

# Physicochemical characterization of biodiesel derived from chicken fat as an alternative for clean production in Sabana of Túquerres-Nariño

## Caracterización fisicoquímica de biodiésel derivado de grasa de pollo como alternativa de producción limpia en la Sabana de Túquerres - Nariño

José Mera-Ayala<sup>1\*</sup>  
 Danilo Revelo-Vargas<sup>2</sup>  
 Milton Mora-Martínez<sup>3</sup>  
 Jonathan Pérez-Barón<sup>4</sup>  
 Yuliana Areiza-Rico<sup>5</sup>

<sup>1\*</sup> Servicio Nacional de Aprendizaje SENA (Colombia); email: [jmera@sena.edu.co](mailto:jmera@sena.edu.co);  
 ORCID: <http://orcid.org/0000-0001-5582-542X>

<sup>2</sup> Servicio Nacional de Aprendizaje SENA (Colombia); email: [drevelo@sena.edu.co](mailto:drevelo@sena.edu.co);  
 ORCID: <http://orcid.org/0000-0002-9172-8763>

<sup>3</sup> Servicio Nacional de Aprendizaje SENA (Colombia); email: [mmoram@sena.edu.co](mailto:mmoram@sena.edu.co);  
 ORCID: <http://orcid.org/0000-0002-5564-3906>

<sup>4</sup> Servicio Nacional de Aprendizaje SENA (Colombia); email: [jonnas1982@gmail.com](mailto:jonnas1982@gmail.com);  
 ORCID: <http://orcid.org/0000-0001-8112-9401>

<sup>5</sup> Servicio Nacional de Aprendizaje SENA (Colombia); email: [yareiza@sena.edu.co](mailto:yareiza@sena.edu.co);  
 ORCID: <http://orcid.org/0000-0003-3988-5996>

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## Resumen

Actualmente, existe una alta dependencia en zonas limítrofes de Colombia por el suministro constante de combustibles derivados del petróleo. La generación de biocombustibles a partir de materiales grasos biológicos de bajo costo, fácil adquisición y que minimicen los impactos ambientales, son temas de investigación. El objetivo de este trabajo fue evaluar las características fisicoquímicas de biodiésel derivado de grasa de pollo, la cual es manejada como residuo agroindustrial del proceso de transformación en las granjas avícolas de la subregión de la sabana de Túquerres del departamento de Nariño, Colombia. Se evaluó la grasa de pollo ó aceite de pollo sometido a procesos de extracción, purificación y transesterificación, por medio de una catálisis básica, utilizando como catalizador hidróxido de sodio en una fase alcohólica de metanol. Los resultados de los análisis del biodiésel de grasa de pollo, cumplieron con lo estipulado en la NTC 5444, a excepción del parámetro de viscosidad ( $7,5 \text{ mm}^2/\text{s}$  a  $40^\circ \text{C}$ ), el cual es superior a lo establecido en la norma. La grasa de pollo es una materia prima alternativa en la producción de biodiésel convencional en las zonas de producción, que cumple con las especificaciones de la normatividad colombiana, de acuerdo a la NTC 5444, y podría ser utilizado en cualquier motor de combustión diésel, para obtener beneficios, como proceder de una fuente renovable, un menor contenido de azufre y contribuir en la búsqueda de sostenibilidad.

**Palabras clave:** biocombustibles; fuente de energía; grasa animal; residuos; transesterificación.

## Abstract

Currently, there is a high dependence in border areas of Colombia for the constant supply of petroleum fuels. The biofuels generation from low-cost biological fat materials, easy acquisition and minimizing environmental impacts, are research topics. The objective of this work was to evaluate the physicochemical characteristics of biodiesel derived from chicken fat, which is managed as an agro-industrial waste of the transformation process in the poultry farms of the Sabana Sub Region, Nariño Department, Colombia. Chicken fat oil was evaluated to extraction, purification and transesterification processes by means of basic catalysis, using sodium hydroxide in an alcoholic phase of methanol. The results of the chicken fat biodiesel analysis comply with the stipulations of NTC 5444, with the exception of the viscosity parameter ( $7.5 \text{ mm}^2/\text{s}$  at  $40 \text{ }^\circ\text{C}$ ), which is higher than the one established in the rule. Chicken fat is an alternative raw material in the production of conventional biodiesel in the same production areas, which meets the specifications of Colombian regulations according to NTC 5444, and could be used in any diesel combustion engine, with benefits like a lower sulfur content and contributing to the research for sustainability.

