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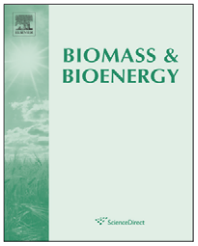

Biofuel potential production from the Orbetello lagoon macroalgae: A comparison with sunflower feedstock

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ABSTRACT

The diversification of different types and sources of biofuels has become an important energy issue in recent times. The aim of this work is to evaluate the use of two kinds of renewable feedstocks in order to produce biodiesel. We have analyzed the potential production of oil from two species of macroalgae considered as waste coming out from a lagoon system involved in eutrophication and from sunflower seeds. We have tested oil extraction yields of both feedstock. Furthermore, a comparison has been carried out based on the emergy approach, in order to evaluate the sustainability and environmental performance of both processes. The results show that, under present conditions, considering oil extraction yields, the production of oil from sunflower seeds is feasible, because of the lower value of transformity of the final product with respect to macroalgae. On the other hand, the results demonstrate that with improvements of oil extraction methodology, macroalgae could be considered a good residual biomass usable for biofuel production.

1. Introduction

In the last 10 years many studies have been conducted on biofuels, pure or blends, for substituting a meaningful share of fossil fuels, in order to reduce GHG emissions and for achieving efficiency and a certain degree of sustainability [1]. The use of biomass to produce biofuels and their benefits are well known [2]. Biodiesel has gained considerable attention as the need to develop alternatives to traditional diesel fuel increases [3]. Biofuels have shown their best applications on the local scale; in fact, it is difficult to produce them for world supply, because of the excessive need for land. Indeed, a production from residual biomass is a feasible option in order to increase the sustainability if emergy-based analysis and other approaches indicate favorable results. The attention should be centered on the feedstocks (oilseed crops, vegetable exhausted oil, animal fats) because of their differences in economic, energetic, and ecological costs [4–6]. In particular, the use of biomass that is not particularly useful for other purposes (food, fibers, etc.) should be pursued. The research should involve not only existing renewable sources available from land but also those coming from aquatic systems. During the last years there have been few attempts to study and estimate the real feasibility and sustainability of algal biomass utilization [7] in order to produce biodiesel. Some works focus on the use of different species of microalgae [8–10] because of their high oil yield with respect to oleaginous plants. After land-based biomass (sunflower, rapeseed), the possibility has been taken in consideration to use spontaneous macroalgae because they can be considered as a residual biomass ready to use for energy purposes. The aim of this work is to study and estimate the potentiality and

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sustainability of the use of two species of macroalgae in order to produce oil to generate biodiesel. A comparison between macroalgal oil production and one of the most common feedstocks (in land), sunflower, has been made on the basis of an emergy evaluation in order to establish the relative level of sustainability of these two kinds of renewable feedstocks.

2. Materials and methods

2.1. *Macroalgae system*

Orbetello lagoon is located in southern Tuscany, Italy (42°25′ and 42°29′ lat. N and 11°10′ and 11°17′ long. E), covers a total area of 25.25 km^2 and is divided in two communicating basins [11] having 1 m average depth (Fig. 1). The system is an important site for fish-farming activities and since approximately 20 years ago the entire lagoon has been involved in an increased flow of nutrients (nitrogen, N and phosphorus, P) that have led the system to a certain level of eutrophication. N and P flows originate from domestic treatment plants, urban phytotreatments, land-based fishfarm outflows, eastern fish-farm phytotreatment outflows. In recent years there has been an excessive macroalgal growth [12–14] that has caused serious problems to the entire ecosystem. Two actions have been undertaken to reduce the ecological impact: the installation of 10 pumps in order to increase water exchanges between the sea and the lagoon, and the harvesting of macroalgal biomass. This last activity is executed every year from June to November by 4 boats collecting approximately 40 t per day of two dominant species: *Gracilariopsis longissima* (Rhodophyceae, 60%) and *Chaetomorpha linum* (Ulvophyceae, 40%). *G. longissima* (S.G. Gmelin) Steentoft, L. Irvine and Farnham occurs in European Atlantic coasts, from northern Iberian Peninsula to British Isles and in the Mediterranean Sea [15], is high up to 45 cm, consisting of subulate erect axes, slightly constricted basally, irregularly branched, sometimes proliferous from break zone, joined in a caespitose base. This red macrophyta contain in their cell walls and intercellular matrices one of the main gelling carbohydrate used in the hydrocolloid industry [16]. *G. longissima* is epilithic in the lower eulittoral or in tide pool, often associated with sand cover, also present in drift materials. *C. linum* (O.F. Muller) Kutzing is a cosmopolitan species. The thalli of this green algae have a siphonocladous level of organization, with thick unbranched filaments made of multinucleate cells. The cell wall has an outer lamellar part mainly made of highly crystalline cellulose and an inner amorphous matrix made of a complex branched polymer of arabinose and galactose, with some xylose. It lives as unattached form in both estuarine systems and coastal lagoons subject to eutrophication [17].

The collection is estimated in 5000 t (wet basis 70% moisture content) per year of algae that are transported and confined in a landfill, with an annual cost of approximately €600,000 [18].

Attempts have been made to use these great quantities of biomass, such as the production of paper and agar, but both have failed because of low yield or quality of final products.

2.2. *Macroalgae collection and oil extraction*

Two samples of *C. linum* and *G. longissima* were collected in October 2006 and processed in laboratories in order to evaluate the lipid extraction yield. Triplicate samples were prepared for each algae species and lipids were extracted by a slightly modified Bligh and Dyer procedure (Fig. 2) [19]. Ground tissues were extracted with chloroform and methanol (2:1) for 20 min by orbital shaker and then chloroform and water (1:1) were added for 10 min in an orbital shaker; the first extracted phase was filtered by filter paper. The residue was extracted three times with chloroform and filtered. Organic phases were collected, evaporated to dry in pre-weighted vials, and the total lipid content was weighed. Results were expressed in mg g^{-1} fresh weight. In order to report laboratory data at the industrial scale, we simulated a small plant (Fig. 3) for oil extraction, composed by three steel reactors working at ambient temperature and pressure, with solvent chemical extraction, separation, and with a solvent-recovery phase, taking into consideration the energy requirement. In this way,

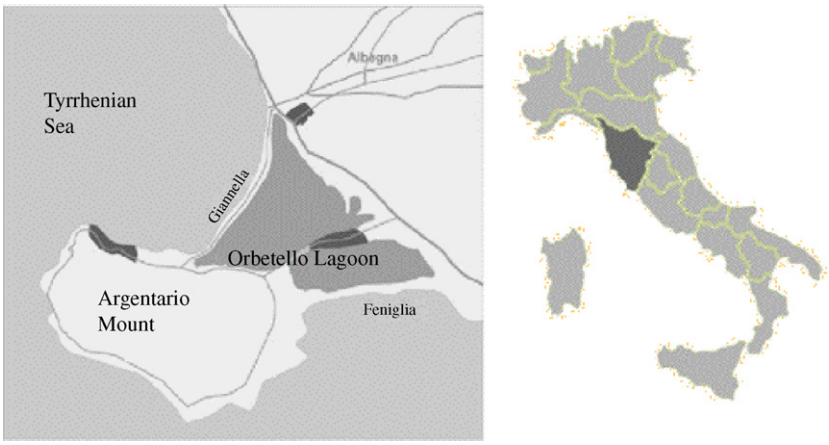

Fig. 1 – Localization of the Orbetello lagoon.