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Energy characterization of biodiesel obtained by transesterification from organic matter and its influence as an additive on the mechanical performance of the engine of the mazda bt-50 vehicle

Caracterización energética del biodiesel obtenido por transesterificación a partir de materia orgánica y su influencia como aditivo en el rendimiento mecánico del motor del vehículo mazda bt-50

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Abstract: The research work obtained biodiesel by using beef fat as raw material, which in our environment is considered as waste, taking advantage of its energy potential through a transesterification process, using sodium hydroxide as a catalyst, which is a substance in aqueous solution "lye"; producing 55% of the raw material in biodiesel due to the chemical reaction that divides the beef tallow into glycerin and products derived from the reaction, in addition to the losses in the washing and drying processes. Blends were made at B25, B40, B55, B70 and B85 % with premium diesel characterized by physical-chemical tests that determine levels of sulfur, water, cloud point, cetane index, copper foil corrosion, density, viscosity, flash point, PH level and calorific value under NTE INEN and ASTM standards that will establish the best samples; to use them the internal combustion engine of the Mazda BT-50 truck, determining the impact on the mechanical performance of the test vehicle such as: torque, power, consumption and opacity to analyze and compare based on nominal values of the vehicle and national regulations in force establishing which is the most optimal sample for use.

Keywords: Transesterification, Biodiesel, Biofuels, Calorific value, Opacity

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Resumen: El trabajo de investigación obtuvo biodiesel mediante el aprovechamiento de la grasa de res vacuno como materia prima la misma que en nuestro medio es considerada como desecho, aprovechando su potencial energético mediante un proceso de transesterificación, utilizando como catalizador el hidróxido de sodio que es una sustancia en disolución acuosa "lejía"; produciendo el 55% de la materia prima en biodiesel debido a la reacción química que divide el sebo de res vacuno en glicerina y productos derivados de la reacción, además de las pérdidas en los procesos de lavado y secado. Se realizó mezclas al B25, B40, B55, B70 y B85 % con diésel premium caracterizadas mediante pruebas físico – químicas que determinan niveles de azufre, agua, punto de nube, índice cetano, corrosión de lámina de cobre, densidad, viscosidad, punto de inflamación, nivel de PH y poder calorífico bajo normas NTE INEN y ASTM que establecerán las mejores muestras; para usarlas el motor de combustión interna de la camioneta Mazda BT-50, determinando la incidencia en el rendimiento mecánico del vehículo de prueba como: torque, potencia, consumo y opacidad para analizar y comparar en función de valores nominales del vehículo y normativas nacionales vigentes instaurando cual es la muestra más óptima para su uso.

Palabras clave: Transesterificación, Biodiesel, Biocombustibles, Poder calorífico, Opacidad

Introduction

The constant world population growth, national vehicle fleet based on industrial development, as well as the decrease in crude oil storage, generates great interest and awareness of the scientific and political community on issues related to pollution and environmental protection produced by internal combustion motor vehicles, hence the need to develop alternatives based on existing natural resources. ASTM This refers to oils and fats of animal origin (oleaginous tissues), such as tallow from cattle and the poultry industry, which can be used as a raw material to obtain biodiesel. Compared to vegetable oils, animal fats and oils are of low cost. Biodiesel obtained from animal fats can be characterized according to their physicochemical properties(Ortiz & Rodriguez, 2013). Among the physical properties that are performed are: sulfur content, water content, copper foil corrosion, density, viscosity, melting point, calorific value and cetane number (ASTM D6751-15).(ASTM D6751-15c, 2010)..

