BEEF TALLOW AS A BIODIESEL FUEL

by

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DISSERTATION TITLE

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DEDICATION

This dissertation is dedicated to my father, MOHAMMED HUSSAIN. He always encouraged me for higher education. One of his ambitions was to send me to USA for my Doctoral Degree. My only regret is that he did not get to see me graduate from the University of Nebraska. He passed away on Sept. 2, 1994.

I always wanted to show him my gratitude and love for whatever he did for me. I would like to think this dissertation serves that purpose. Papa, Thank you ... I Love You ... and I miss you.

BEEF TALLOW AS A BIODIESEL FUEL

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Blends of diesel fuel, methyl tallowate, methyl soyate and ethanol were prepared. Physical and fuel properties including viscosity, specific gravity, API gravity, distillation ranges, calculated cetane index, energy content, flash point, water content, sulfur content, carbon residue, particulate matter, acid value, copper strip corrosion test, ash content, melting point, cloud point, pour point and major constituents of the blends were determined. Viscosity of methyl tallowate was reduced to that of No 2 diesel fuel by blending 35 % (v/v) ethanol. Blends of ethanol and methyl tallowate had melting, cloud and pour points lower than methyl tallowate. All other fuel properties of methyl tallowate and methyl soyate were close to the properties of No.2 diesel fuel.

Performance and emissions characteristics of all fuel blends were evaluated in a Cummins N14-410 diesel engine and compared to engine operation with No.2 diesel fuel. Engine performance was satisfactory without significant reduction in power and torque. There was a slight increase in brake specific fuel consumption. Only hydrocarbon exhaust emissions were affected by increases in the amount of alternative fuel in the blend. Based on engine performance and emissions analyses, an optimum blend of 80:13:7 % (v/v) diesel fuel:methyl tallowate:ethanol was recommended, and a 200-hour endurance test was performed using an Engine Manufacturer's Association test procedure. Engine performance was satisfactory

for 148 h. Three different injectors failed in the subsequent 49 h of operation. The failures were due to cracks across the injector tips. The injector cracking was not due to the fuel, but rather due to improper injector installation. Otherwise, power output, torque produced and brake specific fuel consumption remained, more or less, constant throughout the test period. Engine wear were less than the recommended limits for standard diesel fuel.

Engine in-cylinder pressure characteristics were evaluated using engine cycle analysis data. It was observed that peak pressure was always less than the peak pressure produced by No.2 diesel fuel. Rate of heat release and charge temperatures also were less than those for No.2 diesel fuel. It was concluded that the fuel blends used in this research would have no detrimental effects on long term engine performance, engine wear and knock.

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DISSERTATION FORMAT

This dissertation is written as a series of eight technical papers. Preceding these papers is a brief introduction describing the scope and objective of this research. Each paper has its own introduction, a literature review included as part of the introduction, methods and materials, results and discussion and conclusions section as well as references used in that research paper.

The first paper of this dissertation is a review paper on the use of oils and fats as biodiesel fuel, a review of engine performance, and emissions characteristics of various fuels. The second paper discusses physical properties related to viscosity and the effect of temperature on viscosity. This paper suggests an optimum blend of methyl tallowate and ethanol having the same viscosity as that of No.2 diesel fuel. The third paper in this series presents detailed physical properties of the various blends of diesel fuel, methyl tallowate, methyl soyate and ethanol. Paper number four in this dissertation presents a detailed engine performance and emissions analysis using the 12 fuel blends. On the basis of engine performance when operating on the different fuel blends, one blend was optimized and the optimization process is discussed in the fifth paper of this dissertation. The sixth paper presents a detailed 200 h endurance test suggested by the Engine Manufacturer's Association (EMA). The engine cycle analysis performed during engine testing and the effects of the different fuel blends on in-cylinder pressure characteristics are presented in the seventh paper. The effects of the fuel blends on rate of heat release, ignition delay, burn duration and charge temperature are discussed and presented in paper number eight.

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CHAPTER 1

INTRODUCTION

The downturn in petroleum-based energy cost in early 70's stifled research in the area of alternate fuels but now air quality concerns have rekindled interest in the development and use of non-petroleum based renewable fuels. Among the different renewable fuels being considered are various types of oils and/or fats derived from plant and animal sources. These oils and fats have potential as a fuel for diesel engines, but there is a need for a continuous and concentrated research effort to change the physical properties of these oils and fats to make them compatible with diesel engines.

Vegetable oils and animal fats can be used as fuel in direct injection diesel engines, but there are some limitations on their use. From the point of view of fuel properties, both oil and fat have fuel properties fairly close of diesel fuel, but from the point of view of physical properties they are not close to diesel fuel. One of the most important physical properties of oils and fats is viscosity; oils are 10 to 15 times more viscous than diesel fuel and animal fats are solid at room temperature, making them unusable as a fuel in raw form. Further, long term use oils may cause fouling with varnish-like deposits which can lead to engine failure.

To use these highly viscous oils and fats as fuels in a compression ignition engine, one must modify their physical properties, particularly, viscosity. Several physical and chemical approaches have been used to reduce the viscosity of oils and fats; of them, transesterification is the most common approach.

Transesterification of beef tallow not only helps in reducing viscosity but also helps in keeping the tallow in liquid form at room temperature.

Tallow is a by-product from the meat packaging industry and its production is dependent on the demand for meat. Edible fats have lost a significant share of the domestic cooking fat market as health conscious consumers are switching to vegetable oils. The effect of this loss is a narrow two cent price difference between edible and inedible tallow and excess supply pressure on traditional inedible markets. The surplus of edible fats comes at a time when traditional markets for inedible fats are in transition. The net effect of the transition has been long-term, flat or declining prices. For example, in 1982, the average price of inedible tallow was $0.16 per pound, compared to $0.135 in 1992. Cattle producers and meat packers need a strong by-product market to help stabilize their primary market.

The United States is the largest producer of tallow, with annual production of 7.9 billion pounds at a value of $ 978 million in 1990. The largest market for animal fat is export. In 1990, U.S. net export totaled 3.26 billion pounds of inedible tallow and greases and 461 million pounds of edible tallow and lard. The volume of inedible tallow export would be sufficient to substitute part of diesel fuel on a nation-wide basis.

Tallow, like vegetable oils, is a mixture of esters of long chain fatty acids and the trihydric alcohol, glycerol. The molecular weight of tallow is approximately 890, that of diesel fuel being about 270. Principle fatty acid components of a typical tallow are palmitic, stearic and oleic acids. The total saturated fatty acids in