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ENERGY AND EXERGY ANALYSIS IN CONJUNCTION WITH PUMP MIXTURES OF PASSION FRUIT OIL WITH DIESEL BIODIESEL

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Abstract. *Biodiesel is a biofuel of renewable sources. It can be made from different sources of raw materials. The knowledge of the efficiency of the equipments through the use of these fuels contributes to reduce costs and allows comparison and to choose the best alternatives. The present study treated the energy and exergy's analysis of the motor pump operating with mixtures of passion fruit oil biodiesel with diesel. Values of the Useful Work (W_u), of the Reversible Work (W_{rev}) and of the Second Law of Thermodynamics Efficiency (η_{II}) were obtained. The passion fruit oil biodiesel was produced using Methanol in the proportion of 40% v/v with a 1% of NaOH as a catalyst. Biodiesel/Diesel mixtures were prepared and classified as B0, B25, B50, B75 and B100. These mixtures were submitted to physical and chemical characterization and utilized in the motor pump set. The related set was considered as adiabatic device, with flow in steady state, uniforms properties and single current, despising the kinetic and potential energy changes. Among the results, the kinematic viscosity of the biodiesel and S50 diesel blend was within the established limits of the National Petroleum Agency (ANP). Value of 39004 kJ.kg^{-1} for the higher calorific power of the B100 passion fruit oil biodiesel was obtained. An efficiency of 23.15% for the B25 mixture was verified when the motor pump set operated at maximum flow, passing through 29.82% and 27.42% in intermediate flows, and measuring up to 19.87% of efficiency in lower flow.*

Keywords: *Renewable, efficiency, fuel, Reversible, properties.*

1. INTRODUCTION

From the energy consumed by the transportation department, 90% are originated in petroleum. In this context, the bioenergy is being evaluated as a viable and promising alternative, in a short and medium term, to occupy a larger space in the world energy matrix, mainly to comply with part of the transportation sector necessities (Barros, 2007).

According to Castellanelli *et al.* (2008) the energetics alternatives derived from biomass emerges as considerable options for remotes areas or of difficult access, such as some areas at Northern Brazil. This is due to the fact that they can be offered in a decentralized manner and with a high degree of autonomy.

The biodiesel is a renewable source of biofuel, which can be produced from different sources of raw materials. The knowledge of the efficiency of the equipment from the use of such fuels contributes to reduce the costs and allows comparing and choosing the best alternatives. According to Festel *et al.* (2014) the future evolution of biofuel production costs' in Europe was investigated considering the effects of the technological learning and production scale. In that study it was observed that in the short and medium term, the second generation biodiesel form residual oil, and palm oil are the most promising as production costs.

The supply of water for irrigation takes place, mainly, with the use of centrifugal pumps which can be actuated either by electric motors or Otto cycle and Diesel cycle engines.

1.1 Exergetical Analysis

A system provides the maximum possible work to undergo a reversible process from the initial specified state to the state of its ambience, that is, the neutral state. That represents the useful potential work of the system at specified state and it is called exergy, even more, the exergy represents the upper limit of the amount of work a device can provide without violating any of the laws of the thermodynamics (Çengel, 2013).

1.2 Exergetical analysis and renewable resources production processes

It was used the exergetical analysis as an environmental assessment tool to account waste and emissions, comparing substitutes and other types of energy sources (Talens et al., 2007). The methodology was developed in steps: establishment of system limits' by drawing the diagram of industrial process flow under study, determination of which inputs / outputs steps and byproducts makes part of the system. Definition of the system limits'; process division into operating units for the study of each limit from an independently form. The exergy flow analysis provides a way for the evaluation of the process which can be used as an identification tool of waste materials and energy loss, detecting the areas that need improvement. Exergy is also a useful indicator of measurement of potential material reactivity and quality, comparing different production processes and products of substitution, which is especially useful for comparing renewable energy sources.

1.3 Exergy connected to the biodiesel proction process

The exergetical analisys was effectuated (Peiró et al., 2010), being later compared the biodiesel production process from the frying oil to the rapeseed oil. In this study, the inputs and outputs of balance for the two raw materials were verified, being taken into consideration that the products had different life cycles, same price and tax break. It was found that the exergy inputs for frying oil and rapeseed oil biodiesel are 47.77 GJ/t e 77.05 GJ/t, respectively. The main exergy input to the frying oil was the methanol (2.46GJ). Still in the rapeseed biodiesel production, the main exergy input were the synthetic fertilizers (8.78GJ), methanol (6.48GJ) and ethylene glycol (2.88GJ). It follows also that the methanol has a lower exergy in the production of the frying oil during the transesterification because almost the half of the input is retrieved and supplied in the process.

