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A novel process for enhancing oil production in algae biorefineries through bioconversion of solid by-products

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ABSTRACT

This paper focuses on a novel process for adding value to algae residue. In current processes oleaginous microalgae are grown and harvested for lipid production leaving a lipid-free algae residue. The process described here includes conversion of the carbohydrate fraction into glucose prior to lipid extraction. This can be fermented to produce up to 15% additional lipids using another oleaginous microorganism. It was found that *in situ* enzymes can hydrolyze storage carbohydrates in the algae into glucose and that a temperature of 55 °C for about 20 h gave the best glucose yield. Up to 75% of available carbohydrates were converted to a generic fermentation feedstock containing 73 g/L glucose. The bioconversion step was found to increase the free water content by 60% and it was found that when the bioconversion was carried out prior to the extraction step, it improved the solvent extractability of lipids from the algae.

1. Introduction

There is a growing interest in biofuels as a sustainable and renewable option. Amongst these technologies oils produced by algae is a promising technology due to the amount of oils produced which is much higher than any other terrestrial crops used at the moment for biodiesel production (Schenk, 2008). According to Zeng et al. (2011) an average biodiesel productivity of 3.3 kg m^{-2} $year^{-1}$ can be obtained from a microalgae plant. Algae not only grow and produce oils much faster than plants, but they also do not compete with food crops for land surfaces nor with fresh water; many species of microalgae can grow in brackish or seawater. They also fix atmospheric CO_2 into useful biomass. Currently, the microalgae industry is developing and efforts are being made to produce large amount of oils for biofuel production (Chisti, 2007).

In order to produce biofuels, microalgae species such as diatoms producing large amounts of lipids in short periods of time are of particular interest. They can accumulate lipids in the range 20–50% of dry cell weight (Chisti, 2007). However, for the microalgal biofuel industry to develop, the algae residue remaining after lipid extraction needs also to be addressed. This biomass still contains a significant fraction of carbohydrates and proteins and is normally sold as fish meal (Thurmond, 2011). Unfortunately, a recent review has drawn attention to the fact that non-starch polysaccharides in these residues remain indigestible and cannot be used as an energy source by fish because they do not produce β-glucanases or β-xylanases (Sinha et al., 2011). Moreover, the addition of non-starch polysaccharide to the diet of monogastric animals such as salmon has a negative impact on growth. It would therefore be desirable to convert the carbohydrate fraction of the solid by-product and thereby enhance its value as fish meal.

It is known that microalgae can store both carbohydrates and lipids as food reserves for periods of starvation (Bacic et al., 2009). Carbohydrates have been targeted for ethanol production because of the fast growth of algae. For instance, *Chlamydomonas* biomass can contain around 45% starch, which can be hydrolyzed using commercial enzymes (α-amylase and amyloglucosidase). An ethanol fermentation based on this hydrolysis provided 235 mg ethanol/g algae (Choi et al., 2010). In another study, *Chlamydomonas* biomass with 60% carbohydrates (of which 35% was starch) was hydrolyzed using 3% sulphuric acid at 110 °C for 30 min which released glucose at 58% w/w and the ethanol fermentation provided a yield of 29% from algal biomass (Nguyen et al., 2009). Other papers have used anaerobic digestion or hydrogen fermentation to convert lipid-extracted microalgal biomass residues into methane and hydrogen, respectively. Methane yields in the range 0.2–0.5 m^3/kg volatile solids (Briand, 1997; Morand, 1999) and hydrogen yield of 30 L/kg volatile solids (Yang et al., 2011) have been reported in the literature.

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