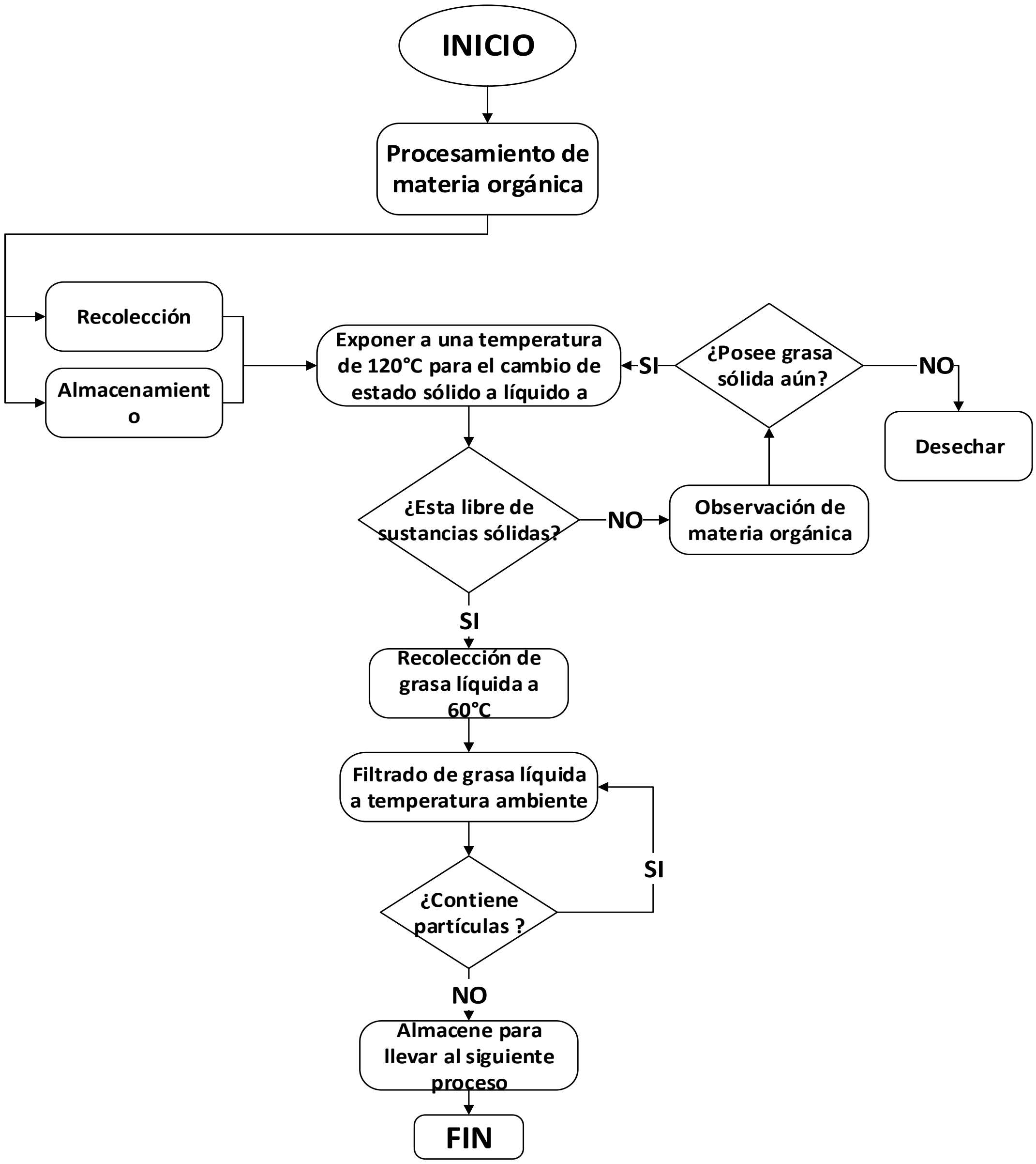
(MICSE, 2012) It argues that "greenhouse gas (GHG) emissions (carbon dioxide -CO2-, methane -CH4 and nitrous oxide -N2O) increased by 10.7% with respect to 2013. This represented the emission of 45.8 million tons of CO2 equivalents12 by the country's energy sector, of which transportation is the largest generator of gases occupying 39% of total emissions. The next largest contributors in emissions are power plants (13.6%) and industry (13.3%)."

