopmans [a,b], Rene H. Wijffels [a,*], Maria J. Barbosa [c], Michel H.M. Eppink [a]

[a] Wageningen University, Bioprocess Engineering, P.O. Box 8129, 6700 EV Wageningen, The Netherlands
[b] Universidad Autónoma de Querétaro, Biosistemas, Facultad de Ingeniería, Cerro de las Campanas, Querétaro, Querétaro, Mexico
[c] Wageningen University and Research Centre, Food and Biobased Research, P.O. Box 17, 6700 AA Wageningen, The Netherlands

ARTICLE INFO

Article history:
Available online 5 November 2012

Keywords:
Microalgae
Biorefinery
Protein
Lipids
Cell disruption

ABSTRACT

Microalgae are a promising source for proteins, lipids and carbohydrates for the food/feed and biofuel industry. In comparison with soya and palm oil, microalgae can be grown in a more efficient and sustainable way. To make microalgae production economically feasible it is necessary to optimally use all produced compounds. To accomplish this focus needs to be put on biorefinery techniques which are mild and effective. Of the techniques described, Pulsed Electric Field (PEF) seems to be the most developed technique compared to other cell disruption applications. For separation technology ionic liquids seems most promising as they are able to both separate hydrophobic and hydrophilic compounds. But additional studies need to be evolved in the coming years to investigate their relevance as novel cell disruption and separation methods. We propose a complete downstream processing flow diagram that is promising in terms of low energy use and state of the art knowledge.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

Microalgae have been of major interest for producing biofuels in de last decade. Recently, development and focus was changed towards the use of microalgae in the food, feed, chemical and pharmaceutical sector as well. Microalgae contain high amounts of lipids, proteins and carbohydrates, which all can be used for different markets. For biofuels only microalgae production appears to be too costly (Wijffels and Barbosa, 2010), one of the main bottlenecks in algae production is the amount of energy used in the whole process and the investment costs (Norsker et al., 2011). Microalgae are grown in large water volumes requiring mixing and for harvesting concentrating is needed, these are very energy-intensive processes. Moreover downstream processing is one of the most influential parameters for high the production costs (Delrue et al., 2012). Most microalgae species have a tough cell wall, which needs to be cracked before being able to extract the product of interest, again an energy-intensive process. When exploiting the whole potential of microalgae ingredients many different products can be obtained simultaneously and the market value will be higher than the production costs (Wijffels et al., 2010). Therefore focus should be put on maximal exploitation of the microalgal biomass while minimizing energy use.

Lipids and proteins are the largest fractions of the microalgae and globally the need for lipids and proteins is rising, carbohydrates are normally a minor part except for a few algae species (Carioca et al., 2009). Lipids can be used as a source for biofuels, as building blocks in the chemical industry and edible oils for the food and health market. The purified proteins can be used in the food, feed, health and bulk chemical market and carbohydrates for producing ethanol and chemicals (Radakovits et al., 2010; http://www.oilgae.com/algae/pro/eth/eth.html). Several studies have focussed on the use of microalgal product for different applications successfully (Chen et al., 2011; Ginzberg et al., 2000; Lu et al., 2004; Mandal and Mallick, 2009). However all these studies focussed on obtaining one specific product from the biomass and therefore extraction methods were only developed for one specific product. This mostly means that the other available and valuable components in the microalgae were lost.

To be able to exploit the complete biomass of produced microalgae it is necessary to use mild extraction techniques. Several commonly used lipid extraction techniques will harm and denature the protein fraction. Conventional extraction and separation techniques, e.g. bead milling, homogenizers, high pressure, heating, osmotic shock and chemicals, are focused on obtaining one product while damaging the other fractions. Biorefinery is a facility that integrates biomass conversion and separation, in which the objective is to obtain several fractions by using mild separation. Biorefinery will be necessary to obtain different types of products from one source. The conventional techniques, like e.g. the use of chemicals or very high pressure, are proven technologies in the downstream processing industry but nowhere near mild and mainly focused on one product, the biorefinery techniques appropriate for mild extraction are relatively new and should therefore be studied thoroughly before commercial use is possible. This

* Corresponding author.
E-mail address: rene.wijffels@wur.nl (R.H. Wijffels).

0960-8524/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biortech.2012.10.135

paper will focus on biorefinery of microalgae, the possible bottlenecks it implies and the markets it can replace or add onto. The main focus is put on the isolation of proteins and lipids as these are the largest fractions that microalgae contain, however other fractions like carbohydrates and pigments will add significant value to the total production process when separated as well. In the future these products are also necessary to study.

2. Current European lipid and protein market

As the biggest fraction of microalgae consist of lipids and proteins the market possibilities of these two products are explored and described in this paper. However, microalgae contain more valuable products such as carbohydrates and pigments. Carbohydrates such as starch or glycogen (cytoplasm) and cellulose (inner cell wall), which are ideal components for producing ethanol and chemicals (Radakovits et al., 2010). Pigments as chlorophyll can be used as anti inflammatory and wound healing additive to pharmaceuticals, carotenoids reduce the risk of cancer, and astaxanthin is a powerful antioxidant (Christaki et al., 2011). These higher valuable products make microalgae even more attractive as food and feed additives.

