Symposium

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Vegetable Oils as Fuel Alternatives – Symposium Overview

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ABSTRACT

Several encouraging statements can be made about the use of vegetable oil products as fuel as a result of the information presented in these symposium papers. Vegetable oil ester fuels have the greatest promise, but further engine endurance tests will be required. These can be carried out best by the engine manufacturers. Microemulsions appear to have promise, but more research and engine testing will be necessary before performance equivalent to the ester fuels can be developed. Such research effort can be justified because microemulsification is a rather uncomplicated physical process and might be adaptable to on-farm operations, which would be doubtful for the more involved transesterification process. Although some answers have been provided by this symposium, others are still not available; engine testing is continuing throughout the world particularly in those countries that do not have access to petroleum.

INTRODUCTION

As noted in the overview of the 1982 AOCS symposium on this topic, considerable progress in evaluating vegetable oils as a farm tractor fuel had been made, but more engine testing and fuel development were required before definitive answers could be given to the many problems arising from the use of such fuels (1). The 1983 symposium provides more information and perhaps some definitive answers, but all of the answers are not in yet. Activity and interest remain high, as shown by the reports given at Seminar III in Peoria, Illinois, in October 1983 (2), as well as by the present AOCS symposium.

VISCOSITY EFFECTS

One controversy that has aroused heated discussions among researchers in the field is the question of whether the unsaturation, particularly polyunsaturation, of the oils or their high viscosity causes excessive carbon deposits, ring sticking and plugging of injector orifices. The work of Ryan, Dodge and Callahan (3), as reported at the 1983 symposium, showed that viscosity may be the predominant factor. Heating the vegetable oil fuel to 145 C lowered the viscosity to near that of No. 2 diesel oil at 40 C (4cSt vs 2cSt). When the heated vegetable oil was injected into the cylinder, characteristics of the fuel spray were greatly improved (as shown by some remarkable high-speed camera work), and the cetane rating of the vegetable oil was increased from 36.6 at 38 C to 39.3 at 145 C, thus approaching the minimum specification of 40 for diesel oil. All of the vegetable oils tested (soybean, sunflower, peanut and cottonseed oils) indicated tendencies for carbon deposition in the injectors, with partially hydrogenated soybean oil having the least tendency, in these short-term engine tests.

SPECIFICATIONS

An extremely important aspect of using vegetable oils as alternative fuels is the setting of specifications, which the work of Ryan, Dodge and Callahan (3) has done. Not only has a fuel temperature requirement of 140 C for acceptable viscosity (5cSt max.) been specified, but also an optimum linolenic/linoleic ratio (with a limitation on the linolenic acid content) and a maximum iodine number. In other words, a high degree of polyunsaturation is undesirable and still is an important factor, even if of somewhat lesser importance than viscosity. Refined vegetable oils were shown to perform better than crude oils; among the 4 vegetable oils tested, the order of ranking from best to worst was soybean > sunflower > peanut > cottonseed oils.

MICROEMULSIONS

Another method of reducing vegetable oil viscosities has been discovered through the formation of microemulsions, which should also improve spray characteristics by explosive vaporization of the low-boiling constituents in the micelles. Ziejewski et al. (4) tested one such microemulsion in the Engine Manufacturers Association (EMA) 200-hr laboratory screening endurance test. Although the microemulsion showed no significant deterioration in performance over the period of the test, problems arose with sporadic sticking of injector needles, heavy carbon deposits, incomplete combustion, dilution of lubricating oil and increasing viscosity. The fuel contained 53% sunflower oil and performed somewhat better than did a 25% blend of sunflower oil in diesel oil (5).

Another microemulsion, this one with soybean oil, was evaluated in the 200-hr EMA screening test by Goering and Fry (6). Although the fuel permitted completion of the test, engine performance had degraded ca. 5% and heavy deposits of carbon and lacquer were noted on the injector tips, intake valves and tops of the cylinder liners. This hybrid fuel contained 25% soybean oil, 50% diesel oil, 20% 1-butanol and 5% 190-proof ethyl alcohol. It also performed better than the 25% blend of sunflower oil in diesel oil. The better performance was attributed to the solvent action and cooling effect of the alcohols in keeping the injector needles and orifices clean.

