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Effects of Murumuru (*Astrocaryum murumuru* Mart.) and soybean biodiesel blends on tractor performance and smoke density

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Abstract

The usage of biodiesel, a renewable and biodegradable fuel, is becoming increasingly popular. The objective of the study was to evaluate the operational performance—tractor forward speed, drawbar power, and fuel consumption—and smoke density of an agricultural tractor using biodiesel, diesel, and biodiesel/diesel mixtures as fuel in a tilled field. Soybean biodiesel, murumuru biodiesel, and three combinations of soybean biodiesel and murumuru were used: 90S10M (90% soybean and 10% murumuru), 80S20M (80% soybean and 20% murumuru), and 70S30M (70% soybean and 30% murumuru). The biodiesel/diesel ratios were: B0, B5, B15, B25, B50, and B100; the letter B indicates the presence of biodiesel and the number is the percentage of biodiesel in the diesel. The results showed an increase in specific fuel consumption (SFC) of 10.13%, 16.66%, 12.69%, 14.59%, and 17.42% for murumuru, soybean, 90S10M, 80S20M, and 70S30M, respectively, when comparing B100 to B0. SFC was influenced by the type of biodiesel, B100 of soybean, 90S10M, 80S20M, and 70S30M consumptions were, respectively, 7.8%, 2.9%, 5.2%, and 8.8% higher than those of murumuru. The hourly volumetric consumption (HVC) of 90S10M was 4.8% higher than soybean and murumuru. The tractor's forward speed and drawbar power did not have any significant difference. Smoke density was reduced by 51.6%, 23.04%, 30.41%, 37.8%, and 36.9% for Murumuru, Soybean, 90S10M, 80S20M, and 70S30M, respectively, when comparing B100 to B0. For Murumuru, the smoke density was 59.0%, 43.8%, 28.6%, and 30.5% lower for this variety of biodiesel when compared to soybean at 90S10M, 80S20M and 70S30M, respectively. The results demonstrate the potential usage of biodiesel as a substitution for diesel.

Keywords: Biofuel; Bioenergy; Farm tractors test; Specific fuel consumption; Emission.

Abbreviations: CO_Carbon monoxide; CO_2_Carbon dioxide; NO_x_Nitrogen oxides; NO_2_Nitrogen dioxide; SO_2_Sulfur dioxide; C:12_Lauric acid; C:14_Myristic acid; BSFC_Brake specific fuel consumption; BIOEM_Biofuel and Machines Test; UNESP_Sao Paulo State University; S90M10_90% of refined Methyl Soybean oil and 10% of refined Methyl Murumuru oil; S80M20_80% of refined Methyl Soybean oil and 20% of refined Methyl Murumuru oil; S70M30_70% of refined Methyl Soybean oil and 30% of refined Methyl Murumuru oil. LADETEL_Development of Clean Technologies Laboratory; USP_Sao Paulo University; VHC_Volumetric hourly consumption; Sv_Supply volume; Rv_Return volume; t_Travel speed; WHC_Weight hourly consumption; SFC_Specific fuel consumption; Dp_Drawbar power; B0_0% of Biodiesel; B5_5% of Biodiesel; B15_15% of Biodiesel; B25_25% of Biodiesel; B50_50% of Biodiesel; B75_75% of Biodiesel; B100_100% of Biodiesel; FWA_Front-Wheel assist; FAPESP_Fundação de Amparo à Pesquisa do Estado de São Paulo; CNPq_Conselho Nacional de Desenvolvimento Cientifico e Tecnológico; CAPES_Coordenação de Aperfeiçoamento de Pessoal de Nível Superior; COOPERCITRUS_Cooperativa de Produtores Rurais.

Introduction

Due to the industrialization of agriculture, improving yields and productivity is crucial in agricultural operations. There is strong evidence that high yields require a higher demand of energy. Therefore, the agricultural tractor as a power source has become essential for performing ordinary farming activities in the agricultural industry and contributes to reduced production costs (Khambalkar et al., 2010; Woods et al., 2010; Yadav, 2013).

