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Carbon distribution of algae-based alternative aviation fuel obtained by different pathways

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ABSTRACT

Algae are considered to be the most viable feedstock for alternative aviation fuel production. The alternative (nonpetroleum) fuel from biomass could be produced as “drop-in” fuels with no effects on flight safety and would be interchangeable with current fuels in performance and handling. Accordingly, alternative fuels blended with petroleum fuels should meet jet fuel's requirements as laid out in the specifications (ASTM D7566). The current jet fuel specifications have implicitly limited jet fuel hydrocarbons with carbon numbers owing to the meeting of suitable physical properties. Accordingly, the carbon distribution of lipids in algae influences the aviation fuel yield and the use of biorefining pathway. This paper investigates the carbon distributions of lipids in different types of algae and characteristics of jet fuels derived from algae have also been discussed by four pathways including Fischer–Tropsch (FT) jet fuel process, hydrotreated renewable jet fuel process, pyrolysis-hydrotreated renewable jet fuel process and hydrothermal liquefaction-hydrotreated renewable jet fuel process. Moreover, carbon distributions of microalgae lipids in 103 species from 10 phyla have been concluded in order to obtain the more potential candidates for sustainable resources of bio-kerosene. The carbon distribution of a typical FT jet fuel can be modeled by the Anderson–Schultz–Flory distribution, which content can be produced to be similar to that kerosene by optimizing the FT process. The hydrotreated renewable jet fuel contains a complex carbon distribution between C_7 and C_{18} due to the hydrotreating reactions applied, including hydrodeoxygenation, hydrocarbonylation, and decarboxylation. Pyrolysis biocrude is similar to hydrothermal liquefaction biocrude as regards carbon distribution. In pyrolysis-hydrotreated renewable jet fuel process, higher pyrolysis temperature and catalyst seem to be helpful to production of C_8–C_{16} compounds in biofuels. In hydrothermal liquefaction-hydrotreated renewable jet fuel process, the carbon distribution of jet fuel is similar to that of pyrolysis-derived jet fuel and it lead to higher bio-kerosene product.

Contents

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1. Introduction

With increasing environmental concerns and a desire for energy independence from conventional fuel sources, the airline industry has begun to focus on biomass-derived alternative fuels. Algae-derived alternative fuels are considered to show the highest potential to meet the current aims for climate change mitigation and provisions of sustainable energy sources. Algae are considered to be the most serious potential feedstock for alternative aviation fuel owing to a high growth rate (some 30–100 times faster than found with terrestrial plants), zero arable land and minimal water requirements against conventional agricultural crops, and are capable of producing 2–20 times more oil per acre than leading oil seed crops. The alternative (nonpetroleum) fuels from biomass could be produced as "drop-in" aviation fuels with no change in engine and aircraft. The fuels would be interchangeable with current fuels in performance and handling, and accordingly, alternative fuels blended with petroleum fuels should meet jet fuel requirements as laid out in the current specifications (ASTM D7566). For commercial reasons, it is important that these alternative fuels are cost- competitive and involve sustainable production methods. Therefore, the whole process of converting feedstock to jet fuel should be optimized for commercialization. It should give priority to aviation fuel production and a reduction in process costs, namely, low input energy and the high energy transfer efficiency. Although jet fuel specifications have only one compositional limit of aromatics $< 25\%$ with a mixture of hundreds of hydrocarbons, the current jet fuel specifications, confining the fuel's physical properties to acceptable ranges, implicitly involve a limit of permitted hydrocarbons to those, which have carbon numbers mainly between 8 and 16. In this point of view, the carbon distribution of lipids in algae is important in that it influences the aviation fuel yield and its production pathway. Considerable research efforts have already been made to summarize the utilization of algae. Nevertheless, none of these review articles exclusively deals with the literature on carbon distribution of biofuel. To fill this gap, many literature are summarized and discussed on conversion of algae into biofuel by different pathways, including Fischer–Tropsch jet fuel (FTJ), hydrotreated renewable jet fuel (HRJ), pyrolysis-hydrotreated renewable jet fuel (PRJ) and hydrothermal liquefaction-hydrotreated renewable jet fuel (LRJ). This paper investigates the carbon distributions in two steps, one is about lipids in different types of algae and the other is jet fuels produced by different pathways.

2. Pathways for algae conversion to alternative aviation fuels

Algae usually comprise protein, carbohydrate and lipid with smaller quantities of nucleic acids. Lipid composition and concentration are the main factors influencing the conversion of algae to jet fuel. Taking into account the distillation and carbon distribution requirements for kerosene, there are four main pathways that can be used to produce jet fuels from algae including Fischer–Tropsch jet fuel, hydrotreated renewable jet fuel, pyrolysis-hydrotreated renewable jet fuel and hydrothermal liquefaction-hydrotreated renewable jet fuel (Fig. 1).

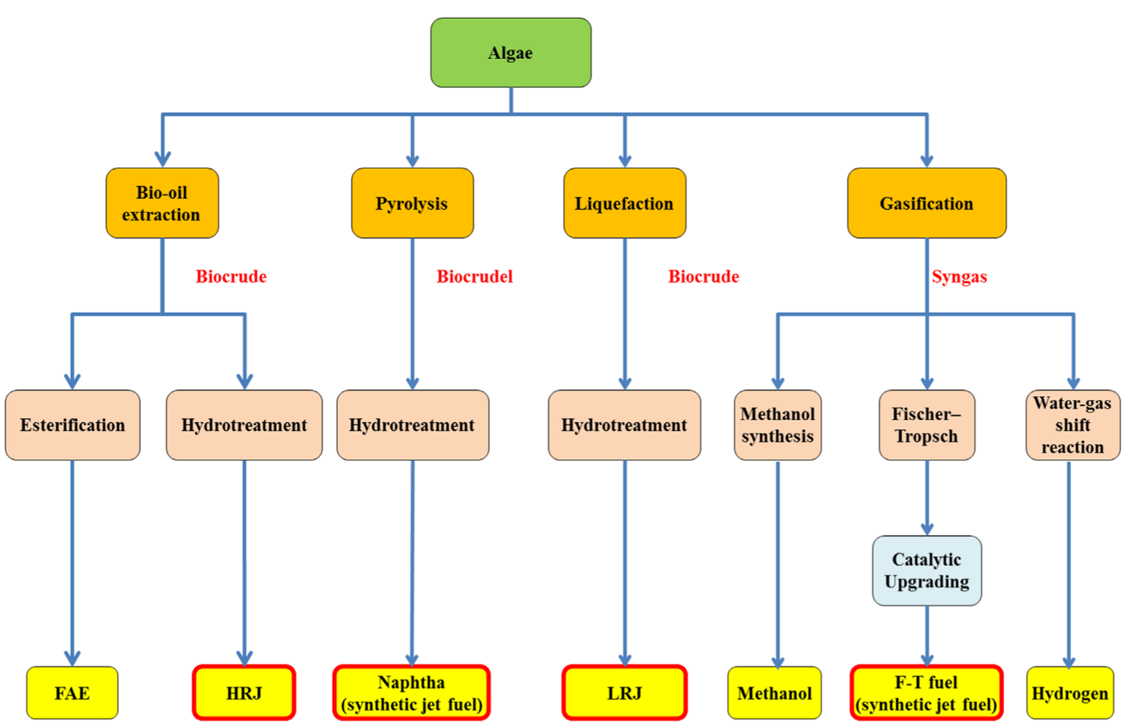

Fig. 1. Pathways for the conversion of algae to alternative aviation fuels.