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Comparison of Biodiesel Extracted from Pork and Duck Fat

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Many countries depend on energy, and it is advisable to generate energy from renewable energy sources. Pork and duck fat are residues that can be used to generate biodiesels. Thus, this research evaluated the obtaining of biodiesel from the oil extracted from pork and duck fat. For the production of biodiesel, the transesterification method was used, mixing different proportions of oil, catalyst and alcohol at a temperature of 60 °C. The results indicated that the best proportion to obtain biodiesel from pork and duck waste was 250 mL of oil, 50 mL of alcohol (methanol) and 1.5 g of catalyst (potassium hydroxide). The lower calorific value was also higher in the duck fat biodiesel (M8) with values of 7433 Cal/g and biodiesel from pork fat (M2) presented values of 7448 Cal/g. Both biodiesel obtained met the quality requirements established in ASTM D6751 standard and could be used as alternatives to common diesel.

1. Introduction

Global energy demand is estimated to increase from 557 billion BTUs in 2014 to 703 billion BTUs in 2040 (Hamdan et al., 2017). This growth was observed in the last decades where there was a growing demand for energy supplied largely through petrochemical resources that are the main source of energy throughout the world, especially for transportation. This energy comes mainly (more than 80%) from three types of fossil fuels: oil, coal and natural gas, which have been the main source of energy production in recent centuries. (Seffati et al., 2019). However, fossil fuels are derived from biomasses that take millions of years to form and are non-renewable resources with limited reserves and high costs. (Banković-Ilić et al., 2014). To counteract this, animal fats that are disposed of in landfills are being used (Sawangkeaw and Ngamprasertsith, 2013). These wastes are potential raw materials for the production of biodiesel (Al-Zuhair et al., 2012; Araújo et al., 2010; Ayalasomayajula et al., 2012; Chung et al., 2009; Kirubakaran and Arul, 2018; Shin et al., 2012) as renewable, sustainable and alternative fuels that could reduce greenhouse gas emissions (Pourhoseini et al., 2020).

In general, the basic raw materials for biodiesel production can be divided in four main groups: vegetable oils (edible and inedible), animal fats, used cooking oils and algae. (Banković-Ilić et al., 2014). The production of biodiesel from animal fat waste is inexpensive and has attracted a lot of attention in recent years (Erdoğan et al., 2020). Various investigations evaluated the efficiency of the use of fats of animal origin to obtain biodiesel, using transesterification reactions (Moreira et al., 2018; Sierra-Vargas et al., 2015; Tejada et al., 2013), in which triglycerides present in vegetable oils and animal fats react with short-chain alcohols in a catalytic process (Furtado et al., 2021). This is an energy-efficient and favorable process, of clean technology with environmental advantages, complying with the ASTM 6751 standard (Abdulrahman and Omar, 2014; López et al., 2015).

The transesterification reaction consists of combining the oil with an alcohol and is usually carried out in an alkaline medium by heating and stirring, where the product of interest is fatty acid esters and the co-product is glycerol. However, triglycerides, diglycerides and monoglycerides may appear if the conversion is not complete. (Furtado et al., 2021). Transesterification reactions can be chemically catalyzed (basic or acidic) using homogeneous or heterogeneous catalysts, or catalyzed by enzymes (mainly lipases), and can be

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influenced by various factors such as: composition of the raw material, content of free fatty acid and water in raw materials, types and amount of alcohol and catalyst, mixing intensity, temperature and reaction pressure (Banković-Ilić et al., 2014). Biodiesel is a mixture of fatty acid methyl esters that can replace diesel and is obtained from the reaction of vegetable oils or fats with methanol (Cerutti et al., 2011). The oils in normal conditions present phospholipids, free fatty acids, sterols, water and impurities (Meher et al., 2006). On the other hand, duck fat contains large proportions of lipids used as a cooking ingredient, a means of preserving food and cooking fat (Salas, 2012). Likewise, pork fat contains in its composition unsaturated and saturated fatty acids, among which we have: oleic, stearic and palmitic acid (Juárez, 2008).
The aforementioned studies show that the use of fats is efficient for the production of diesel and is a favorable alternative to reduce the high percentage of the levels of hydrocarbons, sulfur, carbon monoxide among other polluting elements that are produced by the automobile fleet. Therefore, this research evaluated the obtaining of biodiesel from oil extracted from pork and duck fat, comparing them with common diesel to evaluate the parameters and their quality by meeting the requirements set forth in the ASTM D6751 standard.

