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Chicken fat and biodiesel viscosity modification with additives for the formulation of biolubricants

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HIGHLIGHTS

- Purified chicken fat is a viable raw material for the production of biolubricants.
- Mixtures of chicken fat with EVA additive are biodegradable.
- Viscosity, rheological and thermic properties of biolubricant are as to a mineral one.

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ABSTRACT

This study aimed to develop a lubricant from chicken fat and biodiesel, using additives to meet the standards of physicochemical and environmental quality of the ISO 15380-2012.

The raw material was extracted directly from chicken skin; using two methods: autoclaving and direct heating, being the latter which generated the higher extraction yield (52.06%). Fat purification (physical refining) was performed by degumming, bleaching and fractionation, where in the fat was transformed from a two-phase mixture to a single-phase solution with improved physicochemical characteristics: viscosity, acid value and mainly fatty acids (48.21%) with prevalence of oleic acid. Viscosity modifiers were added in different ratios (EVA and SBS) following a categorical multifactorial experimental design. As a result, fat mixed with EVA 3 and 4% generated products with similar physicochemical properties to a commercial lubricant, i.e. kinematic viscosity at 40 °C and 100 °C was 108.47 to 174.78 and 20.65 to 27.47 mm^2/s, respectively.

Biodegradability of formulations were estimated with the BOD5/COD to give a value of 0.6 showing that the product is biodegradable. Thermogravimetrical analysis were done and results demonstrate that thermogravimetrical characteristics are improved if are compared with those of mineral lubricants.

Results from this work show that chicken fat is a viable alternative to formulate biolubricants with physicochemical and thermic characteristics to those from commercial lubricants with the advantage of coming from a residual feedstock and being biodegradable.

1. Introduction

The majority of lubricants derived from oil reserves have caused serious environmental damages, mainly because they are not biodegradable. The growing international concern for environmental protection has encouraged the development of new lubricant bases, which are less polluting impact. Because of this, some European countries have created new environmental regulations that have forced many manufacturers to develop bio-lubricants, using vegetable oils as the bulk component of the formulation, and non-toxic and biodegradable additives [1–3].

Castor, jojoba, palm, coconut, tallow, soybean, olive, sunflower and rapeseed oils are among the various vegetable oils that have been used as raw material for biolubricants [4]. However, there are other natural sources that can be used for processing, for example animal fat from poultry waste (chicken fat) with 30–40% fat content. Poultry industries generate wastes during processing, in some food companies sell these residues to produce livestock feed and fertilizer starters, while others, simply dispose of them improperly [5,6]. This may be a viable alternative for biolubricant production because as vegetable oils, these are composed of

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triglycerides. Natural oils are excellent lubricants at moderate temperatures, but only contribute about 2–5% in the market for lubricating oils. The reason for this is their low oxidative stability [7]. These disadvantages can be offset by chemical modification of the fatty acids present in the oil by forming stolid [8,9], epoxidation of the double bonds of fatty acids [10], or the use of additives, as in the case of viscosity modifiers and antioxidants [11].

This paper aims to formulate a biolubricant from chicken fat waste and biodiesel with the use of additives; ethylene vinyl acetate (EVA) and styrene butadiene styrene (SBS), to meet the physicochemical quality standards.

Chicken fat is a viable alternative for several reasons. Firstly, as a waste it can be used as a product (biolubricant) giving added value, secondly because it is degradable either by accidental spill or for final disposal in soil or water.

2. Materials and methods

2.1. Materials

The fat residue used (chicken skin) was collected in different markets and chicken outlets in the municipality of Tuxtla Gutierrez, Chiapas, Mexico. All the analytical grade reagents were purchased from Sigma-Aldrich.

2.2. Chicken fat extraction

The raw material for the biolubricant formulation was extracted directly from chicken skin by testing two methodologies: First autoclaving: chicken skin was heated to 120 °C (15 psig) in a flask. The time trials were 20, 40 and 60 min. The liquid phase was separated and the fat was heated again to 90 °C to remove residual water then filtered at 40 °C [12]. Second by direct heating: fatty residues were subjected to 95 °C during 3 h, cooled and filtered at 40 °C [13].