**Keywords:** biofuels; energy source; animal fat; waste; transesterification.

## Introduction

Today, there is a great boom worldwide by obtaining clean energy and fuels that totally or partially replace the use of fossil fuels in mechanical systems. This initiative promotes the use of vegetable or animal oils in the production of diesel-type biofuel, in order to reduce the economic and environmental impacts generated by the use of traditional combustion, without compromising food security (Saka; Kusdiana, 2001; Montenegro; Sierra; Guerrero, 2012) and keeping the optimum engine performance.

In countries like Colombia, bordering populations far away from the main cities have a high dependence on the constant supply of petroleum-derived fuels and depend on contiguous nations to solve their energy demands (Kirubakaran; Arul, 2018). However, distances and transportation costs mean that in some cases fuel supply is scarce and many of the industries are affected. Therefore, the production of an alternative biofuel is proposed based on the use of low-cost and easily acquired animal fat, which contribute to the reduction of biodiesel production expenses (Purandaradas *et al.*, 2018), as is the case from chicken fat, from which fatty acids useful for obtaining biodiesel can be extracted. The fat has a high availability in the department of Nariño because the main poultry activity in the region is the production of broiler chickens, followed by the production of chickens for posture (Pasto Chamber of Commerce, 2018). 50 % of the production is located in the Sabana Sub-region (Guaitarilla, Imués, Ospina, Sapuyes and, Túquerres). Between 22 to 25 % of the total weight of the chicken offal corresponds to the skin, mainly composed of lipids of 32 to 36.5 % (Kyung; Gandemer, 1987), which can be an alternative source for biodiesel production in the region.

The pure biodiesel obtained is biodegradable, without toxicity, free of sulfur and aromatic compounds independently of the alcohol and vegetable oil used (Reyes; Sepúlveda, 2006). In addition to the oil and the catalyst, we also choose to use methanol over ethanol for the economic benefits and the best properties that its use brings (Muniyappa; Brammer; Nouredini, 1996; López; Goodwin; Bruce; Lotero, 2005; Mendonça *et al.*, 2019), resulting, in general, a biodiesel with minimal amounts of sulfur, and that due to the content of oxygen in its chemical composition, presents a more complete combustion, reducing the emission of particles, carbon monoxide, and hydrocarbons not burned (Castro; Castillo; Nazario; Coello; Guevara, 2008).

Transesterification is one of the most used methods in the production of biodiesel from vegetable or animal fat (Hincapié; Mondragón; López, 2011; Zhang; Chen; Yang; Yan, 2010; Alptekin; Canakci, 2009; Montenegro *et al.*, 2012), with the presence of a basic catalyst (Gürü; Artukoglu; Keskin; Koca, 2009) or heterogeneous acidic or basic catalysis to avoid saponification problems (Arnaud, Trystram, Relkin; Collignan,

2006), using sodium hydroxide ( Becerra; López; Centeno; Giraldo, 2008). In addition, the compounds and materials to be used at the laboratory level are unexpensive and feasible to acquire (Arias; Teuta; Parra, 2011). According to Saleh (2011), this method is based on an exchange of the molecules of an ester and a low-density alkyl, obtaining alkyl-ester chains ( $C_xH_yO_2$ ) very similar to the diesel molecule ( $C_{16}H_{34}$ ), except for the oxygen that It is released with combustion gases, generating glycerin as a byproduct (Šimáček *et al.*, 2011).

Transesterification is a reversible process, where alcohol is used in excess in order to achieve balance to the production of esters. Methanol ( $CH_3OH$ ), in the course of the reaction, forms emulsions that dissolve easily, however, it is not miscible with triglycerides, as a consequence, mechanical agitation is necessary, in order to facilitate mass transfer (Steer; Velarde; Cascante, 2017). Therefore, the objective of this research was to evaluate the physicochemical characteristics of biodiesel derived from chicken fat, agro-industrial waste of the transformation process in the poultry farms of the savanna subregion of the department of Nariño.