Large farms rely on diesel-fueled tractors for tilling, planting, cultivating, harvesting, and applying fertilizers and pesticides (Miranowski, 2005). Using nonrenewable resources as a fuel has been proven to have negative effects on the environment and human health (Wei, 2015). Emissions from fuel combustion in diesel engines results in the formation of a complex mixture of gases (gas-phase hydrocarbons, CO, CO_2, NO_x, NO_2, and SO_2) and particulate exhaust (carbonaceous matter, sulfates, and trace elements) (EPA, 2002).

Biodiesel is a strategic way to reduce dependence on petroleum and the damage of emissions from diesel engines. Biodiesel can be blended, in any proportion, with diesel because it has similar characteristics—but biodiesel has lower exhaust emissions. Biodiesel is renewable, biodegradable, non-toxic, and essentially free of sulfur and aromatics, unlike conventional petroleum diesel (Singh and Singh, 2010); furthermore, biodiesel can be used without engine modification (Lin et al., 2011).

Many resources can potentially be a feedstock for biodiesel production: animal fats, algae, used cooking oil, and vegetable oils (Moser, 2009; Ahmad, 2012). In 2010, global proportions of biodiesel produced was synthesized from rapeseed oil (47%), soybean oil (35%), palm oil (10%), sunflower oil (4%), and other oils and fats (including tallow, waste oils, and corn oil) (4%) (Milazzo et al., 2013).

Depending on the geographic location, different raw materials can be used more frequently, such as: soybeans, cotton seed, microalgae, animal residue, palm tree, sunflower, peanut karanja, canola, and rapeseed (Moser, 2009; Nabi et al., 2009; Shin et al., 2014; Martins et al., 2015; César et al., 2013; Cursaru et al., 2014; Lopes et al., 2012; Dhar and Agarwal, 2015; Öztürk, 2015; Duren et al., 2015).

Soybean and Palm oils are the most widely used feedstocks for biodiesel production. Palm trees have very high production yield in comparison to other oilseeds, making it the most energy efficient (Angarita et al., 2009). Palm oil also has other advantages as a feedstock, because it uses less fertilizer, water, and pesticides compared to other biodiesel sources (Mekhilef et al., 2011). Murumuru (*Astrocaryum murumuru* Mart.) is a palm tree from the Amazon, rich in lauric (C:12) and myristic (C:14) fatty acids (Mambrim and Bezerra-Arelanno, 1997). Murumuru oil has favorable physical and chemical proprieties and significant potential for synthesis of biodiesel on an industrial scale (Nascimento et al., 2007; Lopes et al., 2007).

Amazon communities are often isolated from technology and fuel sources, and the use of Murumuru oil for biofuel used in stationary engines may be a feasible source of delivering power to these remote areas; in addition, it has an abundance of native palm dispersed throughout the Amazon territory (Bezerra, 2008). Furthermore, the use of Murumuru would be a socio-economic benefit for the Amazon region, because local communities would generate an income (Teixeira, 2010).

Studies related to engine testing indicate an increase of brake specific fuel consumption (bsfc) and a decline in carbon monoxide and particulate emissions due to the increase of biodiesel content. Özener et al. (2014) observed a 2-9% increase in bsfc while studying diesel, biodiesel, and its blends; however, the use of biodiesel reduced carbon monoxide emissions by 28-46% and the total unburned hydrocarbons by 20-44%.

Biradar and Adeppa (2014) studied performance and emissions of diesel engines operating with biodiesel and its blends; the authors concluded that blends with up to 20% biodiesel did not influence diesel engine performance but reduced particulate matter emissions.

There are limited studies focusing on the influence of biodiesel and its blends on the dynamic performance of tractor diesel engines under field conditions and the resulting smoke density. The objective of the present study is to evaluate the effects of different fuel types and blends on the operational performance and smoke density.

Results and Discussion

Tractor performance (essay I)

The addition of biodiesel in the blends and the type of biodiesel did not change the forward speed. These results are similar to those of Soranso et al. (2008), who worked with soybean soybean oil in agricultural tractors.

Tractor Forward Speed

Drawbar Power

The type of biodiesel and biodiesel ratio did not influence the drawbar power, which averaged 40.5 kW. This result was explained by the uniformity of drawbar pull during the test, at approximately 25 kN. The use of biodiesel does not affect the available power for the drawbar; the lowest heat value of biodiesel compared to diesel was compensated by the increase in fuel consumption, so that the power in the drawbar was not compromised.