2. Materials and methods

2.1 Collection of samples

The samples were collected from the meat markets of the city of Lima, Peru. A total of 2 kg of each fat (pork and duck) were collected. They were selected and then washed to remove any contaminating residue.

2.2 Extraction of oil from pork and duck fat

For the oil extraction process, the samples were subjected to a heating process at a temperature of 100 °C to extract the oil (see Figure 1). Later they were filtered to eliminate residues and impurities, obtaining the refined oil. To demonstrate oil quality, samples of both pork and duck oil were physically and chemically characterized to determine the parameters of density, kinematic viscosity, and acidity index. For this, the test method ASTM D4052, ASTM D 445-04 and AOCS Cd-3d-63, respectively, was used.

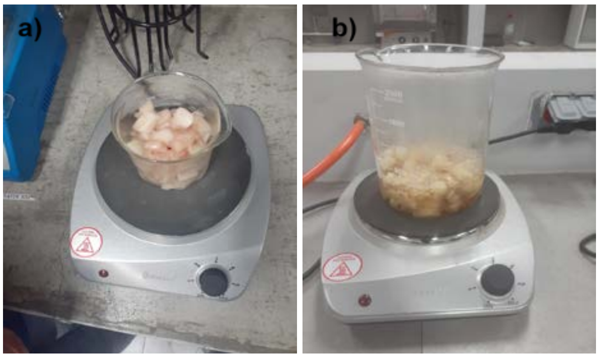

Figure 1: Process for obtaining biodiesel: a) pork fat and b) duck fat

Table 1: Mixing ratio for obtaining biodiesel.

Fat source	Samples	Oil volume (mL)	Catalyst (potassium hydroxide)	Methanol volume (mL)
Pork	M1	200	1,5 g	50
	M2	250	1,5 g	50
	M3	300	1,5 g	50
	M4	200	1,5 g	75
	M5	250	1,5 g	75
	M6	300	1,5 g	75
Duck	M7	200	1,5 g	50
	M8	250	1,5 g	50
	M9	300	1,5 g	50
	M10	200	1,5 g	75
	M11	250	1,5 g	75
	M12	300	1,5 g	75

For this process, six mixing proportions were made, as shown in Table 1. To carry out the transesterification reaction, first the methoxide was prepared, which is the mixture of methanol with potassium hydroxide, then it was combined with the oil, and was subjected to constant stirring at a speed of 300 rpm and a temperature of 60 °C for 2 hours. Subsequently, the mixtures were left at rest for 24 hours to separate the glycerin by sedimentation, and the supernatant was filtered to eliminate impurities, and finally the biodiesel was obtained.

2.3 Characterization of biodiesel

The physical and chemical characterization of biodiesel was carried out in the renewable energy laboratory from Universidad Nacional Agraria La Molina (UNALM). The parameters (physical and chemical) determined were density, kinematic viscosity, acidity index, lower calorific value and moisture content. This characterization was carried out for both the biodiesel from pork fat and duck fat. For this, the test method ASTM D4052, ASTM D 664-04, ASTM D 445-04, ASTM D 7582 and ASTM-D240, respectively, was used. The results were compared with the values established in the ASTM D6751 standard (Table 2).

Table 2: Requirements for the quality of biodiesel

Parameters	ASTM D6751	Testing method
Density (g/mL)	0.8 - 0.9	ASTM D4052, ASTM D1298
Viscosity to 40° C (mm2/s)	1.9 - 6.0	ASTM D445
Humidity content (%)	≤ 0,05	ASTM D2709
Acidity index (mg KOH/g)	≤ 0,5	ASTM D664
Lower calorific value (Cal/g)	≤ 7528	ASTM D2709

3. Results and discussion

3.1 Pork fat and duck fat oil

The results of characterization of the oil from both pork fat and duck fat are shown in Table 3. It was observed that duck oil presented slightly higher values of density, kinematic viscosity and acidity index with respect to pork oil, indicating that both oils have very similar characteristics.

