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Oil Derived from Fats of Animals and Poultry as Additives to Diesel

K Vijayaraghavan[1*] and SP Kamala Nalini[2]

[1]Department of Biotechnology, Hindustan Institute of Technology and Science, Hindustan University, Padur, Chennai, Tamil Nadu, India

[2]Department of Plant Biology and Plant Biotechnology, Sir Theagaraya College, Washermanpet, Chennai, Tamil Nadu, India

[*]**Corresponding author**: K Vijayaraghavan, Department of Biotechnology, Hindustan Institute of Technology and Science, Hindustan University, Padur, Chennai, Tamil Nadu, India, Tel: +91-44-27474262; Fax: +91-44-27474208; E-Mail: vijaya025@yahoo.com

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Abstract

A novel method of solid waste treatment is proposed with the concept of biodiesel production using waste fats obtained from goat, pork, and chicken as feedstocks. The fats of animals and poultry were converted into the oil using rendering operation. The efficiency of rendering operation was determined based on the mass of oil production from a known mass of fat. The results showed that the conversion efficiency from fats to oil was 88% ± 2%, 91% ± 1%, and 92% ± 1% respectively with respect to goat, pig, and chicken fat. The formed oil was characterized for its density, kinematic viscosity, acid value, calorific value and its fatty acid composition. The calorific value of the oil determines its energy capacities towards burning. The results showed that goat, pig, and chicken oil had a calorific value of 39.894 ± 0.170 MJ/kg, 40.285 ± 0.220 MJ/kg, and 39.623 ± 0.120 MJ/kg. The GC-MS analysis showed the presence of oleic acid, eicosanoic acid and 1-octanol 2-butyl in goat oil. While 17-pentatriacontene, eicosanoic acid and n-hexadecanoic acid were the major compounds derived from pork oil. In the case of chicken oil E-2-octadecadecen-1-ol, eicosanoic acid, sulphurous acid and 2-propyl tetradecyl ester were predominant compounds. The current article explores a way in reducing solid waste and subsequently fingerprinting the compounds deriving from fat source. The characteristics of oil derived from waste fats would help to decide the blend ratio in biodiesel.

Keywords: Goat fat; Pig fat; Chicken fat; Fatty acids; Waste fat; Biofuel; Biodiesel

Introduction

The unprecedented demand in energy has occurred due to the exploitation of fossil fuel in the name of improved living standards, increased population, and industrialization; this in turn leads to environmental issues like global warming and acid rain. In-order to cope up with sustainable growth, renewable energy sources were found to be the only alternative for fossil fuel, due to the depleting fossil reserves and political instability coupled with increased price fluctuation [1-8].

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Fats and oils are used for a variety of purposes ranging from cooking, health products, cosmetics, soap and surfactant, and fuel. The quest for renewable energy has opened up new vistas in renewable energy resources like vegetable oil, algae, wood chips, grasses, solid wastes, and animal fats, which does not divert food into energy while removing the dent in the oil market. Deriving fuel from crop-based material such as soya, rapeseed, sunflower, and palm oil was once found to be a promising alternative source of energy, which had slowly given way for low-grade inedible fat and grease from food processing sector [9,10]. Based on the source of fats or oils the composition of fatty acids varies. Hence understanding the oil composition would help a lot in determining the environmental impact with respect to air pollution when used as a biofuel [11,12]. Even though vegetable oils were preferred to supply biodiesel demand, studies have also shown that non-edible oils, lipid wastes, and animal fat wastes are more suited biomass resources [13-18].

Triglyceride or triacylglycerols represent the esters of fat and oil, which were formed from one molecule of glycerol and three molecules of fatty acids. Monoalkyl esters of long-chain fatty acids are termed as biodiesel, which was obtained by the transesterification of vegetable oils or animal fats with short-chain alcohol in the presence of acid or alkali catalyst [19]. Biofuels derived from locally available resources help to reduce the dependence on fossil petroleum products. Fatty acid chains may contain one or more double bonds at specific positions (unsaturated and polyunsaturated), or they may be fully saturated. The composition of fatty acids reveals the degree of unsaturation and its varying chain length, which helps in distinguishing between liquid oils and solid fats. Direct analysis of fat having a high boiling point through gas chromatography is hindered. Hence fat has to be chemically decomposed into methyl esters of each fatty acid before subjecting to GC analysis [20]. Different methods like saponification, liquid-liquid partition, and chromatographic techniques were adopted to isolate the triacylglycerol matrix. Transesterification reaction of vegetable oil or animal fats with methanol in the presence of catalyst gives biodiesel. A mild reaction temperature, short reaction time, and atmospheric pressure; high biodiesel yield is obtained by using a homogeneous alkali catalyst in the transesterification process [19]. The fats derived from lard, beef, mutton, swine, and chicken were characterized using various analytical techniques viz: differential scanning calorimetric analysis [21,22], Fourier transform infrared spectroscopy [23], Gas Chromatography-Mass Spectrometry (GC-MS) [24] and elemental analyzer–isotope ratio mass spectrometry (EA-IRMS) [25,26].

The free fatty acid content in oil plays an important part in determining the technical criterion selection for the biodiesel production process. In this paper, we have described a method of fingerprinting the source of bio-oil derived from the fats of chicken, goat, and pork with respect to the fatty acid profiles obtained using GC-MS and the oil characteristics based on kinematic viscosity, density, acid value, flash point, and calorific value. The characteristics of oil derived from waste fats of animals and fowl would decide the blend ratio in biodiesel production for energy generation in an economically and environmentally sustainable way.

