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"Solvent-free" ultrasound-assisted extraction of lipids from fresh microalgae cells: A green, clean and scalable process

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ABSTRACT

In order to comply with criteria of green chemistry concepts and sustainability, a new procedure has been performed for solvent-free ultrasound-assisted extraction (UAE) to extract lipids from fresh *Nannochloropsis oculata* biomass. Through response surface methodology (RSM) parameters affecting the oil recovery were optimized. Optimum conditions for oil extraction were estimated as follows: (i) 1000 W ultrasonic power, (ii) 30 min extraction time and (iii) biomass dry weight content at 5%. Yields were calculated by the total fatty acids methyl esters amounts analyzed by GC–FID–MS. The maximum oil recovery was around 0.21%. This value was compared with the one obtained with the conventional extraction method (Bligh and Dyer). Furthermore, effect of temperature on the yield was also investigated. The overall results show an innovative and effective extraction method adapted for microalgae oil recovery, without using solvent and with an enable scaling up.

1. Introduction

In recent past years, stimulated by that international energy crisis, research projects on alternative and renewable energies including the concept of producing biofuels from the intensive culture of microalgae, as a third-generation biofuel, have been proposed. This research is specially aimed at facilitating the transition to a low-carbon economy with an emphasis to more diversified energy resources and encouraging investments in sustainable sources. The concept to harness energy released by microalgae seems to be increasingly less marginalized for microalgae have been estimated as very good candidates for fuel production (algaefuel). Their main advantages are their higher photosynthetic efficiency, higher biomass production and faster growth, compared to other energy crops (Mata et al., 2010). Microalgae can be produced in large scale on non-arable lands and do not need potable water to grow. Consequently, there is no competition with food production for a growing human population (Singh and Gu, 2010).

A few microalgae strains are known to contain high level of lipids, and they represent a great interest in the research of sustainable sources for biodiesel production. The lipid and fatty acid amounts of microalgae differ according to the culture conditions. For instance, in conditions of nitrogen starvation, some species can accumulate high amounts of triacylglycerides (TAGs), the major feedstock for biodiesel production (Scott et al., 2010).

Lipids extraction process from dry or wet microalgae biomass and its efficiency represent an important key step in the process of biodiesel production. So it is essential to find an extraction one with an efficient device to increase the lipid extraction yield (Lee et al., 2010; Mercer and Armenta, 2011). Various methods have already been used for this purpose (Ranjan et al., 2010), most of them being assisted with solvent, such as Soxhlet extraction with *n*-hexane (Halim et al., 2011), Bligh and Dyer method with a chloroform/methanol solvent mixture (Bligh and Dyer, 1959), supercritical fluid extraction with CO_2 (Andrich et al., 2005) or methanol (Patil et al., 2010). However, for other authors, processes do not necessary require this solvent assistance, they use bead mills (Richmond, 2004), expeller press procedure, extraction with enzyme (Sander and Murthy, 2009), microwave assisted pyrolysis extraction (Du et al., 2011), ultrasound and microwave assisted extractions, pulsed electric field and hydrothermal liquefaction (Brown et al., 2010). Compared to traditional chemical methods involving solvent addition (usually toxic chemicals such as benzene, ether and hexane), solvent-free extraction is often a more ecologic (in terms of sustainable development) and a more economic process, indeed, it need no supplementary energy to separate phases and to eliminate the solvent if no final product recirculation system exists. At last it avoids the risk of medium contamination.

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