This research work presents the results of obtaining biodiesel in the laboratory and at a semi-industrial level from beef fat by transesterification and its use, mixed in different proportions with conventional diesel fuel, in a diesel engine of a Mazda BT-50 pickup truck. Beef fat belongs to the group of raw materials considered strategic because large quantities are discarded daily in the different feedlots (UNE-EN ISO 660).(*UNE-EN ISO 660:2010 Oils and fats of animal and vegetable origin ...*, n.d.).

The experimental work was carried out in four phases. The first one includes the treatment and characterization of the raw material, the biodiesel production process and the mixture in concentrations from 25% to 85% with variations of 15%, the determination of the main properties of the diesel after using biodiesel as an additive and finally the performance tests in the vehicle with the different samples.(Texo, 2009). In the second phase, mechanical performance, torque, power and fuel consumption tests of the MAZDA BT-50 vehicle engine were carried out in the Dynamometer of the Engines and Rectification laboratory through the interface, emissions and opacity in the Yard Mechanics laboratory with the CARTEK gas analyzer under static and dynamic conditions of the University of the Armed Forces ESPE Latacunga Extension based on a test method of the NTE INEN 960 and 2207 through ideal conditions of execution.

Figure 1 details the refining process carried out on the raw material: collection, change of state and filtering to obtain a liquid substance free of solid particles for subsequent characterization.

Figure 1. Organic matter treatment process



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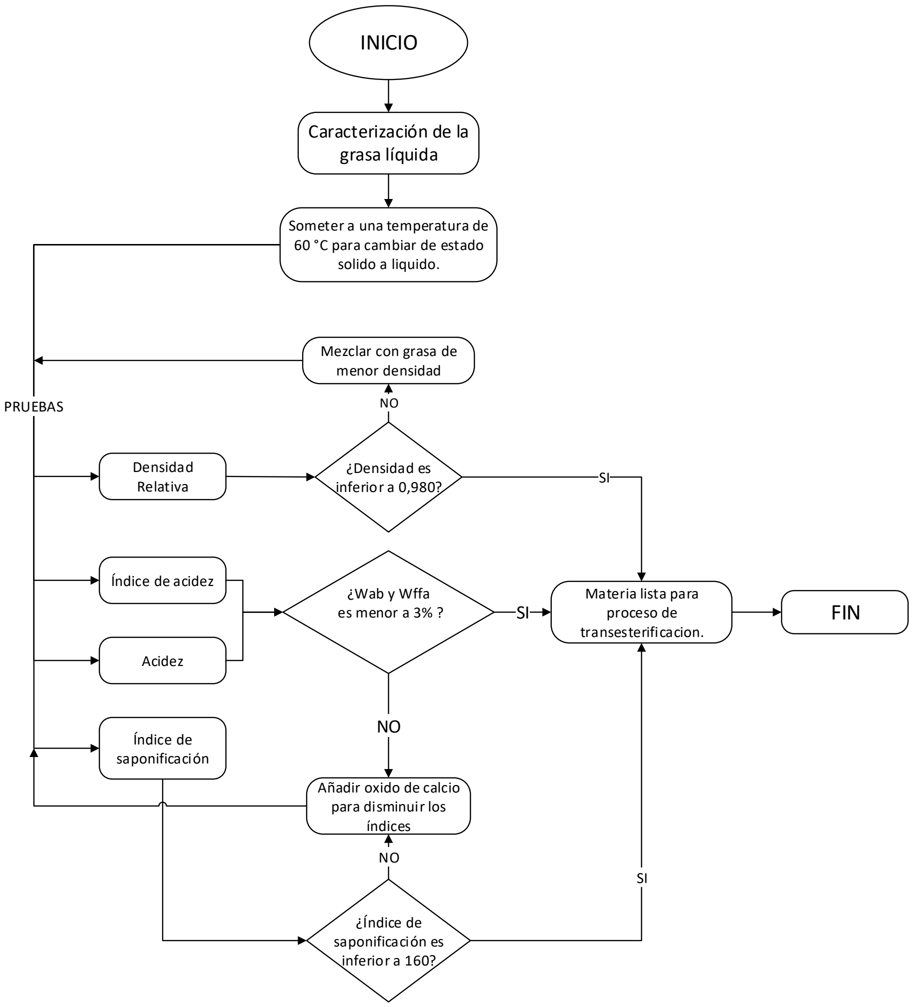
Materials and methods