Materials and Methods

Reagents

The chemicals used were anhydrous ethanol, potassium hydroxide, acetic acid, boron trifluoride, chloroform, sodium chloride, sodium carbonate, and anhydrous sodium sulfate (analytical grade by SD Fine Chemicals, India).

Feedstocks

Crude fat samples were collected from the local butcher shops (Chennai, Tamil Nadu, India.) selling goat, pork, and chicken meat. The collected samples were transported to the lab in an ice-box preserved at 4°C for a maximum holding period of 4 hrs. Segregation and cleaning of the fat sample were carried-out in tap water to remove the adhering flesh and bloodstains. The

cleaned fat was preserved for a maximum period of 1 week at 0°C. Rendering operations were carried out under batch mode with 2.1 ± 0.1 kg. Traces of flesh present in the melted animal fats after rendering were removed by straining through a double-folded muslin cloth. During this process, the quantity of oil yield was recorded to determine the efficiency of the rendering operation. The filtered oil was stored at ambient room temperature 34 ± 3°C.

Analytical methods

The acid value was determined by the titrimetric method and iodine values were determined by the Wijs method (McCutcheon (1940). The density was determined by Leimco density hydrometer LEIMCO-M50, and the water content was measured by oven-drying methods [27]. The calorific value of oil was determined by the Toshniwal Bomb Calorimeter Model CC01/M2. Kinematic viscosity was determined using a capillary viscometer by Stanhope Seta - Model 83700-3) and the fatty acid profiles were estimated using GC-MS NIST 2008 library.

Fatty acid extraction from oil by esterification

The esterification reaction was carried out using ethanolic boron trifluoride. Fatty Acid Ethyl Esters (FAEE's) were extracted with hexane and analyzed by GC-MS. 100 g of oil was mixed with the chloroform-ethanol mixture (2:1) to which 10 ml NaCl solution was added and homogenized. The suspension was centrifuged followed by recovery of the chloroform phase. The dried extracts at 45°C under pressure were treated with ethanolic -sodium hydroxide at 85°C for 10 min. Ethanolic-Boron trifluoride was added dropwise to the sample, followed by hexane. Fatty acids were extracted using hexane by the addition of anhydrous sodium sulfate [28,29].

GC-MS analysis

A GC-MS analysis was performed using a Perkin Elmer-Clarus 680. The analysis employed a fused silica column, packed with Elite-5MS (5% biphenyl 95% dimethylpolysiloxane, 30 m × 0.25 mm ID × 250 μm df) and the components were separated using Helium as carrier gas at a constant flow of 1 ml/min. The injector temperature was set at 260°C during the chromatographic run. The 1μL of extract sample injected into the instrument the oven temperature was as follows: 60°C (2 min); followed by 300°C at the rate of 10°C min^{-1}; and 300°C, where it was held for 6 min. The mass detector conditions were maintained at: transfer line temperature 230°C; ion source temperature 230°C; and ionization mode electron impact at 70 eV, scan time 0.2 sec, and scan interval of 0.1 sec. The fragments were analyzed from 40 Da to 600 Da. The spectrums of the components of the fatty acid were compared with the database of the spectrum of known components stored in the GC-MS NIST-2008 libraries using the software TurboMass ver 5.4.2.

Results and Discussion

The characteristics of the oil derived from goat and pork and chicken fat are shown in **TABLE 1**. The density of goat, pork, and chicken oil was found to be 938 ± 2 kg/m^3, 945 ± 2 kg/m^3, and 917 ± 3 kg/m^3 respectively. Thus chicken oil was found to be less dense followed by goat and pork. A similar observation was made by earlier researchers who stated a density value of 948 kg/m^3 for pork fat and 894.1 kg/m^3 for chicken [30] and 921 kg/m^3 and 932 kg/m^3 [31-34], The saturated fatty acid content was found to be high in goat oil with almost 59 ± 4% followed by pork oil 27 ± 2% and chicken oil 17 ± 3% respectively. The corresponding unsaturated fatty acids were found to be 42 ± 3%, 62 ± 2%, and 69 ± 1% respectively.

The goat, pork and chicken foil had a calorific value of 39.894 ± 0.17 MJ/kg, 40.285 ± 0.22 MJ/kg and 39.623 ± 0.12 MJ/kg respectively which was in corroboration with the earlier researchers who had stated a calorific value of 39.5 MJ/kg and 39.6 MJ/kg for pork and chicken oil [33,35]. The calorific value of diesel derived from fossil fuel was found to be 43.6 ± 0.8 MJ/kg. Hence the oil derived from chicken, goat, and pork could serve as additive provided the viscosity of the oil blended with diesel, falls within the

desired range of operating value in the smooth running of the diesel engine. The use of animal and fowl oil as an additive could help to reduce the fossil fuel deficit and it would be handy in remote areas.