SIMPLE ESTERS

A third method for reducing viscosity is the conversion of the triglyceride oils to simple esters, which, in effect, reduces the molecular weight of the original oil to 1/3 of its former value, reduces the viscosity by a factor of ca. 8 and increases the volatility. Clark et al. (7) found that engine performance with soybean methyl or ethyl esters differed little from diesel oil in the 200-hr EMA screening test, with the exception of some fuel filter plugging, apparently caused by gum formation in the esters. Emission characteristics were good except that NOX levels were consistently higher than for diesel oil. Dilution of lubricating oil was noted, but was not a problem as long as the normal 100-hr oil change interval was observed. They conclude that the methyl and ethyl esters of soybean oil could be used as alternative fuels on a short-term basis, provided certain fuel quality standards are met.

A recent brief report by Quick, Woodmore and Wilson (8) indicates that methyl esters of linseed oil can fuel a direct-injection engine for as long as 1000 hr, in contrast to engine failure in a few hours when linseed oil itself is used. This evidence again supports the importance of viscosity compared with the effect of polyunsaturation.

With simple esters of vegetable oils yielding such good results as alternative fuels for farm tractors, increased knowledge on the transesterification process for preparing the esters becomes very important. Freedman et al. (9) found that this reaction is 99% complete within 1 hr at 60 C and with in 4 hr at 32 C when strong alkali (sodium hydroxide or methoxide) catalysts and a molar ratio of alcohol to triglyceride of 6:1 are used. The presence of moisture and free fatty acid, which destroy the catalysts, needs to be avoided in the reactants.

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The Effects of Vegetable Oil Properties on Injection and Combustion in Two Different Diesel Engines

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ABSTRACT

Four different vegetable oils, each in at least 3 different stages of processing, have been characterized according to their physical and chemical properties, their injection and atomization characteristics, and their performance and combustion characteristics in both a direct-injection and an indirect-injection diesel engine. The injection and atomization characteristics of the vegetable oils are significantly different than those of petroleum-derived diesel fuels, mainly as the result of their high viscosities. Heating the oils, however, results in spray characteristics more like those observed with diesel fuel. The 2 engine types demonstrated different sensitivities to the composition of the various oils. The combustion characteristics and the durability of the direct-injection engine were affected by the oil composition. The indirect-injection engine, however, was not greatly affected by composition. Two different preliminary specifications have been proposed: a stringent specification including compositional requirements for direct-injection engines, and a less stringent specification for indirect-injection engines. The specifications are discussed in terms of the data and the rationale used in their development. Some precautions concerning the application of the specifications are also presented.

INTRODUCTION

The use of vegetable oils as fuels for diesel engines is not a new concept. Since the invention of the diesel engine, however, the development of this engine has been based on the availability of petroleum-derived diesel fuel which, in turn, has been tailored to meet the needs of the current engines. During this period, a wealth of empirical knowledge has been developed that serves as the data base for the current diesel fuel specifications. Periodically, the vegetable-oil fuel concept has been reintroduced, usually during periods of petroleum shortages. In most cases, interest faltered because of renewed availability of more economical petroleum-derived fuels. As a result, vegetable oils have not been developed as potential fuels, nor have the necessary physical and chemical properties been defined to make them totally acceptable as a fuel source.

The 1973 oil embargo signaled the beginning of a new period of petroleum shortages. As a result, international interest in the use of vegetable oil as diesel fuel has been renewed once again. Much of the current work is being performed in countries that have little or no internal petroleum resources, e.g., South Africa (1), Brazil and Australia (2,3). Work has been progressing in the United States at Ohio State University (4), North Dakota State University (5,6), Southwest Research Institute (7), University of Idaho (8), University of Alabama (9) and at several engine manufacturers including International Harvester

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