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Blends of pyrolysis oil, petroleum, and other bio-based fuels: A review

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ABSTRACT

Pyrolysis oil is a promising renewable fuel. However, crude pyrolysis oil use in conventional engines or boilers can be limited without modifications to these systems. Other bio-oils such as oils from vegetables or animal wastes face similar issues. One option to enhance the applicability of bio-oils is blending with petroleum or other bio-based fuels. A literature review on the blending of bio-oils to enhance their fuel properties is presented. Included in the review is information on types of oils that have been blended, additives used to enhance blending, and engine/boiler performance. Upgrading, such as transesterification or hydroprocessing, of bio-oils is often used to improve fuel properties. However, there is limited work on blending of "crude" bio-fuels (e.g. unrefined), such as pyrolysis oils and bio-based waste oils, Therefore, included in this review is a preliminary study of blending of fast pyrolysis oil from hardwood with fish oil extracted from fish processing by-product. The heating value and pH of the blended pyrolysis/fish oil is increased relative to pure pyrolysis oil while the cold flow properties of the blends are better than the pure fish oil. However, the miscibility of the oils is limited and therefore, the next step is to determine if this can be enhanced through upgrading or additives.

Contents

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1. Introduction

Biofuels are attractive sources of alternative energy in the short and long term due to the compatibility and similar functionality of petroleum based fuels [1]. That is, if produced and processed properly, biofuels can be blended with or replace fossil fuels with limited changes to infrastructure and equipment [2–7]. Pyrolysis oil and fish oil are promising alternatives that are renewable and reduce emissions such as CO_2 and other greenhouse gases (GHG) [8]. Pyrolysis oil and fish oil can be used directly as fuels in boilers for power or heat generation as these systems can tolerate lower fuel quality than diesel engines [5,9–11]. Subsequent upgrading to produce transportation fuels and bulk chemicals is also possible [12].

There are various social, economic, environmental and technical issues associated with biofuels. The main concern is the food vs. fuel issue that questions the land potentially available for food crops to be used for the production of biomass [13]. A possible solution is to focus on oils from waste materials such as grease from foodservices, fish waste oil, rendered animal fats, forest residues, sawdust, etc. [14]. The major advantages of transforming biomass to liquid fuels are ease of transportation, reduced cost of handling, and much higher energy density and power-to-heat ratio [10,15]. Biofuels are commonly divided into three different categories depending on their feedstock: triglyceride-based biomass, starch- and sugar-derived biomass, and cellulosic biomass [16]. In this work, the focus will be on pyrolysis oil from cellulosic biomass and triglyceride-based biomass which includes vegetable oil and animal fats and oils, especially from fish waste.

Pyrolysis oil is also referred to as bio-oil, pyrolysis oil, pyrolysis liquid, pyrolytic oil, liquid wood, liquid smoke, [12] etc. It is produced by heating biomass without oxygen as outlined in Fig. 1. The pyrolysis oil is obtained by condensing the produced gases. By-products of the pyrolysis process are bio-char and non-condensable gases.

Limitations of the pyrolysis-to-energy chain are the quality of pyrolysis oil as a fuel, the production costs, and the necessary adaptation of energy conversion systems [17]. The introduction of ASTM standard D7544 for the quality control of pyrolysis liquid biofuels has been a major step towards the introduction of pyrolysis oil as a fuel for transportation, heating, and electricity production [18]. Pyrolysis oil has many drawbacks that limit its usability as a fuel. These drawbacks are low heating value due to high oxygen and water content, ignition delay, high acidity, low thermal stability, high viscosity, poor lubrication, and the formation of engine deposits [18].

Fish oil is commonly used in animal and aquaculture feed, human dietary supplements, and in cosmetics and pharmaceuticals [9]. At remote fish processing plants, production and storage of fish oil can be challenging due to infrastructure limitations and degradation of the oil over time [19,20]. Therefore, the quality required for edible and nutraceutical standards are difficult to meet where plants are far from the market. Under these conditions, oil extracted could be used on site or in the region as a heating oil or marine fuel [9]. Fish oil can be challenging with respect to cold flow properties, poor lubricity, and formation of deposits when used in engines [9]. Fish oil is less thermally stable compared to petroleum fuel, however, it has been successfully

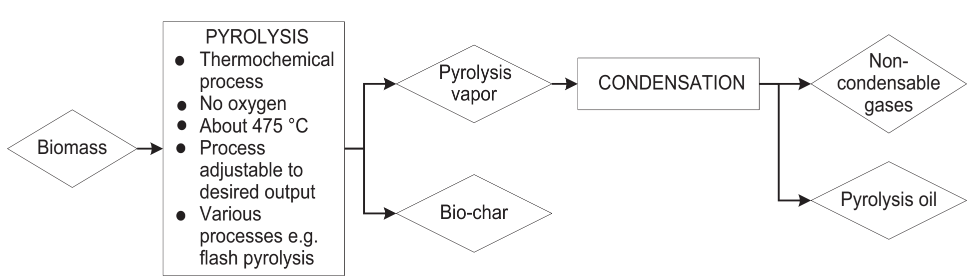

Fig. 1. Pyrolysis process adapted from [14].