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ABSTRACT

Transient smoke emissions pose potential hazards to human health and the environment. With the increased popularity of biodiesel, there is a need to determine if these fuels produce different levels of particulate matter in exhaust emissions. This study examined the transient smoke emissions of three fuels: No. 2 petroleum diesel fuel (D2, ASTM D 975), a blend of 20% biodiesel and 80% petroleum diesel (B20, ASTM 6751), and a 100% pure biodiesel derived from animal fats (B100, ASTM D 6751). Measurements of smoke emissions were taken using the SAE J1677 snap acceleration test procedure on a John Deere 3203 compact utility tractor. The results indicate there were no statistically significant differences in smoke opacity between the three fuels ($p>0.05$). The low, non-significant emissions may be due to the diesel engine being EPA Tier II-compliant and the use of ultra-low-sulfur diesel. Recommendations for further study include testing biofuels made of varying feed stocks rather than animal fats, testing steady state load conditions in addition to transient loads, and testing tractors manufactured prior to initiation of EPA tier-compliance standards.

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MEET THE STUDENT- AUTHOR

Kristin Pennington

I am a native of Rogers, Ark., and graduated from Rogers High School in 2005. I transferred to the University of Arkansas as a junior agricultural education major and later declared a minor in agricultural systems technology management. I have been active in multiple student clubs including Ag Mech, AEED Reps, and Collegiate FFA/4-H. I am also a member of Alpha Zeta and Gamma Sigma Delta. I serve on the Bumpers College Student Advisory Board. In 2007-2008, I was honored as the Distinguished Transfer Scholar for the college. Upon completion of my undergraduate degree, I plan to further my education at the University of Arkansas and pursue a master's degree in agricultural education.

I would like to give a special thanks to Dr. Donald Johnson, the mentor for this project, for his guidance and patience throughout this project. Also, I would like to thank all the faculty and staff of the Agricultural and Extension Education Department for their support and encouragement.

INTRODUCTION

Transient smoke emissions pose potential hazards to human health and the environment. According to U.S. Environmental Protection Agency (2007),

> Particulate matter (PM) is a complex mixture of extremely small particles and liquid droplets in the air. Particulate matter causes concern because it is associated with serious health effects such as aggravated asthma, difficulty breathing, chronic bronchitis, decreased lung function, and premature death. PM contributes to haze and can harm the environment by changing the natural nutrient and chemical balance of the soil (p.1).

Approximately one-fourth of the particle mass inhaled by humans accumulates in the pulmonary region, some of which is retained with a half-life of several hundred days (Glancey et al., 2007).

From 2004 to 2005 alone, production of biodiesel in the U.S. increased from 97 to 291 million liters, a threefold increase (National Biodiesel Board, 2006). Biodiesel is typically blended with petroleum diesel and the percent biodiesel in the blend is designated as BXX, where XX is the percent of biodiesel (e.g. B20 is 20% biodiesel and 80% petroleum diesel). With the increased popularity of biodiesel, and in an effort to lessen emission problems, there is a need to determine if these fuels produce different levels of particulate emissions. The purpose of this study was to compare the particulate matter emissions in a compression ignition engine fueled by petroleum diesel (D2) versus biofuels (B20 & B100).

MATERIALS AND METHODS

This study used an experimental design to find average smoke opacity of an agricultural tractor fueled with three fuel blends. Opacity is a direct indicator of the level of particulate matter in the exhaust stream from a given engine.

Fuels were tested in a John Deere (Moline, Illinois) 3202 three-cylinder, four-stroke, naturally aspirated, compression-ignition, compact utility tractor with a rated engine power of 23.9kW at 2800 rpm and a compression ratio of 19:1. The engine displacement was 1.5 L with an 84 mm bore and 90 mm stroke. The three fuels tested were: D2 (ASTM D 975); B20 (ASTM 6751); B100 (ASTM D 6751) (Table 1).

An Autologic® (Sussex, Wis.) SAE J1667- compliant opacity meter was used to measure opacity. Before running tests, the opacity meter was properly calibrated according to the operation manual. Emission characteristics were quantified by measuring the opacity of the emission gases using the Snap Acceleration Smoke Test Procedure for Heavy-Duty Powered Vehicles (SAE, 1996). Opacity is measured by the percent of light that can pass through the exhaust. If the light passes through the meter with no deflection, the opacity is 0%. Light deflection is due to the amount of particulate matter in the exhaust. The test procedure consisted of three phases, each held for five (5) seconds. The three phases are warm-up, idle, and maximum governed speed. Each test run consisted of three clean-out trials followed by three recorded trials. When switching between fuels, the fuel tank was drained and the fuel lines were flushed to avoid contamination of fuel samples. Four replications were conducted for each of the three fuels (D2, B20, B100). Data were analyzed using one-way analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Petroleum diesel and biofuels were analyzed to display their effects on opacity in the test vehicle. Data analysis showed no significant differences ($p \geq 0.05$) among opacity values of the tested fuel types. The F value for analysis of tested fuels was 0.60 with a $p = 0.57$. All opacity values were less than 1% by differentiated fuel types (Table 2).

Having no significant differences among means and opacity values less than 1% in all fuel combinations gives little reason for concern about particulate emissions in this type of engine. However, it should be noted that this test was run with a modern, EPA Tier II-compliant engine. Tier II-and-above compliant engines are designed to produce fewer particulate emissions. Since there are many tractors still in use that were manufactured prior to EPA tier requirements (pre- 1996), which are common in agriculture, further research on tractors that were produced before the Tier I-IV system was adopted should be conducted. Additionally, the D2 utilized in this test was "ultra-low" sulfur diesel (<15 ppm), which produces less emissions than older petroleum- based fuels (Walsh, 2004).

Future studies may include testing biofuels made of varying feedstock's, rather than animal fats, and/or testing steady-state load conditions in addition to transient-load conditions. Varying load conditions may produce combustion characteristics that could produce a wider range of particulate emissions.

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Table 1. Analytical data for each fuel type.

Tested fuel	$D2_a$	$B20_a$	$B100_b$
Heat of combustion	45.1	44.2	39.8
Cloud point	-14.9	-7.7	-1
Specific gravity	0.8414	0.8485	0.886
Sulfur (ppm)	6.6	6.9	NA
Free glycerin (%)	$-_c$	$-_c$	$-_d$
Total glycerin (%)	NA	.025	NA
Iodine number	NA	14.3	NA
Viscosity (CS@40°C)	2.6	2.9	NA

$-_a$ Samples of D2 and B20 used in this study were tested by the Future Fuel Chemical Company Laboratory as part of a related project.
$-_b$ National Renewable Energy Laboratory Liquid Fuel Database.
$-_c$ Free glycerin not present in petroleum diesel.
$-_d$ Amounts too small to detect.

Table 2. Exhaust opacity percentages by fuel type.

Fuel Type	*Mean*	*Standard Deviation*
D2	0.94	0.57
B20	0.62	0.50
B100	0.56	0.40

Table 3. Opacity of Fuel Types.

Fuel Type	*Mean*	*Standard Deviation*
D2	0.94	0.57
B20	0.62	0.50
B100	0.56	0.40