## Materials and methods

Biodiesel production was carried out at the Tecnoacademia facilities of the South Colombian Center for International Logistics, SENA - Regional Nariño, located in the municipality of Túquerres, department of Nariño (Colombia), located 4,070 meters above sea level (masl) at an average temperature of  $11 \pm 1$  °C and an average relative humidity of 70 %.

### Oil extraction and purification

A sample of 750 g of the fat tissue generated as a residue of the transformation processes in the poultry farms of the Saquerres savanna was used. The sample was subjected to a heating process at 70 °C in an electric oven (HACEB, model EM-1), for 20 min, in order to break down the cell tissues and extract the liquid oil. Subsequently, filter paper was used to separate the oil from the other tissues and, finally, the oil was subjected to dehumidification on a stirring and heating plate (Thomas Scientific, Hotplate and stirrer) at a temperature of 105 °C for 15 min as illustrated in Figure 1, from which the oil was obtained.

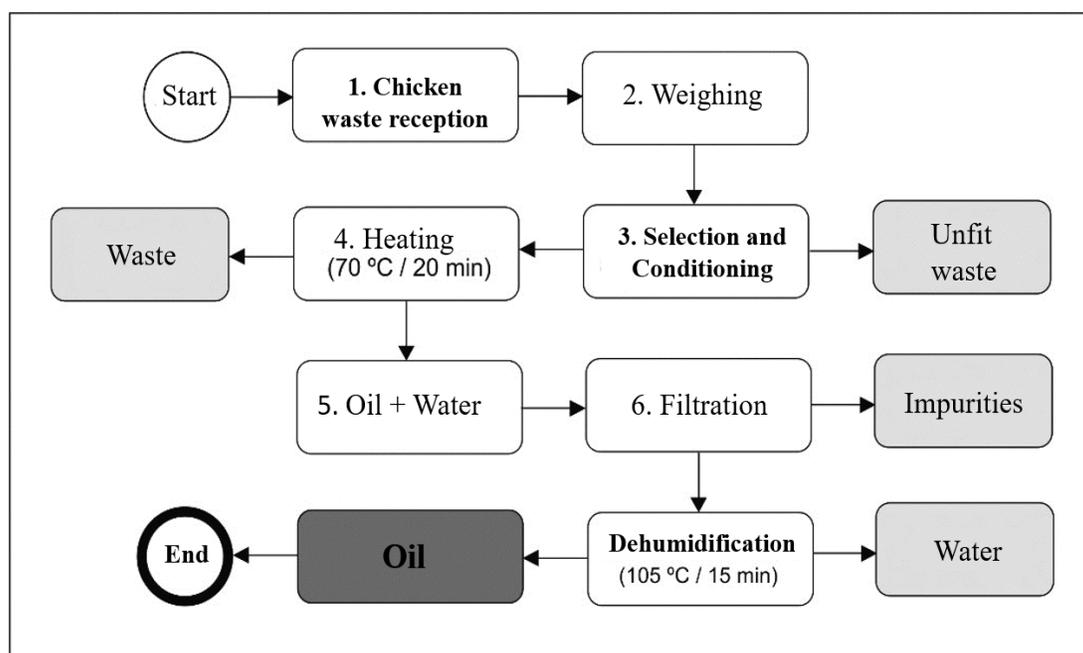


Figure 1. Flowchart for the extraction and purification of chicken fat oil  
Source: self-made.

## Chicken oil characterization

Chicken fat oil was subjected to analysis of physicochemical properties in order to characterize the final product after the chemical reaction. Oil density was determined by means of a digital densimeter (ASTM D4052, ASTM, 2018); and the properties concerning the characteristics of instauration, amount of oxygen incorporated and total acidity of the samples, were determined by means of refractive index methods (NTC 289, ICONTEC, 2002), peroxide index (NTC 236, ICONTEC, 2011) and acidity index (ASTM D664, ASTM, 2017), respectively.