Fuel Consumption

The hourly volumetric consumption (HVC) is the difference between the supply and return fuel amount. As shown in Table 1, the difference between the lowest (Murumuru) and highest (90S10M) HVC was 4.81%; also, there was no statistical difference between Murumuru, Soybeans, 80S20M, and 70S30M. The difference in HVC of Murumuru and 90S10M could be related to cetane number (CN). The biodiesel proportion does not affect the average for HVC statistically.

The specific fuel consumption (SFC) is the ratio between mass flow of the tested fuel and the effective power. SFC averages are shown in Table 1; notably, the interaction between factors was significant, so the variable was analyzed using a complementary deployment table.

For biodiesel proportion (in line), the SFC increased as the ratio of biodiesel in the blends increases (Table 2). B0 (diesel) was not statistically different from the following: B15 of Soybeans, B50 of Murumuru, and B25 of S90M10, S80M20, and S70M30. The mean increase on SFC comparing B0 to B100 was 10.13%, 16.66%, 12.69%, 14.59%, and 17.42% for Murumuru, Soybean, 90S10M, 80S20M, and 70S30M, respectively. Similar results were observed by Lopes et al. (2009) and Graboski and McCormick (1998).

The increased SFC of biodiesel proportions may be a consequence of the lower heating value compared to diesel. Generally, blends of biodiesel have higher SFC than diesel, and the trend increases with a higher blending ratio. This is caused by the increased flow rate for maintaining the same power output—more fuel is required to produce the same torque as the ratio of biodiesel in the blend increases. As the fuel pump delivers fuel on a volumetric basis and as biodiesel density is higher than diesel, more biodiesel is delivered to compensate the lower heating value (Qi et al., 2009). When equating the same fuel amount, the HVC was similar and SFC was typically higher. The higher density of biodiesel compensated the difference in heating value. Therefore, in terms of fuel mass, the injection system provides more biodiesel than diesel due to the increased density. Another reason for increased SFC is the poor atomization of biodiesel blends. According to Alptekin and Canakci (2008), biodiesel and it blends have higher density and kinematic viscosity values compared to diesel.

Table 1. Summary of variance analysis and mean test for volumetric hourly consumption (HVC) and specific fuel consumption (SFC).

Factors	HVC L h^{-1}	SFC g kW h^{-1}
Type of fuel (Tf)		
Murumuru	13.91 b	282
Soybean	14.01 b	305
90S10M	14.58 a	287
80S20M	14.34 ab	291
70S30M	14.34 ab	297
Biodiesel proportion (Bp)		
B0	14.40 a	275
B5	13.99 a	277
B15	14.25 a	283
B25	14.15 a	287
B50	14.15 a	296
B75	1442 a	308
B100	14.27 a	321
F TEST		
Tf	5.2333 **	23.5697 **
Bp	1.1470 ^{NS}	59.2176 **
TfxBp	1.1909 ^{NS}	1.6966 *
C.V.(%)	4.0331	2.9250

Averages followed by the same letter are not statistically different by Tukey's test at 1% and 5% of probability. **Significant ($p\leq0.01$), *Significant - ($p\leq0.05$) and NS - Not Significant.

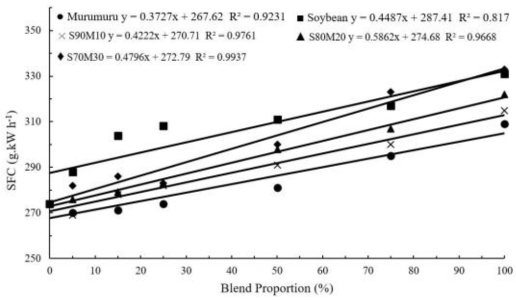

Fig 1. Graphical representation of specific fuel consumption as a function of different types of biodiesel and proportions.

Table 2. Deployment of the interaction between source and proportion of biodiesel for Specific Fuel Consumption (g kW h^{-1}).