(Ecuadorian, 2013) The raw material, beef tallow, was characterized to determine the concentration of the reagents to be used, then once the biodiesel was obtained it was characterized using the physical-chemical tests that diesel complies with here in Ecuador under the NTE INEN 1489-2012 standard.

Figure 2 describes how to determine whether or not the organic matter is suitable for the transesterification process, taking into account fat characteristics such as: density, acidity index, acidity and saponification index.

Figure 2. Organic matter characterization process



Taking into consideration the values of the acidity index and the saponification index to calculate the mass of the raw material, the volume of sodium hydroxide and methanol. To carry out the transesterification, a catalyst is needed, which in this case will be potassium hydroxide (KOH), which allows a complete reaction in the process due to its higher ion content; the chemical product regulatory bodies restrict its free distribution to the public, so sodium hydroxide (NaOH) is used, which is a substitute and free sale to the public.

Table 1. *Molecular Weight of Sodium Hydroxide (NaOH)*

Sodium hydroxide (NaOH)	**Molecular mass (gr)**
Na	22,9897
O	15,9994
H	1,0079
Total	39.9970

Beef fat contains glycerides that need to be converted into esters, this is achieved by the reaction of the fat with high purity (99.9%) concentration methanol. The physicochemical properties of methanol Table 2.

Table 2. *Physical and chemical characteristics of methanol*

Physical and chemical characteristics of methanol	
Purity	99,9 %
Density	0.79 g/cm^3
Molecular mass	32.04 g/mol

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Table 3 presents the calculations to determine the proportion of reagents needed for the transesterification process, optimally without leaving fatty acid molecules unreacted and ensuring the quality of the biodiesel.

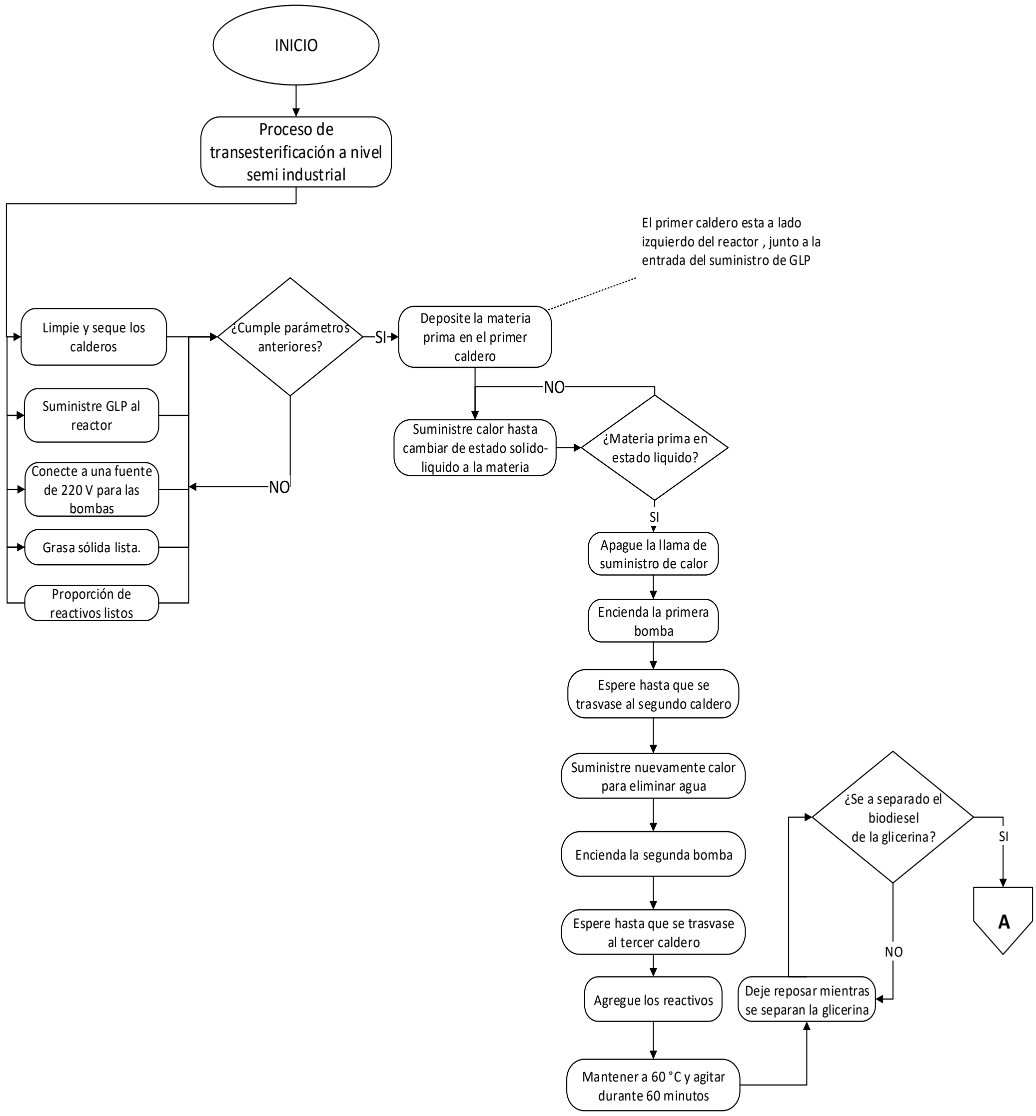
Table 3. *Summary of calculations to determine the quantity of reagents*