TABLE 1. **Characteristics of oil derived from goat, pig and chicken fats.**

Parameter	Goat Fat	Pig Fat	Chicken Fat
Density (kg/m^3)	938	945	917
Kinematic viscosity (mm^2/s)	45.03	43.05	40.03
Water content (g/kg)	0.262 ± 0.037	0.197 ± 0.059	0.123 ± 0.069
Acid value (mg KOH/g oil)	0.68	0.73	0.86
Iodine value (g iodine/ g oil)	73.7	72.4	68.2
Calorific value (MJ/kg)	39.894	40.285	39.223
Saturated fatty acid (%)	63 ± 4	27 ± 2	17 ± 3
Unsaturated fatty acid (%)	49 ± 4	62 ± 2	69 ± 1

The total ion chromatogram of the fatty acids ethyl esters from the saponified goat oil by the GC-MS analysis is shown in **FIG. 1**. The major compounds detected in the total ion chromatogram were found to be oleic acid, eicosanoic acid, 1-octanol 2-butyl, d-glucitol 1-s-heptyl-1-thio, octacosane, n-hexadecanoic acid, 17-pentatriacontene, octadecane 1-(ethenyloxy), octadecane 2-methyl, octacosane, nonadecane, heneicosane 11-(1-ethyl propyl), oxalic acid heptadecyl hexyl ester, cis-9,10-epoxyoctadecan-1-ol, heneicosane 11-(1-ethylpropyl) and 3-heptadecenal (**TABLE 2**). The electron ionization mass spectrum of 3 major compounds in goat oil was found to be oleic acid, eicosanoic acid, and 1-octanol 2-butyl, which displayed a m/z top peak as shown in **FIG. 2.**

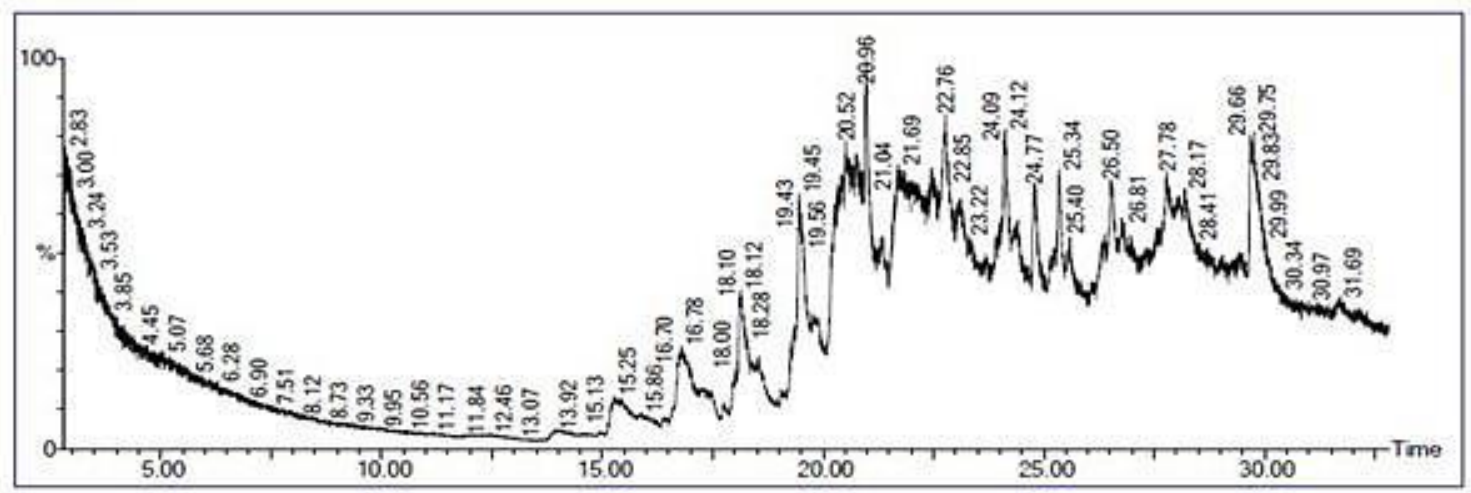


FIG. 1. **Chromatogram of fatty acid esters of goat oil.**

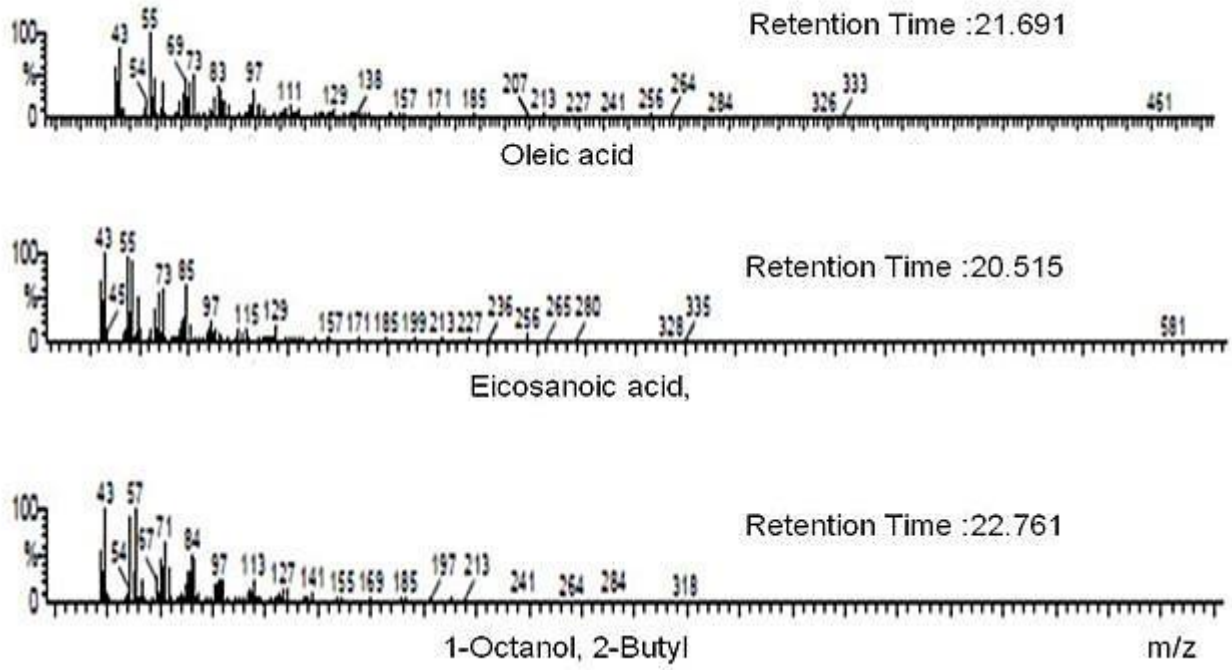


FIG. 2. **The mass spectrum m/z versus relative intensity of the major identified compound present in goat oil.**