Type of fuel	Biodiesel Proportion						
	B0	B5	B15	B25	B50	B75	B100
Murumuru	275 Abc	272 Ac	269 Bc	274 Bc	280 Bbc	296 Cab	306 Ba
Soybeans	275 Ad	288 Acd	306 Abc	312 Aab	309 Abc	316 ABab	330 Aa
90S10M	275 Acd	269 Ad	277 Bcd	283 Bbcd	291 ABbc	300 BCab	315 ABa
80S20M	275 Ad	276 Ad	279 Bcd	283 Bcd	298 ABbc	307 ABCab	322 ABa
70S30M	275 Ac	282 Abc	283 Bbc	286 Bbc	300 Ab	323 Aa	333 Aa

Averages followed by the same lowercase letter in the line and by capital letter in the column are not statistically different by Tukey's test at 5% of probability, *Significant ($p\leq0.05$).

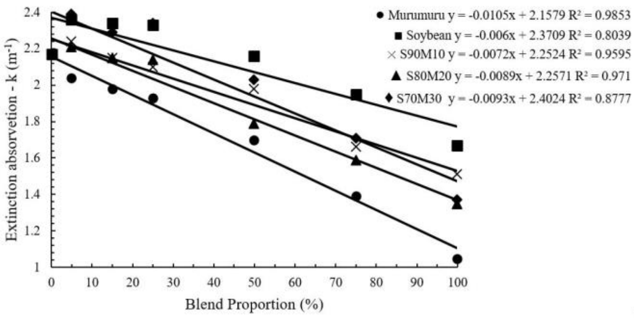

Fig 2. Graphical representation of the smoke density as a function of different types of biodiesel and proportions.

Table 3. Summary of variance analysis for smoke density.

Factors	Smoke Density (m^{-1})
Type of fuel (Tf)	
Murumuru	1.75
Soybean	2.14
90S10M	1.97
80S20M	1.91
70S30M	2.04
Biodiesel proportion (Bp)	
B0	2.17
B5	2.24
B15	2.18
B25	2.16
B50	1.93
B75	1.66
B100	1.39
TESTE F	
Tf	488.2257 **
Bp	1717.6054 **
TfxBp	25.6509 **
C.V. (%)	3.0929

Averages followed by the same letter are not statistically different by Tukey's test at 1% of probability. **Significant ($p\leq0.01$).

Table 4. Deployment of the interaction between source and proportion of biodiesel for smoke density (m^{-1}).

Type of fuel	Biodiesel Proportion						
	B0	B5	B15	B25	B50	B75	B100
Murumuru	2.17 Aa	2.04 Cb	1.98 Cbc	1.93 Cc	1.70 Dd	1.39 De	1.05 Df
Soybeans	2.17 Ab	2.36 Aa	2.34 Aa	2.33 Aa	2.16 Ab	1.95 Ac	1.67 Ad
90S10M	2.17 Aab	2.24 Ba	2.15 Bb	2.10 Bb	1.98 Bc	1.66 Bc	1.51 Be
80S20M	2.17 Aab	2.21 Ba	2.15 Bab	2.14 Bb	1.79 Cc	1.59 Cd	1.35 Ce
70S30M	2.17 Ac	2.39 Aa	2.29 Ab	2.34 Aab	2.03 Bd	1.71 Be	1.37 Cf

Averages followed by the same lowercase letter in the line and by capital letter in the column letter are not statistically different by Tukey's test at 5% of probability, Significant ($p\leq0.05$).

SFC for each type of biodiesel (shown in the columns) shows no statistical difference between B0 (standard) and B5. The SFC for Soybean was slightly higher for B25 than B15. B25 and B15 are not statically different for Murumuru, S90M10, S80M20, and S70M30. Murumuru had a lower SFC values for B50, B75, and B100, which is statistically similar to 90S10M and 80S20M. Figure 1 presents the plotted SFC values measured; the calculated values are expressed as lines derived from regression analysis.

For each biodiesel, the difference in fuel consumption could be explained by the cetane number (CN), which is a dimensionless unit of diesel engine ignition quality. The higher the cetane number, the shorter the ignition time, which results in better fuel burning and, consequently, better energy use. Higher CN is related to palm feedstocks and soybean feedstocks that typically have lower CN, as observed by Knothe (2014), Peres et al. (2007), Ramos et al. (2009), and Tong et al. (2011).

Smoke Density (Essay II)

Table 3 shows the smoke density averages; notably, the interaction between the factors was significant, so the variable was analyzed using a complementary deployment table.