Calculations to determine the amount of reagents						
Parameter	**Data**		**Units**	**Equation**	**Value**	**Units**
Densidad (ρ)	m_{p1}	15.5617	gr	$\rho = \frac{m_{p2} - m_{p1}}{v}$	0,9267	$\frac{gr}{ml}$
	m_{p2}	38.7300	gr			
	v	25	ml			
Stoichiometric ratio($R.E.S.$)	$3\ mol\ NaOH$	119991	mg	$R.E.S. = \frac{3\ mol\ NaOH}{1\ mol\ grsa\ de}$	119991	mg/gr
	$1\ mol\ grasa\ de\ res$	1,000	gr			
Tallow dough (M_{grasa})	$R.E.S.$	119991	mg/gr	$M_{grasa} = \frac{R.E.S.}{Is}$	854,2717	$\frac{gr\text{ grasa de res}}{mol\ grasa\ de\ res}$
	Is	140,46	mg/gr			
M_{grasa}	ρ	0,9267	$\frac{g}{ml}$	$M_{grasa} = \rho\ x\ v$	463,35	gr
	v	500	ml			
Methanol mass ($m_{metanol}$)	M_{grasa}	463,35	gr	$M_{metanol} = m_{grasa} * MR * \frac{Mmetanol}{Mgrsa}$	208,2784	gr
	MR	12				
	$Mmetanol$	32	gr			
	$Mgrasa$	854,2717	gr			
Methanol volume ($V_{metanol}$)	$m_{metanol}$	206.2782	gr	$V_{metanol} = \frac{m_{metanol}}{\rho_{metanol}}$	263,6436	cm^3
	$\rho_{metanol}$	0,79	g/cm^3			
Mass of hydroxide (m_{NaOH})	m_{grsa}	458,9	gr	$m_{NaOH} = m_{grasa}\ x\ \frac{\%}{100}$	4,6335	gr
	$\%\frac{p}{p}NaOH$	1,00	%			
	grease	100	gr			

For the transesterification reaction of 500 ml of beef tallow with a mass of 463.35 g, 4.634 g of NaOH sodium hydroxide and 263.64 g of methanol are required for the transesterification reaction. cm^3 of methanol.