The total ion chromatogram of the fatty acids ethyl esters from the saponified pork oil by the GC-MS analysis is shown in **FIG 3**. 17-pentatriacontene, eicosanoic acid, n-hexadecanoic acid, 1-octanol,2-butyl, 2-tert-butyl-4,6-bis (3,5-di-tert-butyl-4-hydroxybenzyl) phenol, eicosanoic acid, octadecanal 2-bromo, 1-hexyl-2-nitrocyclohexane, dodecane 2,6,11-trimethyl, n-hexadecanoic acid, octacosane, octadecane 3-ethyl-5-(2-ethylbutyl), tritetracontane, heptadecane 2,6,10,15-tetramethyl, octatricontane 1,38-dibromo are the major compounds detected in the total ion chromatogram **(TABLE 3)**. The electron ionization mass spectrum of the major compounds which displayed the m/z top peak is as shown in **FIG 4.**

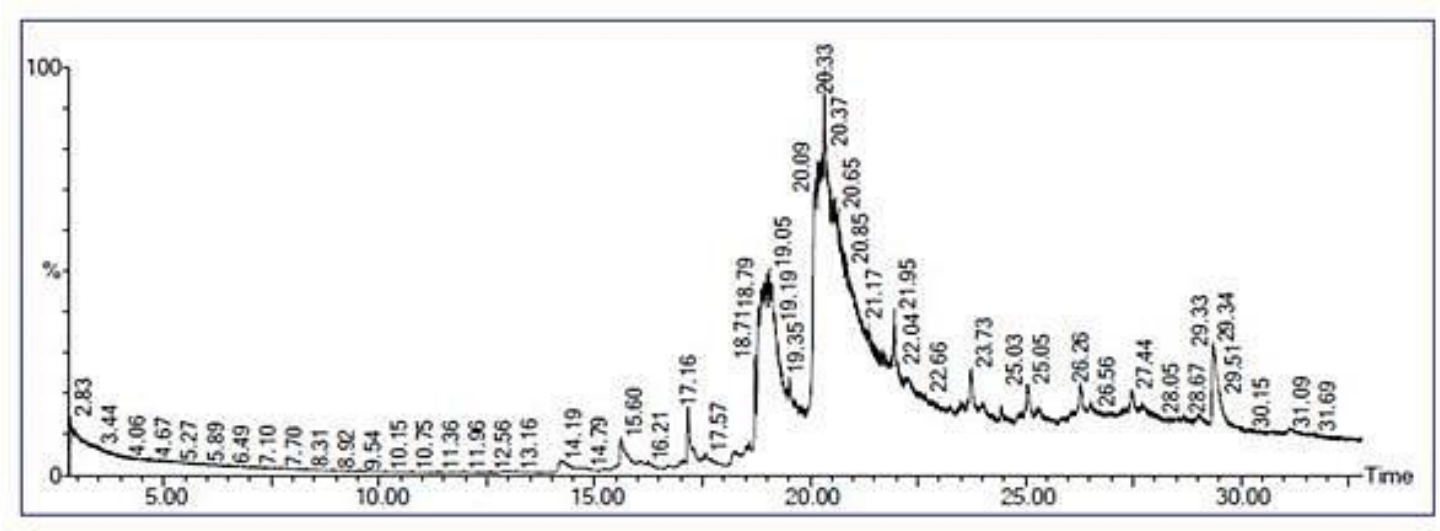


FIG. 3. **Chromatogram of fatty acid esters of pig oil.**

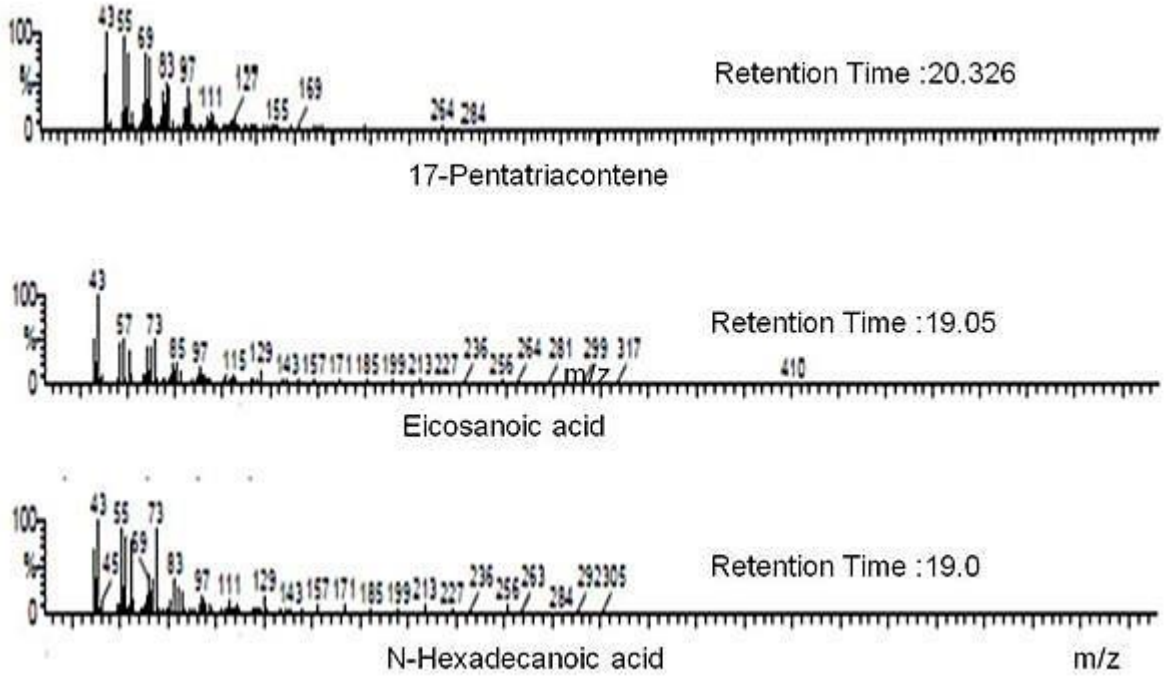


FIG. 4. **The mass spectrum m/z versus relative intensity of the major identified compound present in pig oil.**

The total ion chromatogram of the fatty acids ethyl esters from the saponified chicken oil by the GC-MS analysis is shown in **FIG 5**. The major compounds detected in the total ion chromatogram were found to be E-2-octadecadecen-1-ol, eicosanoic acid, sulfurous acid, 2-propyl tetradecyl ester, 17-pentatriacontene, 1,19-eicosadiene, pentanoic acid, 10-undecenyl ester, 12-methyl-E-E-2,13-octadecadien-1-ol, octadecane, 1-chloro nonadecane, heptacosane, 1-hexyl-2-nitrocyclohexane, octadecane, 3-ethyl-5-(2-ethylbutyl), acetoxyacetic acid, nonyl ester, octacosane, biphenyl chloride, sulfurous acid and octadecyl 2-propyl ester **(TABLE 4)**. The electron ionization mass spectrum of major compounds displayed m/z top peak as shown in **FIG 6.**

