Biodiesel from Microalgal, Yeast, and Bacteria: Engine Performance and Exhaust Emissions
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ABSTRACT

Biodiesel (fatty acid methyl esters) derived from oleaginous microbes (microalgae, yeast, and bacteria) are being actively pursued as potential renewable substitutes for petroleum diesel. Here, we report the engine performance characteristics of biodiesel produced from a microalgae (Chaetoceros gracilis), a yeast (Cryptococcus curvatus), and a bacteria (Rhodococcus opacus) in a two cylinder diesel engine outfitted with an eddy current brake dynamometer, comparing the fuel performance to petroleum diesel and commercial biodiesel from soybeans. Key physical and chemical properties, including heating value, viscosity, density, and cetane index, for each of the microbial-derived biofuels were found to compare favorably to soybean biodiesel. Likewise, the horsepower, torque, and brake specific fuel consumption across a range of engine speeds also compared favorably to petroleum diesel and soybean biodiesel. Analysis of exhaust emissions (hydrocarbon, CO, CO₂, NOₓ and NO) revealed that all biofuels produced significantly less CO and hydrocarbon than petroleum diesel. Surprisingly, microalgae biodiesel was found to have the lowest NOₓ output, even lower than petroleum diesel. The results are discussed in the context of the fatty acid composition of the fuels and the technical viability of microbial biodiesel as replacements for petroleum diesel.

INTRODUCTION

• Biodiesel is a renewable liquid transportation fuel that can be used to displace petroleum-derived diesel fuel without significant modifications to existing engines or fuel distribution networks.

• Current biodiesel used in the United States is derived from oilseed crops, thereby competing with food products and requiring quality farmland. Traditional crops (corn or soybean) are only capable of meeting a small fraction of the US transportation fuel demand.

• Microbial lipids are extracted and converted to biodiesel using a direct transesterification approach developed at Utah State University. Biodiesel production from yeast, bacteria, or microalgae was initiated by the addition of 0.5 to 1 kg of dried microbial biomass to methanol containing 2% (v/v) H2SO4, at a ratio of 201 (L/kg) in a 20 L pilot reactor. Reaction was maintained at 62°C for 6 hours with stirring at 400 rpm. Once the reaction was complete, chloroform was added to force a phase separation. The bottom organic layer, containing the crude biodiesel was then distilled off. The FAME was recovered from the crude biodiesel mixture by utilizing vacuum distillation up to a temperature of 180°C.

• Evaluating how biofuels from different microbes perform in engines will reveal insight on how different fatty acid profiles affect the resulting fuel and allow for selection or genetic engineering of specific microbial strains in order to produce superior fuels.

METHODS

Materials
Microalgae: Chaetoceros gracilis (UTEX # 2658) Yeast: Cryptococcus curvatus (ATCC # 20900) Bacteria: Rhodococcus opacus P630 (DSM # 41493)

Biodiesel production from microbial biomass
Microbial lipids are extracted and converted to biodiesel using a direct transesterification approach developed at Utah State University. Biodiesel production from yeast, bacteria, or microalgae was initiated by the addition of 0.5 to 1 kg of dried microbial biomass to methanol containing 2% (v/v) H2SO4, at a ratio of 201 (L/kg) in a 20 L pilot reactor. Reaction was maintained at 62°C for 6 hours with stirring at 400 rpm. Once the reaction was complete, chloroform was added. The chloroform filtrate was then mixed with the methanol and then water was added to force a phase separation. The bottom organic layer, containing the crude biodiesel was then distilled off. The FAME was recovered from the crude mixture by utilizing vacuum distillation up to a temperature of 180°C.

Engine test procedure
To begin each test, the engine was first started and idled for 30 seconds. The throttle was then increased to full (3000 rpm) and run for an additional 30 seconds. An electronically-controlled down-sweep load was then applied to the engine via the ECR to load the engine from 3800 rpm down to 2450 rpm at a rate of 150 rpm/s. For each fuel, the test procedure was performed in triplicate. Upon completion of triplicate engine performance tests, emissions data for each fuel was collected by operating the engine without load at 3500 rpm for 60 s, using a 5-gas analyzer (CO, CO₂, NOₓ, unburned hydrocarbon, and O₂).