Figure 4 details the transesterification process to transform beef tallow into biodiesel by means of the chemical reaction between the catalyst, methanol and raw material, which break their molecules and form methyl esters and glycerin.

Figure 3. Transesterification process.



(Pablo, Ignacio, & Pablo, 2009) The by-products at the end of the process are glycerin and biodiesel, it is necessary to let them rest while they are separated by density difference, decanting helps to separate the

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glycerin that is deposited at the bottom of the boiler and by means of the valve it is extracted by the action of gravity. Once the biodiesel and glycerin separation process is completed, the biodiesel is purified by washing and drying methods. The characterization tests of the diesel-biodiesel mixtures carried out in the chemistry laboratories of the Universidad de las Fuerzas Armadas ESPE Latacunga Extension are detailed below: density, calorific value, viscosity and PH level. According to the results obtained from the different experimental tests developed in the research, the energy potential of the Premium diesel blends with biodiesel in different concentrations as an alternative energy source for use in diesel engines was determined. The measurement of torque and power was carried out in the roller dynamometer of the Universidad de las Fuerzas Armadas ESPE-L in the engine and rectification laboratory, resulting in graphs according to the engine speed, generating torque and power data. The MAZDA BT-50 vehicle was used to perform the tests, in order to obtain the characteristic curves prior to the measurement of its performance, preventive maintenance was performed.

Result

The results of the characterization table 4 of beef fat according to the physical-chemical analysis report.

Table 4. *Beef tallow characterization*

Parameter	Result	Allowable values	Unit	Method of analysis
Relative density	0,9267	0,980	gr/ml	PA-FQ-74/ NTE-INEN-35-1
Acid number	0,98	3	mgNaOH/gr	MAL 29/NTE INEN ISO 660
Acidity	0,49	3	%	MAL 29/NTE INEN ISO 660
Saponification index	140,46	160	mg/gr	MAL 29/NTE INEN ISO 660

(BENAVIDES, BENJUMEA, & PASHOVA, 2007) The main variables that determine or influence the quality and completeness of the transesterification reaction are directly related to the quality of the raw material, the type, quantity and purity of the catalyst, the purity level of the alcohol, the alcohol/oil molar ratio and the conditions under which the reaction is carried out, such as temperature, pressure and agitation speed.

Table 5 details the results of density, sulfur content, cetane number, flash point, kinematic viscosity, copper foil corrosion, water by distillation, cloud point, calorific value and pH according to the test methods performed.(Galeano L. & Guapacha M., 2011).. The analysis of the results to characterize the blends considers the NTE INEN 1489 and ASTM 6751 standard that establishes parameters that diesel fuel for vehicles with compression ignition engines must meet.(INEN, 2016)

Table 5. *Summary of characteristic parameters of biodiesel at various percentages*

Comparison of biodiesel characteristic parameters and standards								
ESSAY	**UNIT**	**B25**	**B40**	**B55**	**B70**	**B85**	**NTE INEN 1489**	**ASTM 6751 STANDARD**
Density 15°C	Kg/m^3	835.60	842,90	846	851,2	855,2	860mi- 900 max.	860 min - 900 max.
Sulfur Content	%P	0,0068	0,0029	0,0009	0,0002	0,0000	max. 0.05	0.0015 max.
Cetane number	--	53	51	51	50	49	51 min.	47 min.
Flash point	°C	168,90	171,00	185,33	202,83	219,33	min. 51	Minimum 130
Kinematic viscosity 15°C	Cst	3,88	3,93	4,09	5,37	5,71	min-max. 2,0-5,0	1.9 min - 6 max.

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Water by distillation	%V	0,00	0,00	0,00	0,05	0,05	max. 0.05	0.05 max.
Copper Sheet Corrosion	Corrosion	1a	1a	1a	1a	1a	1a	No. 3 max.
Cloud point	°C	0	6	8	11	15	--	--
Calorific Power	J/gr	67028.7 0	65688,13	63677, 27	60549,26	57421, 25	--	--
PH	--	5	5	5	5	5	--	--

The density increases as the biodiesel concentration increases, none of these diesel-biodiesel blends are within the minimum value.