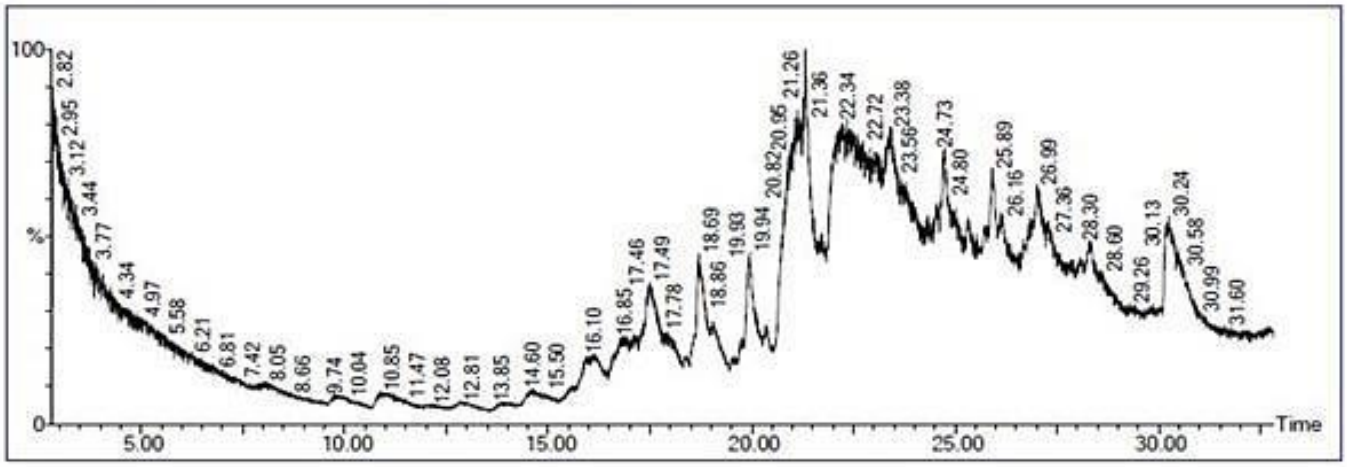


FIG. 5. **Chromatogram of fatty acid esters of chicken oil.**

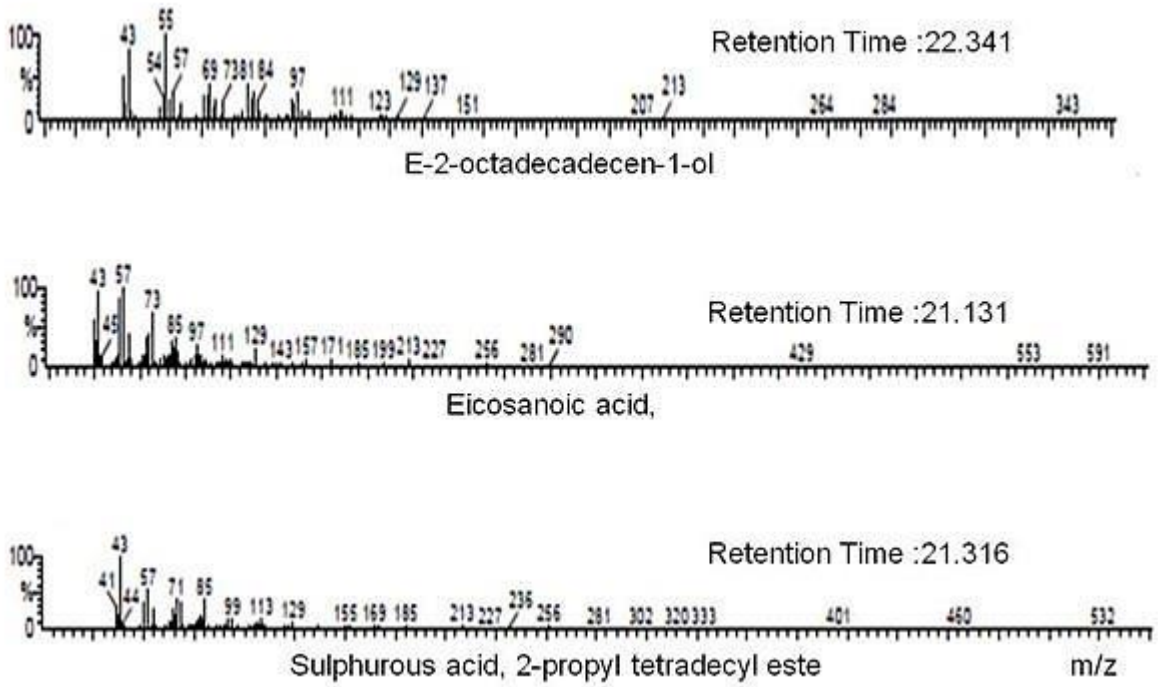
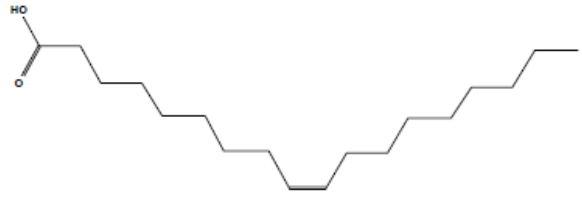
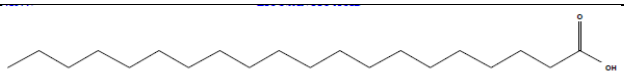
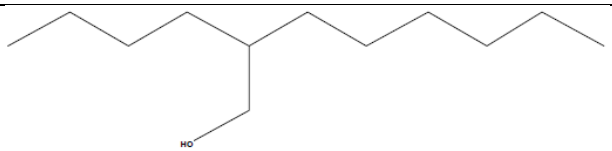
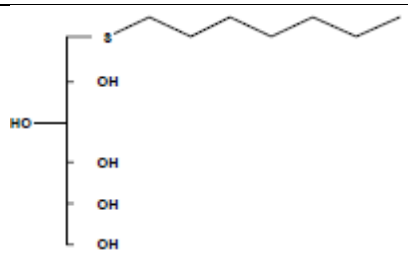


FIG. 6. **The mass spectrum m/z versus relative intensity of the major identified compound present in chicken oil.**

TABLE 2. **Fatty acid composition of the extracted goat fat oil.**

Retention Time (min)	Compound name	Compound structure	Molecular formula and Molecular weight	Relative abundance (%)
21.691	Oleic acid		$C_{18}H_{34}O_2$; 282	18.865
20.515	Eicosanoic acid		$C_{20}H_{40}O_2$; 312	16.787
22.761	1-Octanol, 2-butyl		$C_{12}H_{26}O$; 186	8.434
29.749	D-Glucitol, 1-S-heptyl-1-thio		$C_{13}H_{28}O_5S$; 296	7.617