In Table 4, the analysis for each biodiesel (in rows) shows that the average smoke density decreases as the ratio of biodiesel in blends increases. A decrease was observed when compared the smoke density of B0 (diesel) to B5 of Murumuru, B75 of Soybean, and B50 of 90S10M, 80S20M, and 70S30M. Comparing B0 and B100, the mean decrease in smoke density was 52%, 23%, 30%, 38%, and 37% for Murumuru, Soybean, 90S10M, 80S20M, and 70S30M, respectively.

The smoke density varies with the number of smoke particles per volume unit (SAE, 1996). Smoke density has many causes, but the main reason this occurs is the incomplete combustion of fuel. Studies show that smoke opacity decreases when the percentage of biodiesel in the blend increases. The results found in the present study are similar to Lopes (2006) and Koike (2010); they found that the reduction in smoke density was linear to the addition of biodiesel in the blends. Graboski and McCormick (1998), Pianocski and Velásquez (2002), and Oliveira et al. (2015) attributed the reduced smoke particles emissions to the higher oxygen content in biodiesel. For these authors, the increased oxygen in the combustion chamber causes the combustion to be more complete, reducing the number particles in the smoke. In addition, Frijters and Baert (2006) found a good relationship between particulate matter emissions and fuel oxygen content. Furthermore, biodiesel contains almost no aromatics and Sulphur compounds (almost none) than diesel which contributes to the reduction of general engine emissions (Sahoo et al., 2009, Ong et al., 2014). Yoshiyuki (2000), Korres et al. (2008), and Wu et al. (2009) reported a decrease of emissions due to the interaction of different oxygen content, viscosity, and the cetane number in biodiesel. When analyzing the type of biodiesel (in the columns), it was observed that the average smoke density was less when using Murumuru. B100 of Murumuru reduced emissions compared to other types of biodiesel by 59.0% for 90S10M, 43.8% for 80S20M, and 28.6% for 70S30M, and 30.5% for Soybean. The difference in emissions related to the biodiesel source could be a result of the different cetane numbers in the feedstocks and its interactions. Biodiesel from palm contents have a higher cetane number and oxygen content than other biodiesels, promoting a better combustion and reduced emissions (Ramos et al., 2009). Moreover, the low density and viscosity of palm biodiesel also minimizes the carbon deposits formed in the fuel injectors and combustion chambers during long operations (Pehan et al., 2009). Figure 2 presents the plotted smoke density values; the calculated values are expressed as lines from regression analysis.

Materials and Methods

Area and Soil Description

Experiments were conducted at *Faculdade de Ciências Agrárias e Veterinárias*, *UNESP Universidade Estadual Paulista*, *Campus Jaboticabal*, *Departamento de Engenharia Rural*, *Biocombustível e Ensaio de Máquinas* – BIOEM. Coordinates 21º15' south and 48º18' east, 570 meters above sea level. The annual average temperature is 22.2 ºC, annual average precipitation is 1.425 mm, average relative humidity is 71%, and an atmospheric pressure of 94.3 kPa (UNESP, 2011). The regional weather is classified by Kottek et al. (2006) as Cwa, a subtropical climate with a droughty winter which transitions to Aw in the summer with a tropical-wet climate and a defined rain period. The soil is classified as Eutrustox with a gentle rolling topography and an average slope of 3%, according to Brazilian Soil Classification System (Andreoli and Centurion, 1999). The average water content was measured by the gravimetric method on the experiment day was 11.2 and 13.4% for 0-15 and 15-30 cm deep, respectively. The soil is classified as clayey, with a 0-20 cm particle size, with layers of clay, silt, and fine and coarse sand at 51, 29, 10, and 10%, respectively.

Diesel and Biodiesel

The fuels consisted of a standard diesel fuel containing at maximum 1,800 mg kg^{-1} of sulfur and density of 860 $kg.m^{-3}$, and 5 types of biodiesel: Refined Methyl Soybean oil, refined Methyl Murumuru oil, S90M10 (90% of refined Methyl Soybean oil and 10% of refined Methyl Murumuru oil), S80M20 (80% of refined Methyl Soybean oil and 20% of refined Methyl Murumuru oil), and S70M30 (70% of refined Methyl Soybean oil and 30% of refined Methyl Murumuru oil).