2.3. Chicken fat purification (Physical Refining)

The obtained fat was degumming, bleaching/deodorized and finally fractionated. Degummed was performed according to the proposal from Ref. [14]. To bleach/deodorize the degummed chicken fat was heated to 80 °C and added with 3% w/w of activated carbon. The mixture of fat and coal was stirred for 15 min at 80–90 °C, then it was cooled to room temperature and filtered under vacuum. Finally the fractionation step was conducted by crystallization at room temperature and filtered under vacuum for separating liquid clean chicken fat (olein) and solid (stearin) [15].

2.4. Transesterification process

Biodiesel was made using our chicken fat following the method described by Alptekin et al. [5]. Methanol was used as alcohol and potassium hydroxide (KOH), as catalyst for transesterification. Molar ratio between alcohol and fat was 6:1, a temperature of 60 °C and stirring of 600 rpm.

2.5. Preparation of biolubricating oil formulations

2.5.1. Experimental design

A categorical multifactorial experimental design was used with two factors: raw material and additives concentration of EVA and SBS, designed in the statistical program Statgraphics Centurion XV©, and oil viscosity as response variable in cSt. The formulation of the analyzed mixtures are expressed in Table 1.

2.5.2. Preparation of formulations

Blends were prepared by stirring at 600 rpm and agitation times of 2 h at 120 °C, depending on polymer nature and concentration. This thermal treatment was required to completely solubilize the polymer in fat. Afterward, all samples were cooled to room temperature. A single homogeneous phase was obtained in all cases [11,16].

2.6. Raw material characterization

Physicochemical characterization of raw material was made before and after purification. The following analysis were performed: oxidative stability (EN 14112), kinematic viscosity (ASTM D7042), viscosity index (ASTM D2270), density (EN ISO 3675) and acid number (ASTM-D-664).

2.7. Gas chromatography analysis

A gas chromatograph 5975 inert XL (GC, Agilent Technologies) with a DBWax (Agilent Techologies) capillary column (60 m × 0.25 mm × 0.25 μm), was used to determine fatty acid composition of the chicken fat before and after purification. 1 μL was injected (injector at 250 °C), oven at 150 °C which was maintained for 5 min, subsequently raised to 210 °C using a heating rate 30 °C/min it went from 210 °C to 213 °C at a rate of 1 °C/min, finally at 225 °C at a rate of 20 °C/min, for 20 min for a total of 30.6 min. Helium was used as carrier gas at a flow of 1 mL / min. All analysis were made by triplicate.

2.8. Rheological study of biolubricating oil formulations

Dynamic viscosities were measured with a rotational controlled-strain rheometer (Paar Physica RHEOLAB MC 1), in a temperature range between 25 and 80 °C. Viscous flow tests were carried out in a shear rate range of 10–500 s^{-1} using the measurement system cylindrical according to DIN 54453 standard. Two replicates of each test were performed on fresh samples.

2.9. Thermogravimetric analysis

Decomposition characteristics were determined with a Q500 TA Instruments (New Castle, DE). About 20 μL of each sample was placed in the platinum pan and heated from 30 to 700 °C at a heating rate of 10 °C/min under nitrogen atmosphere.

2.10. Biodegradability test

BOD_5/COD ratio has been used to assess the biodegradability of a substance [17]. The procedure for determining the chemical oxygen demand was according to the Mexican Standard NMX-AA-030-SCFI-2001.

3. Results and discussion

3.1. Chicken fat extraction

According to the results the highest yield was obtained by direct heating with a yield of 52.06% extraction. With the autoclave method two phases were obtained, and in order to eliminate water it was necessary to heat at 90 °C. The results of our measurements are shown in Table 2. Other works [12,13] indicate that regardless of the extraction method used, the fat content in the waste depends on intrinsic factors (breed of animal, feed and part of chicken extract).

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