Table 3: Physical and chemical characterization of the oil

Oil source	Density (g/mL)	Kinematic viscosity to 40 ºC (mm^2/s)	Acidity index (mgKOH/g)
Pork oil	0.921	28.37	0.59
Duck oil	0.943	30.58	1

3.2 Biodiesel

Table 4 shows the physical and chemical characterization of the biodiesel obtained from animal fats. The results of each mixing ratio (oil / alcohol / catalyst) were compared with the values shown in Table 1.
In Table 4 it is observed that the sample M2 (credo biodiesel) and M8 (duck biodiesel) presented the best results regarding the requirements established by the ASTM D6751 standard for the analyzed parameters. Both samples obtained density values of around 0.9g/mL, and these were higher than those found by Galeano and Guapacha (2011), and Gashaw et al. (2015), who obtained densities of 0.8758 g/mL and 0.8620 g/mL, respectively for biodiesel produced from recycled oils from common homes. Regarding kinematic viscosity, duck fat biodiesel presented a higher value (4.83 mm^2/s) than pork fat biodiesel (3.03 mm^2/s), indicating variability in kinematic viscosity that may be influenced by acids. fatty acids and the residual glycerin content (Mishra and Goswami, 2018; Moser, 2009). These values were compared and kinematic viscosity values of 4.5384 mm^2/s (Galeano and Guapacha, 2011) and 4.71 mm^2/s (Sierra-Vargas et al., 2015) were obtained for biodiesel produced from chicken fatty residues.

Table 4: Physicochemical parameters of biodiesel

Biodiesel source	Sample	Density (g/mL)	Kinematic viscosity to 40 ºC (mm^2/s)	Acidity index (mgKOH/g)	Lower calorific value (cal/g)	Humidity content (%)
Pork Biodiesel	M1	0,914	3.73	0.140	7697	0.0752
	M2	0,901	3.03	0.463	7448	0.0346
	M3	0.892	3.73	0.330	9153	0.0420
	M4	0.905	5.46	0.420	8088	0.1160
	M5	0.892	5.27	0.107	8401	0.0920
	M6	0.894	4.53	0.573	8401	0.0970
Duck Biodiesel	M7	0.861	6.52	0.617	7070	0.1150
	M8	0.892	4.83	0.510	7433	0.0250
	M9	0.902	6.82	0.327	8541	0.0200
	M10	0.885	6.37	0.830	7960	0.1320
	M11	0.886	3.22	0.317	7894	0.1340
	M12	0.913	6.17	0.583	7932	0.1240
ASTM D6751		0.8 – 0.9	1.9 – 6.0	≤ 0.5	≤ 7528	≤ 0.05

The lower calorific value and acidity index were also higher in the duck fat biodiesel (M8) with values of 7433 Cal/g and 0.510 mgKOH/g, respectively. Meanwhile, biodiesel from pork fat (M2) presented values of 7448 Cal/g and 0.463 mgKOH/g, respectively. This indicates that the duck fat biodiesel releases a greater amount of energy, and has a greater amount of peroxides due to the oxidation of the ester bonds it contains (Bouaid et al., 2009). Dávila and Cortés (2017) achieved an acidity index of 0.34 mgKOH/g for a biodiesel from frying oils, a value very similar to that obtained from pork fat.
The humidity results for the selected samples (M2 and M8) were 0.0346 and 0.0250% for the biodiesel from pork fat and duck fat, respectively. These results are lower than those obtained by Tsoutsos et al. (2019) that obtained a moisture content of 0.3220% for a biodiesel generated from recycled cooking oil. For this, Zuleta et al. (2012) recommend the use of vacuum evaporation systems to achieve better water extractions without damaging the biodiesel.

3.3 Advantages of using animal fats in biodiesel production

The use of animal fats in the production of biodiesel is an environmentally and economically favorable alternative. Environmentally, because it reduces the contamination caused by the meat industry waste resulting from the growing annual consumption of meat, and also seeks to take advantage of the various animal wastes to generate clean energies that reduce carbon emissions. In economic terms, the costs of obtaining the raw material will be minimal because most of these wastes are discarded at meat marketing stands. In addition, animal fats have a considerably lower cost than vegetable oils (Ferrero et al., 2021).
On the other hand, much research has shown that animal fats can be effectively transformed into a high quality biodiesel that meets ASTM specifications (Ferrero et al., 2021). This is one of the reasons that allowed biodiesel to receive great attention in several countries, in addition to being a non-toxic, biodegradable and renewable diesel fuel (Alptekin et al., 2014).

4. Conclusions

Pork and duck fat are residues that can be used as energy (biodiesel), and could be used as alternatives to common diesel. The best mixing proportions (oil / alcohol / catalyst) to obtain the biodiesel were sample M2 (250 mL of pork oil, 1.5g of catalyst, 50 mL of methanol) and sample M8 (250 mL of duck oil, 1.5g of catalyst, 50 mL of methanol). Both samples showed favorable values of density, kinematic viscosity, acidity index, lower calorific value and moisture content established by the ASTM D6751 standard.

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