## Chicken oil transesterification and biodiesel production

Initially, chicken oil or chicken fat was preheated to a temperature of  $50 \pm 1$  °C on a stirring and heating plate (Thomas Scientific, Hotplate /stirrer). The preparation of the alcoholic methanol phase was carried out by mixing and initial reaction with the sodium hydroxide catalyst, because of its advantage of dissolving in oil in the presence of methanol, it is chosen due to the solubility, it is more efficient and cost-effective (Kirubakaran; Arul, 2018), which was added to the reactor in a proportion of 0.5 % based on the oil content. It was decided to use a methanol content in excess of 200 % to obtain a stoichiometric molar ratio of alcohol: oil (3: 1), as recommended by Sánchez-Cantú et al., (2019), where the predominant fatty acid was taken as oleic acid, which represents 41 % (Amado; Villamizar; Gafaro, 2005). Finally, the transesterification reaction was mixed and carried out for 60 min.

## Biodiesel Separation and Purification

For the separation of the two phases formed (biodiesel and glycerin) in the transesterification reaction, the products were subjected to a decantation process for 30 min as shown in Figure 2. Subsequently, two washes were carried out with acetic acid (6 % v/v) to remove sodium hydroxide. Water and residual methanol were removed by heating the biodiesel at 105°C (Thomas Scientific, Hotplace/stirrer) for 15 min.

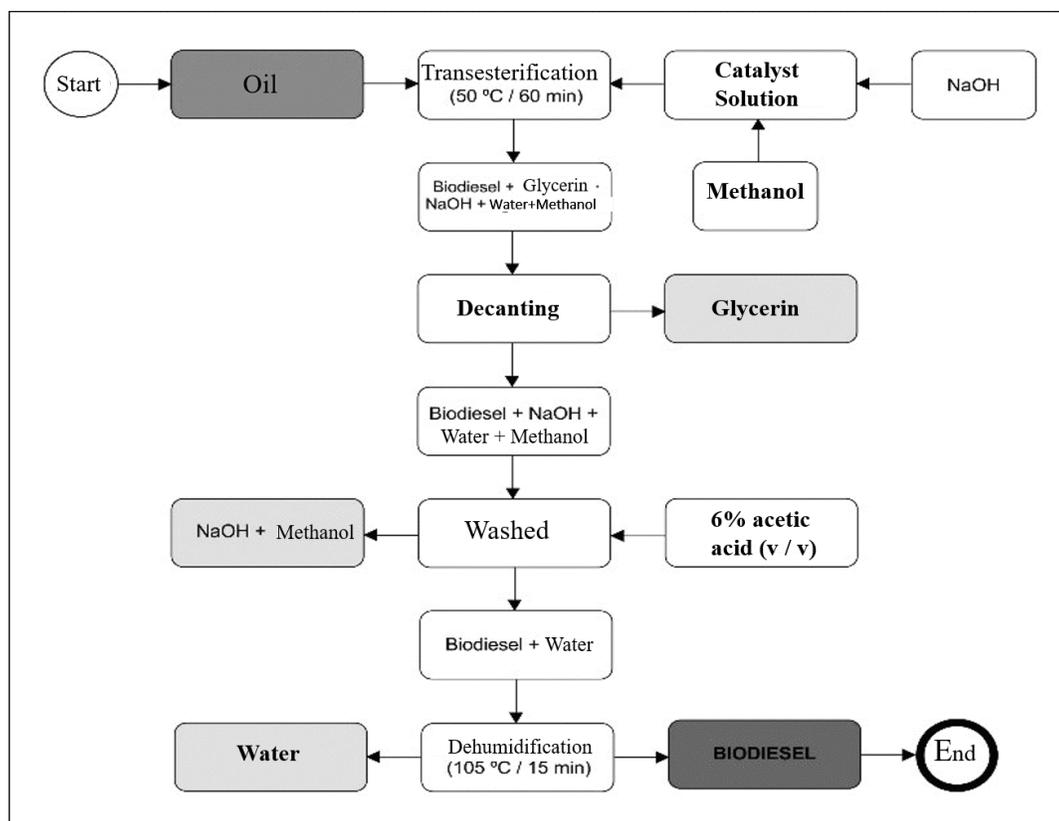


Figure 2. Flowchart for the production and purification of biodiesel from chicken fat  
Source: self-made.