Densities decrease by 2.84%, 1.99%, 1.63%, 1.02% and 0.56% for samples B25, B40, B55, B70 and B85 respectively; B85 being the value that approaches the minimum of INEN 1478 with a value of 855.2 Kg/m3.

The ASTM D6751 standard for biodiesel establishes that the minimum flash point must be 93°C and in NTE INEN 1489 it is 51°C for diesel; based on these values, all samples are within specifications.

The sample of B25 and B40 present a similar inflation point of 168.9 °C and 171 °C respectively, B55 is 134.33 °C above the minimum value of INEN 1489, the proportions B70 and B85 present a variation of 151.83 and 168.33 respectively being the highest variations in relation to the value established by INEN 1489.

The viscosity of samples B25, B40 and B55 have the following values 3.88 3.93 and 409 respectively, which are within the range determined by the Ecuadorian technical standard; mixtures B70 and B85 are outside the maximum value established in INEN 1489. The B70 sample is 7.40% higher than the maximum value, and B85 is 14.20% above the maximum value.

Table 6. *Summary of measured engine operating parameters.*

Vehicle operating parameters with biofuel samples							
	Manual values		Measured values		Fuel consumption		
Samples	Power (KW)	Torque (Nm)	Power (hp)	Torque (Nm)	Time (gal/h)	Mileage (6Km) (gallons)	Opacity
Diesel	105	330	137,5	249,51	0,48	0.20	0,95
B25	--	--	108,3	180,39	0,62	0.39	0,81
B40			115,4	263,04	0,65	0.32	0,64
B55			100,7	173,82	1,35	0.33	0,53
B70			105,9	186,47	1,81	0.71	0,40
B85			84,2	152,45	3,50	0.68	0,26

(*BIOFUEL PERFORMANCE IN DIESEL ENGINES | NÚÑEZ ISAZA | Energetics*, n.d.)The torque that the engine reaches when supplying diesel is 249.51 Nm at 1800 rpm, and a power of 137.5 Hp at 3500 rpm, a value very close to the value of the manual which is 141 HP at the same engine speed. When the B40 sample is supplied to the engine it reaches a torque of 263.04 Nm, exceeding the torque obtained with the diesel, but in terms of power the diesel undoubtedly exceeds it by 21.8 HP. The samples of B25, 55 and B70 develop a similar power of 108.3, 100.7 and 105.9 HP respectively, being the samples with a performance very close to that of B40, while the diesel - biodiesel mixture presents a decrease of 53.3 HP with respect to the performance with diesel.

The following shows the loss and gain of torque and power in percentages, according to each of the samples, as previously analyzed, the only one with an increase in power is B40.

The B85 sample is the one with the greatest decline in torque and power performance, clearly showing a decline of 38.90% in torque and 38.76% in power with reference to diesel. While the B25, B55 and B70 samples present a similar decrease and not as abrupt as the B85 sample.

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On the other hand, it is important to highlight the performance of the B40 sample, which presents an increase of 5.42% in torque compared to diesel.

Fuel consumption is one of the key parameters to carry out a proper selection of the best blend to use in the engine. Figure 10 below shows the fuel consumption variations according to the biofuel concentration.

Conclusions

All samples show an increase in fuel consumption with respect to diesel, so that more fuel is needed to achieve similar performance to that of the diesel-fueled engine.

Fuel consumption with diesel is 0.2 gallons per 6 km traveled, while consumption with the B40 and B55 samples is 0.32 and 0.33 gallons respectively, being these the samples with the lowest consumption among the 5, consuming 0.12 gallons more with respect to diesel.

The CARTEK opacimeter determines the light absorption coefficient (k) of the exhaust gases in diesel engines and must be converted to opacity percentage. As in the performance tests, the blends are made at the percentages (B25, B40, B55, B70, B85 and 100% diesel).

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