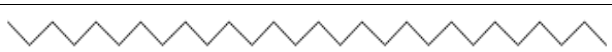
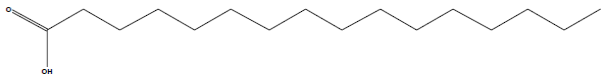
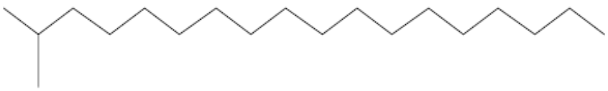
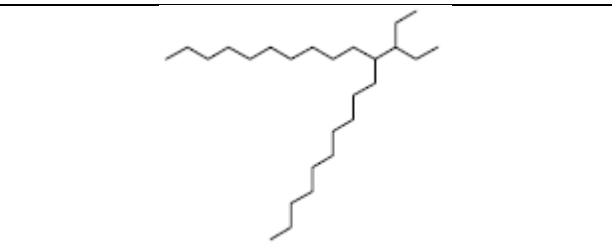
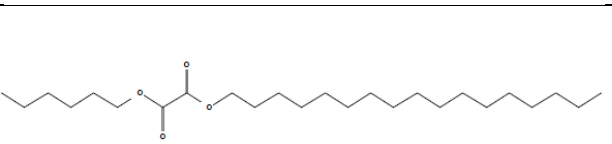
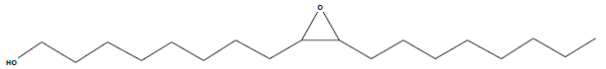
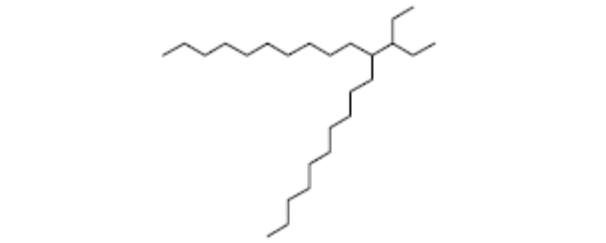
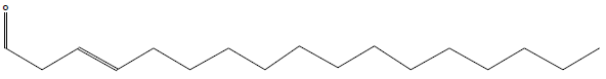
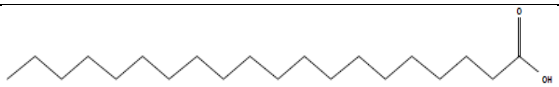
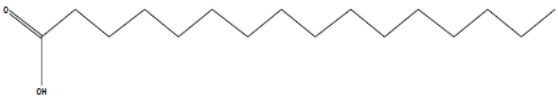
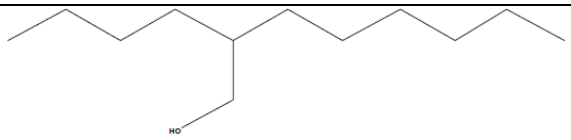
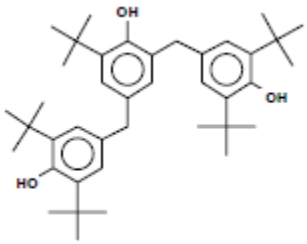
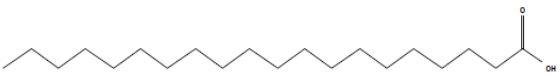
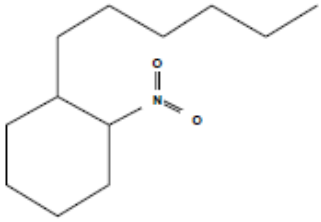
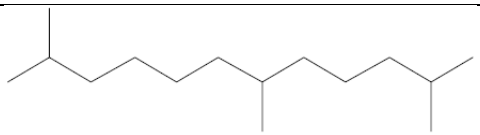
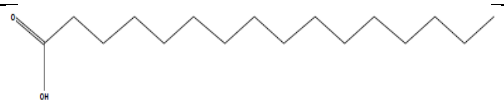
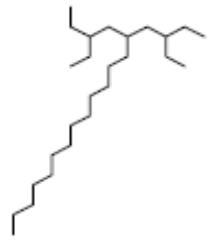
20.971	Octacosane		$C_{28}H_{58}$; 394	7.555
20.741	N-hexadecanoic ACID		$C_{20}H_{40}O_2$; 312	6.601
22.456	17-pentatriacontene		$C_{35}H_{70}$; 490	5.969
23.107	Octadecane, 1-(ethenyloxy)-		$C_{35}H_{70}$; 490	5.125
19.45	Octadecane, 2-methylhits		$C_{19}H_{40}$; 268	4.352
25.342	Octacosane		$C_{28}H_{58}$; 394	3.827
16.784	Nonadecane		$C_{19}H_{40}$; 268	3.639
21.331	Heneicosane, 11-(1-ethylpropyl)-		$C_{26}H_{54}$; 366	3.478
24.117	Octacosane		$C_{28}H_{58}$; 394	2.922
25.578	Oxalic acid, Heptadecyl hexyl ester		$C_{21}H_{44}O_3S$; 376	2.433
24.797	cis-9,10-Epoxyoctadecan-1-ol		$C_{12}H_{23}O_2N$; 213	2.395
18.130	Heneicosane, 11-(1-ethylpropyl)-		$C_{26}H_{54}$; 366	2.214
26.518	3-heptadecenal		$C_{17}H_{32}O$; 252	1.862

TABLE 3. **Fatty acid composition of the extracted pork fat oil.**

Retention Time (min)	**Compound Name**	**Compound Structure**	**Molecular formula and Molecular weight**	**Relative abundance (%)**

20.326	17-pentatriacontene		$C_{35}H_{70}$; 490	62.625
19.05	Eicosanoic acid		$C_{20}H_{40}O_2$; 312	10.379
19	N-hexadecanoic acid		$C_{16}H_{32}O_2$; 256	9.445
21.946	1-octanol, 2-butyl		$C_{12}H_{26}O$; 186	3.412
29.344	2-tert-butyl-4,6-bis(3,5-di-tert-butyl-4-hydroxybenzyl)phenol		$C_{40}H_{58}O_3$; 586	2.972
19.51	Eicosanoic acid		$C_{20}H_{40}O_2$; 312	2.369
21.666	Octadecanal, 2-bromo		$C_{18}H_{35}OBr$; 346	2.198
22.231	1-hexyl-2-nitrocyclohexane		$C_{12}H_{23}O_2N$; 213	1.12
15.614	Dodecane, 2,6,11-trimethyl		$C_{15}H_{32}$; 212	1.031
19.8	N-hexadecanoic acid		$C_{20}H_{40}O_2$; 312	0.87
18.725	Octacosane		$C_{28}H_{58}$; 394	0.801
23.737	Octadecane, 3-ethyl-5-(2-ethylbutyl)-		$C_{26}H_{54}$; 366	0.719