The biodiesel (B100), obtained by transesterification, were provided by *Laboratório de Desenvolvimento de Tecnologias Limpas*- LADETEL from *Universidade de São Paulo* – USP, diesel was acquired from a gas station and the mixing of biodiesel and diesel was performed before each test.

Tractor

In this research the tractor was an AGCO-Valtra, model BM 125i, 4x2 with front-wheel assist (FWA) and 7,000 kg distributed between the front (40%) and rear axle (60%) with tires 14.9-26 inches on the front axle and 23.1-30 inches on the rear axle. The tractor had a four stoke and four-cylinder AGCO POWER 420DS engine with a maximum power of 91.9 kW at 2,300 rpm (ISO 1585), equipped with a turbocharger and intercooler. The power to weight ratio was 76 kg/kW.

The information from this study was divided in two essays: Essay 1 - conducted under field conditions in order to evaluate tractor performance and Essay 2 - static to measure smoke opacity from the engine. The experiments were categorized into two topics as follows: Essay I – Tractor Performance and Essay II – Engine Smoke Opacity.

Experiment Procedures

Tractor Performance (Essay I)

The performance of the tractor was evaluated through measurement of drawbar power, forward speed, specific weight, and volumetric fuel consumption during chisel plowing. In order to define the maximum drawbar load, a pilot test was conducted with a chisel plow AST/MATIC 7–Marchesan. It had a total mass of 1,400 kg and 5 shanks 45 cm long with an 8 cm reversible point working at a depth of 30 cm (shank distance/depth ratio 1.5) with coulter blades equipped to each shank and an automatic spring-cushioned system, trip/reset mechanism, and rolling harrow. The measured travel reduction (slip) was 10%, consistent with ASAE (2006) and the force of the drawbar's pull to the chisel plow in operating condition was 25 kN. Due to the large variability of the soil resistance during operation, the chisel plow was replaced by a second tractor, exerting a force of 25 kN obtained through the combination of 4th gear and range L. The second tractor was a Valmet, model 118-4, 4x2 FWA, and 7,310 kg distributed between the front (40%) and rear axle (60%) with tires 14.9-28 on the front axle and 23.1-30 on the rear axle. It is equipped with a four stoke six-cylinder MWM D229/6 engine with a maximum power of 82.43 kW at 2,400 rpm. According to Lopes (2006), the second tractor was connected to the test tractor by a stainless-steel cable. The second tractor was off and in gear, since its function was to provide a drawbar pull load to the test tractor with little variation in the work speed while applying the necessary load (25 kN).

In all experimental plots, in order to stabilize the determinations, the tractor movement began 15 m outside the plot. When the tractor reference, the center of the rear wheel, crossed the first landmark, data acquisition began to record and ended when the reference crossed the second landmark.

Fuel consumption was determined by the difference in volume of the amount of fuel supplied to the injection pump and the volume of fuel returned to the tank. The fuel temperature was used to correct for changes in density. The data acquisition system consisted of two sets: one for the injection pump at the supply line and one for the tank return line. Each set contained an Oval Corporation brand flow meter—Flowmate LSF 41 model with 1% precision on nominal flow and a maximum flow of 100 L h^{-1}—and a platinum resistance thermometer PT 100 (resistance 100 ohms at 0 ºC and 138.4 ohms at 100 ºC) with a temperature range from -200 ºC to 800 ºC. The consumption prototype

was built and described in Lopes et al. (2003). The system has three auxiliary fuel tanks, which allows testing with various types and mixtures of fuels without contamination.
To determine the fuel consumption the equations 1, 2 and 3 were used.