## Biodiesel characterization

The properties of biodiesel obtained from chicken fat were evaluated, with the following properties: density (ASTM D4052, ASTM, 2018), methanol content (UNE-EN 14110, European Standard EN, 2003), moisture content (NTC 287, ICONTEC, 2018), viscosity at 40 °C (ASTM D445, ASTM, 2018), acid number (ASTM D664, ASTM, 2017), flash point (ASTM D93, ASTM, 2018), sulphated ash (ASTM D874, ASTM, 2018) and lower calorific value (ASTM D5865, ASTM, 2013). These properties were compared, according to NTC 5444 (biodiesel for use in diesel engines: specifications, ICONTEC, 2018).

## Results and Discussion

### Characterization of chicken oil or chicken fat

The results of the characterization of the oil obtained from chicken fat and its comparison with soybean oil, according to the Colombian Technical Standard (NTC 254, ICONTEC, 2016) is recorded in Table 1.

**Table 1.**

*Characterization of the oil obtained from chicken fat*

Property	Chicken fat oil	Soy oil (NTC 254)	Testing method
Density 13 °C (kg/m <sup>3</sup> )	922,9	917 - 924	ASTM D4052 (ASTM, 2018)
Refractive index a 12,2 °C	1,4674	1,4760 – 1,4720	NTC 289 (ICONTEC, 2002)
Peroxide index (m-eq g de O <sub>2</sub> /kg)	3,0	5 máximo	NTC 236 (ICONTEC, 2011)
Acidity index (mgNaOH/g)	0,2	0,1 máximo	NTC 218 (ICONTEC, 2011)

Source: self-made.

According to the results of Table 1, it was evidenced that with the exception of the acidity index parameter (0.2 mg NaOH/g), chicken fat oil complies with the provisions of NTC 254 (ICONTEC, 2016), standard on which the parameters of the oil currently marketed in Colombia are based. Therefore, the viability of producing oil from animal sources is clear, complying with Colombian regulations.

### Biodiesel characterization

The evaluated properties of the biodiesel obtained were compared with NTC 5444 (ICONTEC, 2018), which specifies the characteristics of the biodiesel for use in diesel engines (Table 2).

Chicken fat biodiesel complies with the provisions of NTC 5444 (ICONTEC, 2018) (Table 2), with the exception of the viscosity parameter whose value was higher than that established in the standard. However, according to Rakopoulos; Papagiannakis and Kyritsis (2011), the viscosity of biodiesel is usually higher than commercial diesel, in that case, the engine will require more power for its operation, and thus avoid difficulties generated by the variation in the flow of fuel during combustion and a possible reduction of engine efficiency (Alptekin; Canakci 2009; Pehan; Jerman; Kegl; Kegl; Kirubakaran; Arul, 2018). Therefore, to reduce the viscosity of biodiesel, it is recommended to make a standard mixture of B5 or B10 (5 % biodiesel – 95 % diesel or 10 % biodiesel – 90 % diesel).

**Table 2.**

Characterization of biodiesel obtained from chicken fat

Property	Testing method	Chicken Fat Biodiesel	Biodiesel B100 (NTC 5444)	Other authors
Density 15 °C (kg/m <sup>3</sup> )	ASTM D4052 (ASTM, 2018)	892,8	860 - 900	867 (Bhatti; Hanif; Qasim; Rehman, 2008) 858,9
Methanol content (% mass)	ISO 14110 (EN, 2003)	0,001	0,2 maximum	0,06 (Kirubakaran; Arul 2018)
Moisture content (mg/kg)	NTC 287 (ICONTEC, 2018)	120	500 maximum	100 (Bhatti <i>et al.</i> , 2008)
Viscosity to 40 °C (mm <sup>2</sup> /s)	ASTM D445 (ASTM, 2018)	7,5	1,9 - 6,0	4,71 (Montenegro <i>et al.</i> , 2012)
Acidity index (mgNaOH/g)	ASTM D664 (ASTM, 2017)	0,2	0,5 maximum	0,25 (Bhatti <i>et al.</i> , 2008)
Flashpoint (°C)	ASTM D93 (ASTM, 2018)	169	120 minimum	180 (Gürü <i>et al.</i> , 2009) 164 (Montenegro <i>et al.</i> , 2012)
Sulphated ash (%mass)	ASTM D874 (ASTM, 2018)	0,02	0,02 maximum	0,02 (Ramos; Fernández; Casas; Rodríguez; Pérez, 2009)
Lower calorific value (kJ/kg)	ASTM D5865 (ASTM, 2013)	39.456,1	+/- 39.500	44.947,5 (Gürü; Koca; Can; Cinar; Sahin, 2010)

Source: self-made.