Microalgae oils and proteins have the potential to replace and add to the current oil and protein markets. Globally the demand is rising due to the rising population. Therefore it is necessary to find sustainable sources of lipids and proteins. The energy and food market demands high quality products at large quantities. The major imported sources for lipids and proteins in Europe are palm oil and soybeans and cake of soybeans (www.faostat.fao.org). Both these sources lead to deforestation in their region of origins (Lima et al., 2011; Wicke et al., 2011), thus further increasing the production of these crops is highly unwanted. Alternative sources for biofuels, vegetable oils or proteins derived from terrestrial crops, e.g. maize, sugarcane, rapeseed, contribute to water scarcity, forest devastation and they impose pressure on the food market (Timilsina et al., 2012). Algae have much higher areal oil productivities and therefore less area will be necessary to produce similar quantities (Mata et al., 2010). Moreover microalgae are not bound to arable land and can be grown in sterile places or even on the sea. Therefore, microalgal production is not competitive with other food production sources and a sustainable source for lipids and proteins.

Ninety percents of global palm oil production and trade comes from Asia, more specifically Malaysia and Indonesia (Thoenes, 2009). A total amount of 6.8 million tonnes of palm oil is imported in Europe, this corresponds to 17 million tonnes of microalgal biomass containing 40% lipids. In 2010 soy beans were mainly imported from Brazil (45%), USA (22%) and Paraguay (19%). The soybeans are mostly imported into The Netherlands (20%), Germany (19%) and Spain (18%) where they are processed and mostly further exported as soy oil or soybean meal towards other countries in and out of Europe (http://comtrade.un.org/db/dqBasicQuery.aspx). Soy oil is the main competitor with palm oil but its total market is much smaller. Soybean meal is also imported into Europe, again The Netherlands and Germany are the main receivers, 24% and 20% respectively. A total amount of 6.5 thousand tonnes of soy bean meal is imported into Europe, which is neglectable, in respect to protein, to the total amount of soybean imported, less than 0.2%. The total amount of soy beans imported in Europe is 7.5 million tonnes, containing 40% protein this means 3 million tonnes of protein. This corresponds to 10 million tonnes of algal dry weight having a 30% protein content. Producing 17 million tonnes of microalgae as a lipid source generates sufficient biomass for the necessary protein production if both products can be separated efficiently. 17 million tonnes of algae can be grown, considering a production of 50 tonnes per Ha per year, on 340.000 Ha land, which is as big as 0.7% of the total area of Spain. These numbers show that Europe does not need to be dependent on other continents for its production of lipids and proteins. Moreover, extension of production for biofuels will also be possible when the demand will rise.

3. Lipid and protein quality

To replace the current oil and protein market not only the quantity but also product quality is important. Edible oils and proteins have a nutritional and functional property in foods, such as taste, structure and stability. These functionalities should be considered when replacing the current sources. For most applications, oil present as triacylglycerides (TAGs) is preferred. These TAGs are widely present in different species of microalgae. TAGs are used to store fatty acids under stress conditions (Hu et al., 2008). When stress conditions, e.g. nutrient depletion, pH changes, high salinity, are applied during microalgal cultivation, accumulation of fatty acids were found in TAGs up to 50% of total biomass (Hu et al., 2008). Moreover, algae contain the two essential fatty acids, EPA (C20:5) and DHA (C22:6) and other omega 3 fatty acids that most other crops do not contain. These essential fatty acids are necessary in human and animal metabolism even though they are not able to synthesize these fatty acids themselves. Therefore it is very important to obtain EPA and DHA from food sources. Fig. 1 shows a comparison of fatty acid composition of different algal species and palm oil. Here can be seen that algae oil contain the same fatty acids as palm oil and have a more diverse range scale of fatty acids, moreover they contain more healthy unsaturated fatty acids.

In terms of proteins, the amino acid content is the major quality factor. 20 amino acids exist of which 8 are essential. Human and animals require these essential fatty acids sufficiently in their nutrition. In animal feed soya and maize are mostly used as a feed source. These crops do contain the complete range of amino acids, however not always in the right ratio. Addition of specific amino acids, such as methionine and lysine, in the chicken branch increases growth rate (Lima et al., 2008), however this is costly. Different types of algae contain different amounts of the essential amino acids and therefore selecting the right species for specific applications can lower the costs in animal production. Fig. 2 shows the comparison between soya and three different species of algae in their essential amino acid content. It is shown that a balanced diet can be made using algae instead of or in combination with soya.

To achieve feasible algae production first focus should be put on improving the production efficiency and with that lowering production costs. Moreover the produced algae should be used to obtain both the oil and the protein fraction from the same biomass, therefore biorefinery is necessary. Biorefinery used for microalgae is not yet developed, in this review the potential of applying different biorefinery techniques in the field of microalgae is described. Advances made so far for microalgae and other fields are discussed.

4. Biorefinery

Biorefinery techniques are necessary to exploit all products produced by microalgae after cultivation. The main bottleneck is to separate the different fractions without damaging one or more of the product fractions. Technologies to overcome these bottlenecks need to be developed, and they should be applicable for a variety of end products of sufficient quality at large quantities. For that, the developed techniques should be mild, inexpensive and low in energy consumption. First focus in obtaining the products should be on cell disruption to release the products or to make them available for extraction. When the products are released from the cells,

Download English Version:

https://daneshyari.com/en/article/7083116

Download Persian Version:

https://daneshyari.com/article/7083116

Daneshyari.com