Developed studies (Macedo, 2013) consider for the energetic analysis a volume of control that could cover the pump of a motor pump set having, thus, input and output mass (process fluid).

It was based on the energy balance applied to a process for volume of control, the expressed in the Equation 1:

$$\dot{E}_{in} - \dot{E}_{out} = dE_{system}/dt = 0 \text{ (steady state)} \quad (1)$$

Considering: steady state, uniform properties, single current; $\dot{Q} = 0$ and nulls kinetic and potential energy variations, the useful work consumption W_u (real) becomes a function of merely the difference of enthalpy between states 1 (initial, at the input of the bomb) and 2 (final, at the output of the bomb), according to Equation2:

$$\dot{W}_u = \dot{m}\,(h_2 - h_1) \quad (2)$$

Being the bomb an adiabatic device, the term X_{heat} was despised. To obtain an expression for W_{rev}, the destroyed exergy was made zero, there is, $X_{destroyed} = 0$. As: $X_{work} = [w - p_0(V_2 - V_1)]$; $X_{Mass} = \dot{m}\psi$ (single current), being the steady state and uniform properties, it can be expressed in rate form. In this case the work represents the minimum work consumed by the bomb being expressed as Equation (3):

$$W_{rev} = \dot{m}(\psi_2 - \psi_1) \quad (3)$$

Finally, it is verified according to efficiency of Second Law $\eta_{II,}$ that for devices that consumes work (4), it is the ratio between the minimum consumption of work W_{rev} (reversible) and the useful work consumption W_u(real).

$$\eta_{II} = \dot{W}_{rev} / \dot{W}_u = (\psi_2 - \psi_1) / (h_2 - h_1) \quad (4)$$

The purpose of the presente study was to obtain the biodiesel through the vegetal oil of passion fruit, prepare the mixtures of the biodiesel produced with Diesel S50, use them in a motor pump set coupled at a hydraulic circuit instrumentalized and effect the Energetic and Exergetic Analysis of the system.

2 METHODOLOGY

2.1 Production and characterization of biodiesel

The production of passion fruit biodiesel was investigated using the methanol anhydrous PA 99.7% at a 40% v/v proportion used in Tulcan (2009) at the production of dendê biodiesel. The experiments were leaded in batches of 100 mL of oil, aiming to guarantee the homogeneity.

The biodiesel obtained was fractioned and mixture to the oil diesel at the followings proportions in volume: diesel 100%; biodiesel 25% and diesel 75%; biodiesel 50% and diesel 50%; biodiesel 75% and diesel 25%; and biodiesel 100%. These mixtures were denominated B0, B25, B50, B75 and B100, respectively, and they were conditioned in bottles of amber color.

The mixtures were characterized, being determined the kinematic viscosity, through a capillary viscometer (ASTM D 445 norm) and the superior calorific power (ASTM D 4809 norm). This second test was accomplished by National Institute of Technology.

2.2 Energetic and Exergetic Analysis

Such analysis underlies in the energy balance and in the efficiency of the Second Law of Thermodynamics, which is a measure of separation that the bomb presents from its ideal performance, once the real work of the bomb (W_u) will always be greater than its ideal work (W_{rev}). For this case, the exergetic analysis can be based at the pressure collection and suction temperature and repression of the fluid in motor pump in work, and in room temperature.

Therefore, at the period that the motor was effectively working, it was registered suction and discharge temperatures of the bomb close to the water tank, the room temperature, the pressures read at the manometer of suction and in the two manometers positioned before and after the global valve that were restricted into six positions.

3 RESULTS AND DISCUSSION

3.1 Biodiesel production

The average of the passion fruit biodiesel batches produced presented a yield of 75.69%. It is understood that for being a process dependent of variables, such as temperature, catalyst and alcohol, the yield of the production of biodiesel can differ between authors. The founded values can be justified for limitations at the equipment, such as the absence of devices that presents an effective rotation of the magnetic agitator, which prevented the obtainment of higher yields.

3.2 Kinematic viscosity characterization and superior calorific power determination

The kinematic viscosity of the mixtures (Table 1) from the biodiesel with the diesel was kept inside the limits established by ANP. As expected, the increase of the percentage of the biodiesel at the diesel mixture leads to a rise at the mixture’s viscosity, once the biodiesel is more viscous than the oil diesel. This behavior was also reported by Souza *et al.* (2009); Mejia *et al.*(2013); Geller *et al.* (2008).