According to Torres *et al.*, (2011), it could be evidenced that the density in the biodiesel obtained is adjusted within the parameter of the norm, which allows reducing the risk of problems during combustion, such as delays in injection and decreased engine performance, which are caused by densities outside of the standard.

Regarding the methanol content, which is a biodiesel quality parameter, it could be shown that the result obtained is a significantly low value, the product of a total reaction during transesterification. An incomplete reaction can lead to low cetane number and high glycerin percentages, generating blockages in the injectors (Arias *et al.*, 2011).

Regarding the moisture content, it was shown that the result of 120 mg/kg was low, according to parameters of NTC 5444 (ICONTEC, 2018); similar to the result reported by Bhatti *et al.*, (2008), of 100, 200 and 150 mg/kg with chicken fat biodiesel, ram and cooking oil, respectively. This parameter is related to the lower calorific value, because of the lower the moisture content, the greater its calorific value. Rakopoulos *et al.*, (2011) state that the hygroscopic property of ethanol and methanol is associated with its water content, which can be increased if biodiesel is not stored in a suitable container (Geller; Adams; Goodrum; Pendergrass, 2009). The presence of water can cause phase separation in mixtures with commercial diesel, as well as corrosion and proliferation of microorganisms that affect the quality of the biodiesel (Arias *et al.*, 2011).

It was also noted that the Acidity Index of 0.25 mg NaOH/g coincides with that reported by Bhatti *et al.*, (2008), in their study of biodiesel production of discarded fat, which includes chicken fat as a competitive alternative to conventional diesel.

On the other hand, the reported flashpoint was 169 °C, whose value represents an important effect on engine power, so that when the biodiesel concentration content in the fuel mixed with diesel and biodiesel is increased, it will also increase engine power similar to that of biodiesel from multiple vegetable oil sources (Ramos *et al.*, 2009; Hoseini *et al.*, 2019), which conforms to the provisions of NTC 5444 (ICONTEC, 2018), which is considered a Safety index for handling and deposit of biodiesel.

The sulfated ash content obtained meets the requirement of the standard, reducing the generation of deposits in the engine, which represents a cleaner fuel that will not harm its useful life (Kaplan; Arslan; Sürmen, 2006). In addition, the use of biodiesel, in contrast to diesel, is the high value of the flashpoint in biodiesel fuel and a higher cetane number, which is of great importance in combustion within diesel engines, improving performance and reducing the pollution produced (Hoseini *et al.*, 2019), converting chicken fat-based biodiesel into a viable aspirant to replace fossil fuels (Khan *et al.*, 2014).

As for the reported calorific value, similarity to what is stipulated in the standard was evidenced, however, this may increase if it is mixed with diesel in a ratio of 10 % biodiesel – 90 % diesel, as reported by Gürü *et al.*, (2010), who conducted a comparative study of the properties of diesel and mixing diesel with biodiesel obtained from chicken fat. Similarly, it is to be considered that biodiesel of vegetable origin has a higher cetane number than commercial diesel (Kaplan *et al.*, 2006), which can compensate for biodiesel with lower values of lower calorific value.

## Conclusions

Chicken fat generated as an agro-industrial waste in poultry farms is an alternative raw material for the production of biodiesel, which can be used in rural areas where access to conventional fuels is very difficult. The experimental results allowed us to identify the physical-chemical properties of chicken fat biodiesel, which complies with the specifications of Colombian regulations, according to NTC 5444, except for viscosity and could be used in any diesel combustion engine. It is recommended to perform a standardized mixture (B5 or B10) with commercial diesel, which would not represent negative effects during use since it does not require any engine modification. Likewise, chicken fat biodiesel stands out for its environmental qualities and clean production by coming from a renewable source, having less sulfur and contributing to sustainability as an alternative energy source.

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