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Research review paper

Oleaginous yeasts for biodiesel: Current and future trends in biology and production

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ABSTRACT

Production of biodiesel from edible plant oils is quickly expanding worldwide to fill a need for renewable, environmentally-friendly liquid transportation fuels. Due to concerns over use of edible commodities for fuels, production of biodiesel from non-edible oils including microbial oils is being developed. Microalgae biodiesel is approaching commercial viability, but has some inherent limitations such as requirements for sunlight. While yeast oils have been studied for decades, recent years have seen significant developments including discovery of new oleaginous yeast species and strains, greater understanding of the metabolic pathways that determine oleaginicity, optimization of cultivation processes for conversion of various types of waste plant biomass to oil using oleaginous yeasts, and development of strains with enhanced oil production. This review examines aspects of oleaginous yeasts not covered in depth in other recent reviews. Topics include the history of oleaginous yeast research, especially advances in the early 20th century; the phylogenetic diversity of oleaginous species, beyond the few species commonly studied; and physiological characteristics that should be considered when choosing yeast species and strains to be utilized for conversion of a given type of plant biomass to oleochemicals. Standardized terms are proposed for units that describe yeast cell mass and lipid production.

Contents

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Introduction

The purpose of this review is to provide a broad perspective on use of yeast-derived oils for biodiesel production. Topics covered in depth in other publications are introduced to provide perspective, and readers are directed to other publications and reviews for more details. Topics discussed in particular detail in this review include technologies developed in the early research and industrial production of yeast lipids, the taxonomic diversity of oleaginous (high-oil) yeasts, and a comparison of industrially relevant characteristics of a broad range of oleaginous yeast species.

Transportation is the fastest growing energy sector, and the second largest energy consuming sector in the U.S. (28%) after electric power (40%) (US Energy Information Administration, 2013). Alternatives to petroleum for liquid transportation fuels are being sought due to global concerns over climate change, energy security, and impending depletion of petroleum reserves. Biodiesel is highly degradable, non-toxic, renewable and sustainable. It has similar combustion properties to petroleum diesel, is a drop-in replacement fuel for existing diesel vehicle and boiler engines without major modifications, and is compatible with current fuel infrastructure. Biodiesel produces very low sulfate emissions, and presents economic potential for rural growers.

So-called "first generation" biodiesel, from edible plant oils, actually predates petroleum diesel. Sir Rudolf Diesel demonstrated his first compression ignition engine at the World Exhibition in Paris in 1898 using peanut oil as fuel (Crew, 1963). Vegetable oils were used to run diesel engines until they were modified to be compatible with petroleum products in the 1920s. Plant oils are comprised primarily of triacylglycerides (TAG). Biodiesel is produced by trans-esterification of TAG using an alcohol, either ethanol or methanol, in the presence of a base, producing fatty acid methyl- or ethyl-esters (Fig. 1). Fatty acid composition has been reported to have significant impacts on the performance of biodiesel (Knothe, 2005, 2008; Steen et al., 2010). Chain length, the degree of unsaturation and branching modify the cetane number, melting point, oxidative stability, kinematic viscosity and heat of combustion, which are relevant properties that a biodiesel must meet in order to comply with official standards, such as ASTM D6751 and EN 14214 (Knothe, 2008). The relationship between the structural features and the chemical specifications is described in Table 1.

Edible plant oils used for biodiesel worldwide are rapeseed (84%), sunflower (13%), palm oil (1%), soybean and others (2%) (Atabani et al., 2012), primarily because these oils have high oleic acid content. This fatty acid provides superior ignition quality, ideal melting point, kinematic viscosity as well as improved oxidative stability (Knothe, 2005, 2008; Steen et al., 2010). The fatty acid profile of biodiesel derives from its precursor oil or mixture, if no intermediate winterization (i.e. improvement of cold flow properties) or selective interesterification is applied. For example, when the source is low erucic rapeseed oil (canola), the predominant fatty acids are oleic (55–65%) and linoleic (18–24%) (Hui, 1996). Two types of sunflower oil are available: high oleic (60–65%) or high linoleic (73–78%) sunflower oil (Hui, 1996). The former

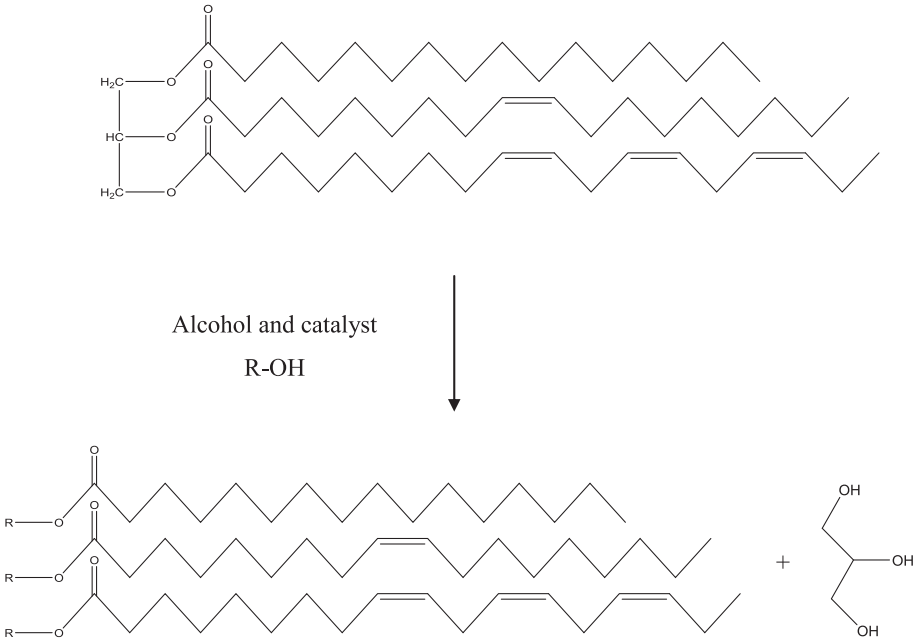

Fig. 1. Conversion of triacylglycerides (TAG) to fatty acid methyl esters (FAME) plus glycerol by transesterification.