Table 1. Kinematic viscosity of the mixtures ($mm^2.s^{-1}$).

Diesel	Mixtures			
B0	B25	B50	B75	B100
2.545	3.195	3.404	3.841	4.720

The Diesel S50 presented Superior Calorific Power of 45280 $kJ.kg^{-1}$, and the passion fruit biodiesel, 39004 $kJ.kg^{-1}$. Although the passion fruit biodiesel has revealed a PCS 13.86% smaller than the diesel S50, it has presented a good behavior when used in the motor pump set, not being noticed any anomaly at the motor operation.

3.3 Energetic and Exergetic Analysis

3.3.1 Useful work

At Table 2, there are the values founded for the useful work regarding the outputs for diverse mixtures. The smaller output condition implicated at a smaller useful work.

Table 2. Useful Work Values.

Diesel		B25		B50		B75		B100	
m^3/h	W_{rev}	m^3/h	W_{rev}	m^3/h	W_{rev}	m^3/h	W_{rev}	m^3/h	W_{rev}
12.260	2.066	11.980	1.915	12.300	2.268	12.140	2.100	12.240	2.097
11.690	2.423	11.560	1.588	11.850	2.205	11.460	1.992	11.470	1.875
10.220	1.261	9.890	1.857	9.760	2.063	9.910	2.117	9.640	1.915
8.800	1.527	9.450	1.340	9.380	1.769	9.520	1.809	9.380	1.769
7.170	1.636	7.950	1.606	8.200	1.466	8.370	1.700	8.260	1.666
5.010	1.084	6.720	1.600	6.880	1.131	6.980	1.581	6.760	1.452

3.1.2 Reversible Work

The smaller output condition implied at a smaller reversible work, as shown in Table 3.

Table 3. Values founded for Reversible Work.

Diesel		B25		B50		B75		B100	
m^3/h	W_{rev}	m^3/h	W_{rev}	m^3/h	W_{rev}	m^3/h	W_{rev}	m^3/h	W_{rev}
12.260	0.557	11.980	0.444	12.300	0.463	12.140	0.462	12.240	0.449
11.690	0.892	11.560	0.435	11.850	0.468	11.460	0.446	11.470	0.471
10.220	0.435	9.890	0.419	9.760	0.408	9.910	0.445	9.640	0.402
8.800	0.352	9.450	0.400	9.380	0.406	9.520	0.430	9.380	0.408
7.170	0.387	7.950	0.360	8.200	0.371	8.370	0.392	8.260	0.376
5.010	0.264	6.720	0.318	6.880	0.304	6.980	0.332	6.760	0.320

3.1.3 Efficiency of Second Law of Thermodynamics

The behavior of the efficiency of the second law, as the global valve was restrained, presented a similar form as a characteristic curve of centrifugal bombs that relates “Output x Efficiency”, as shown in Figure 1, for different mixtures of passion fruit biodiesel with diesel. The efficiencies present maximum values in intermediates positions, and smaller values at extremes. The passion fruit biodiesel B25, for example, presented an efficiency of 23,15% at maximum output, passing through 29,82% and 27,42% in intermediate outputs, reaching a 19,87% of efficiency at lower output.

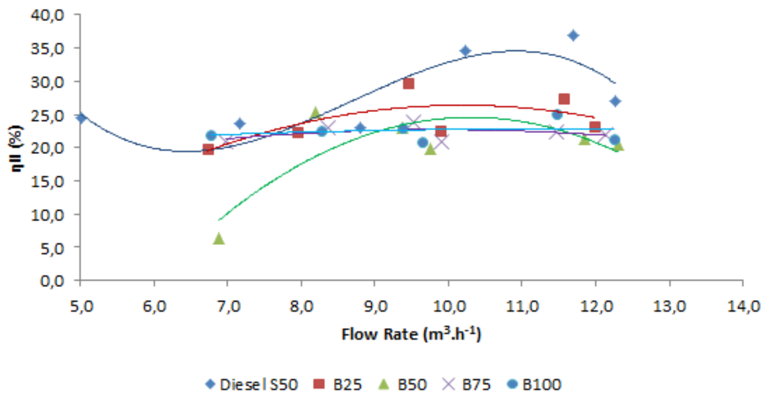

Figure 1. Efficiency of Second Law for mixtures in different outputs.

4 Conclusions

The extracted oil from the passion fruit seeds constitutes of a potential raw material for biodiesel production;

The biodiesel obtained through the passion fruit seed presented a kinematic viscosity value within the limits established by ANP;

The system's efficiency presented better results at intermediates operations position, as verified in the behavior curves of the centrifugal bombs.

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