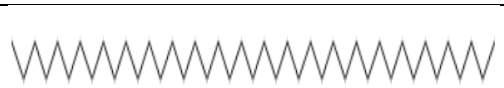
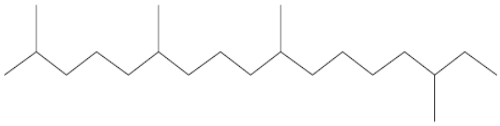
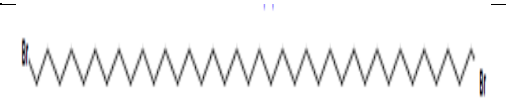
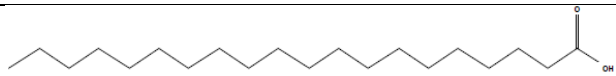
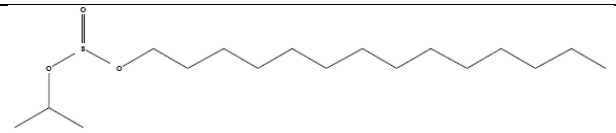
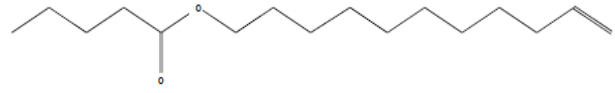
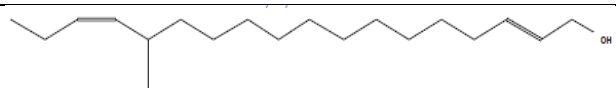
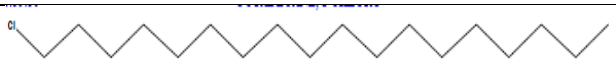
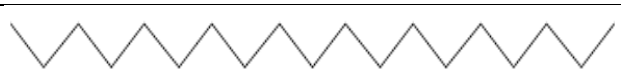
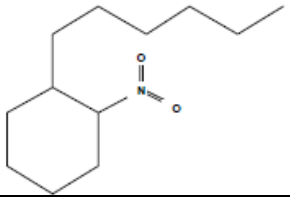
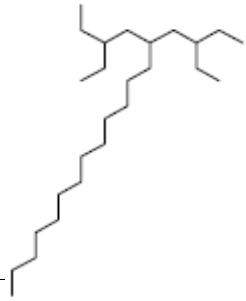
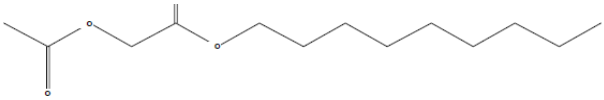
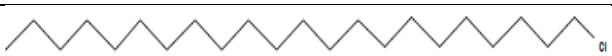
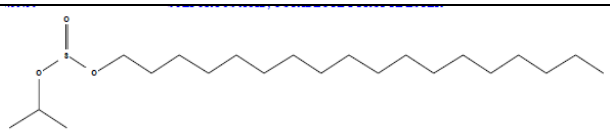
25.52	Tritetracontane		$C_{43}H_{88}$; 604	0.719
17.164	Heptadecane, 2,6,10,15-tetramethyl		$C_{21}H_{44}$; 296	0.7
26.263	Octatriacontane, 1,38-dibromo		$C_{21}H_{44}O_3S$; 376	0.644

TABLE 4. **Fatty acid composition of the extracted chicken fat oil.**

Retention Time (min)	**Compound Name**	**Compound Structure**	**Molecular formula and Molecular weight**	**Relative Abundance (%)**
22.341	E-2-octadecadecen-1-ol		$C_{18}H_{36}O$; 268	18.38
21.131	Eicosanoic acid		$C_{20}H_{40}O_2$; 312	16.319
21.316	Sulfurous acid, 2-propyl tetradecyl este		$C_{17}H_{36}O_3S$; 320	12.757
23.432	17-pentatriacontene		$C_{35}H_{70}$; 490	8.783
22.601	1,19-eicosadiene		$C_{20}H_{38}$; 278	5.901
22.906	Pentanoic acid, 10-undecenyl ester		$C_{12}H_{23}O_2N$; 213	5.766
23.682	12-methyl-E,E-2,13-octadecadien-1-ol		$C_{12}H_{23}O_2N$; 213	4.75
30.239	Octadecane, 1-chloro		$C_{18}H_{37}Cl$; 288	4.251
17.489	Nonadecane		$C_{19}H_{40}$; 268	3.6
18.7	Heptacosane		$C_{27}H_{56}$; 380	3.067

22.791	1-hexyl-2-nitrocyclohexane		$C_{12}H_{23}O_2N$; 213	2.743
25.908	Octadecane, 3-ethyl-5-(2-ethylbutyl)-		$C_{26}H_{54}$; 366	2.732
30.474	Acetoxyacetic acid, nonyl ester		$C_{13}H_{24}O_4$; 244	2.682
24.732	Octacosane		$C_{28}H_{58}$; 394	2.596
19.94	Octacosane		$C_{28}H_{58}$; 394	2.07
26.993	Behenyl chloride		$C_{22}H_{45}Cl$; 344	1.903
26.128	Sulfurous acid, octadecyl 2-propyl ester		$C_{21}H_{44}O_3S$; 376	1.7

Conclusion

The current research work described the technical criterion for considering the fats derived from animals and fowl as a biofuel source. The GC-MS method of fingerprinting fatty acid helps us identify the source bio-oil from where it was derived. In the case of goat, pig, and chicken fat the major unsaturated fatty esters were found to be oleic acid, 17-pentatriacontene, and E-2-octadecadecen-1-ol respectively. The characteristics of the fat oils would throw light on the possibility of using the oils as an additive to the fossil diesel fuel and to determine the blend ratio. This effort would reduce waste generation from the slaughterhouse as well as derive a renewable energy source from waste fats.

Conflict of Interest

The authors declare that they have no conflict of interests.

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