Based on the consumed amount of fuel and travel time across each plot, hourly volumetric consumption was determined according to equation (1):

$$HVC = \left(\frac{Sv - Rv}{t} \right) * 3.6$$

(1)
where,
HVC = hourly volumetric consumption (L h^{-1});
Sv = supply fuel volume (mL);
Rv = return fuel volume (mL);
t = travel time (s); and,
3.6 = conversion factor.
The weight of hourly consumption was calculated using the fuel density and the difference of supplied and returned fuel during the test, according to equation (2):

$$WHC = \left(\frac{Sv * Sd - Rv * Rd}{t} \right) * 0.0036$$

(2)
where,
WHC = weight hourly consumption (kg h^{-1});
Sv = supply fuel volume (mL);
Sd = supply fuel density (kg m^{-3});
Rv = return fuel volume (mL);
Rd = return fuel density (kg m^{-3});
t = travel time (s); and,
0.0036 = conversion factor.
Specific fuel consumption was expressed in units of mass per unit of power required in the drawbar, according to equation (3):

$$Sfc = \left(\frac{WHC}{Dp} \right) * 1000$$

(3)
where,
SFC = specific fuel consumption (g kW h^{-1});
WHC = Weight hourly consumption (kg h^{-1});
Dp = Drawbar power (kW), and
1000 = conversion factor.

Speed was determined using a radar—Dick John brand, model RVS II—which has 97% accuracy for speeds from 3.2 to 70.8 km h^{-1}. Drawbar pull, measured by M. Shimitsu load cell, model TF 400. To measure travel reduction (slip), a sensor manufactured by S&E—Testing and Measurement Instruments, model GIDP-60-U12V—was installed on each tractor wheel, which provided a number of individual pulses to all four wheels. This sensor has the principle function of determining angular displacement based on the rotation of the wheel. One revolution corresponds 60 pulses to the sensor.

All transducers and sensors were powered by an auxiliary battery. The data relating to fuel consumption, fuel temperature, drawbar power, wheel rotation, and travel speed were monitored and stored in a data acquisition system, Campbell Scientific, Inc.—model micrologger CR23X— which is programmed to obtain data on the frequency of 1 Hz and to transfer by a serial port (RS232).

Smoke Density (Essay – II)

Performed according to the snap-acceleration smoke test. In the snap-acceleration test, the throttle was moved to its maximum and remains in this position until the engine reaches the maximum governed speed, then it is held for an additional 1 to 4 s. Later, the throttle was released and the engine is allowed to return to the low-idle speed. Once the engine reaches low-idle speed, the engine idled for a minimum of 5 s up to 45 s before initiating the next snap-acceleration test cycle.

The smoke density (k) is also known as "Light Absorption Coefficient." Conventionally, smoke density is expressed per meter (m^{-1}). The smoke density is a function of the number of smoke particles per unit volume, size distribution, light absorption, and optical scattering properties of the smoke particles (SAE, 1996).

The smoke density was measured by a partial-flow opacimeter TM 133, attached to a serial TM 616 (both are produced by Tecnomotor) and the data was then transmitted to a computer with IGOR version 2.0 software.
Before each test, all fuel that was not consumed was collected from deposits, filters and pipes, to prevent contamination of subsequent testing. After changing the fuel, the engine remained in operation for ten minutes before the beginning of each test to be consistent.

Statistical analysis

Both tests were performed with a randomized 5x7 factorial design, with three replications, totaling 105 observations. The factors were seven blends of biodiesel/diesel—B0, B5, B15, B25, B50, B75 and B100, in which the letter B indicates the presence of biodiesel and the number represents the percentage of biodiesel in diesel. For the performance test, each plot was 40 m long, with an area of 15 m for maneuvering machinery traffic and tractor stabilization in each replication.

Data was analyzed by the variance and Tukey's range test. Variance analysis (F-test) was used to select the equation model with the most significant exponent.

Conclusion

The biodiesel proportion had no influence on the drawbar power or forward speed in agricultural tractors. Blend ratio had no effect on hourly volumetric consumption. Hourly volumetric consumption was influenced by type of fuel. Murumuru and Soybean had lower consumption rate than 90S10M. When comparing the SFC of B0 to B100, an increase of 10.13%, 16.66%, 12.69%, 14.59%, and 17.42% for Murumuru, Soybean, 90S10M, 80S20M and 70S30M was observed, respectively. Type of fuel influenced SFC on ratios higher than B15. When comparing the smoke density of B0 (Diesel) and B100, a reduction of 52%, 23%, 30%, 38%, and 37% for Murumuru, Soybean, 90S10M, 80S20M and 70S30M was observed, respectively. The smoke density produced by combustion of Murumuru derived biodiesel was lower than the smoke density produced by consumption of Soybean derived biodiesel.

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