Available online at: http://www.ijmtst.com/vol5issue06.html

International Journal for Modern Trends in Science and Technology

ISSN: 2455-3778 :: Volume: 05, Issue No: 06, June 2019

Utilization of waste chicken fat for production of Fatty acid methyl ester: Waste to Energy

Kumar Gaurav

Amity Institute of Biotechnology, Amity University Haryana, Gurugram- 122413, India

To Cite this Article

Kumar Gaurav, "Utilization of waste chicken fat for production of Fatty acid methyl ester: Waste to Energy", *International Journal for Modern Trends in Science and Technology*, Vol. 05, Issue 06, June 2019, pp.-31-35.

Article Info

Received on 12-May-2019, Revised on 30-May-2019, Accepted on 11-June-2019.

ABSTRACT

Biodiesel has emerged as a promising alternative to combat the crisis of energy security and global warming. The dominant feedstocks for its production, i.e vegetable oils, are expensive as well as have their own share of constraints and problems such as social and economic constraints. Research in this field is now mainly focused on reducing the cost of biodiesel production by using lower cost feedstocks. One such possibility is to use waste animal fat, which is otherwise considered useless and contributes to pollution. The present study focuses on the various methods for production of biodiesel from waste chicken fat, analyzing various parameters affecting its production and physiochemical properties of biodiesel thus obtained.

KEYWORDS: *Chicken fat waste, renewable energy, fatty acid methyl ester (FAME), transesterification*

I. INTRODUCTION

The energy demand increasing day by day and stock of fossil fuels are dwindling; research is being conducted towards the development of renewable energy. Renewable sources of energy like wind, hydro, biomass and geothermal, they are available in plenty and don't produces pollutant [1]. Biowaste is mainly composed of cellulose hemicelluloses, starch, protein, and lipid. It is generated from (food and agriculture industry, paper industry, municipal solid waste, and forest residue).It can act as low-cost feedstock for biofuel production (biogas, biohydrogen, bioethanol, biodiesel etc.) Biodiesel, chemically fatty acid methyl ester (FAME), second most important liquid fuel after biethanol and derived from vegetable oils (edible/non-edible) as well as animal fat, and produces via esterification/ transesterification process of triglycerides with alcohol. It is biodegradable, non-toxic, alternative fuel, eco-friendly and it reduces the emission of carbon monoxide, sulphur, hydrocarbons, particulate matter, polyaromatics hydrocarbons, noise and smoke due to, higher content of oxygen than petroleum diesel [2, 3, 4, 5]. The overall carbon dioxide emission is reduced by 78% by biodiesel as compared to petrodiesel. Presently, the overall biodiesel cost is high due to high cost of reactant, particularly feedstock. Globally, maximum biodiesel production (95%) is made from edible vegetable oils (84% rapeseed oil, 13% sunflower oil, 1% palm oil , 2% soybean and others) [6]. Edible oil feedstock for biodiesel production can affect food security [7, 8] and production cost. The raw material for biodiesel production is vegetable oil (triglycerides) and methanol; it contributes 75% of total production cost. This is major obstacle in biodiesel commercialization. To reduce the cost of FAME, there is need to utilize inexpensive and

non-edible feedstock. Waste cooking oil is better feedstock as compared to vegetable oil [9] but the waste animal fats are more abundantly available as compared to waste cooking oil and can be best option for biodiesel production. In India, 700,000 tonnes of chicken meat is consumed every year and during their rendering, it produces 77,000 tonnes of waste chicken fat [10]. These waste animal fats composed of triglycerides and can be used as inexpensive feedstock for biodiesel production.

II. Waste animal fat feedstock

Waste animal fat are generated during the slaughtering of chicken [11], goat [12], fish [13], beef [14], pork [11, 15] and duck [16], these easily available, non-edible and low cost feedstock (two or three times cheaper than vegetable oil) can be efficiently utilized for biodiesel production. Chicken waste is by-product of poultry industry, and composed of fat (38.92%), protein (8.93%), moisture (50.78%) and ash (1.28%).The waste chicken fat contain 25-35% saturated fatty acid and 40-75 % unsaturated fatty acids. The fatty acid composition are ; 26 % palmitic acid, 5.5 % stearic acid, 0.9% myristic acid, 37.5% oleic acid, 7.3 palmitoleic acid, 21.2% linoleic acid and 1.2 % linolenic acid. Waste chicken fat provides 99% biodiesel [17] and have similar cetane number, density and heating value to that of ASTM biodiesel standard [18].

III. Extraction of oil form waste chicken fat

There are various methods for extraction of oil from waste chicken fat viz heating, microwave heating and solvent extraction. Waste chicken fats are heated at 90-100^{0}C to extract oil [19]. After that they are centrifuged to separate oil. Microwave heating is rapid method for extraction of oil from fat, in which, there is electromagnetic (frequency in range of infrared) interaction among fat and solvent. Solvent (hexane commonly used at commercial scale) heated at certain temperature to extract the oil from fat. Hexane is most suitable solvent for extraction of oil from fat, because it has low boiling point and relatively cheaper.

IV. Methods for fatty acid methyl ester production

Animal fat have high viscosities and low fluidity, so, it cannot be directly used in diesel engine. In order to decrease viscosity, the different methods are used like blending process, supercritical methanol, catalytic cracking and transesterification. Among these methods, transesterification is most suitable method for biodiesel production

IV.I Blending process

Animal fat can be used as a fuel in blended form. The advantages of blending biodiesel with normal diesel are; reduction the emissions of harmful gases (CO, SO_2, nitrate compound, polycylic aromatic hydrocarbon and particulate matter) and increase in break thermal efficiency (BTE) as well as cylinder peak pressure. B10 biodiesel (10% biodiesel derived from chicken fat and 90% petro diesel) was studied by Guru et al. [20] and reported that there is decrease in viscosity, flash and pour point. B20 biodiesel increases in BTE and cylinder peak pressure with reduction of hydrocarbon and carbon monoxide emission [21].

IV.II Catalytic cracking

Catalytic cracking, widely used in petrochemical industry to produce fossil-fuels. It works at low temperature and pressure with aid of catalysts (pillared clay, zeolites, alumina-metal supported catalyst) in fluid catalytic cracking (FCC) unit to converts triglycerides into CO_2, CO and mixture of hydrocarbons and aromatic compounds [22]. Hua et al. [23] studied the catalytic cracking of vegetable oils and animal fat in FCC unit and repotted that high yield of liquefied petroleum gas (45%) and olefins C2-C4 (47%).

IV.III Transesterification

Transesterification (alcoholysis) is the reaction of triglycerides (waste animal fat) with short chain alcohol (methanol, ethanol or butanol) in presence of acid (sulfuric, sulfonic and hydrochloric acid), base (sodium hydroxide, potassium hydroxide, sodium methoxide) or enzyme catalyst (lipase). Immobilized lipase-catalyzed transesterification reaction can be used for waste cooking oil, tallow fat and other waste fat and provides the high yield of FAME under mild conditions (20-60^{0}C). Chemical catalyst may be either in homogeneous or heterogeneous phase. Acid -catalyzed reaction is slow but quite effective for converting FFA to ester. Alkali-catalyzed transesterification of triglycerides with methanol is widely used for production of biodiesel. This process is faster, more efficient, cheap and requires lower amount of catalyst as compared to acid-catalyzed reaction, and can be used only when FFA content in triglycerides is less than 1% [5, 8].

IV.IV SUPERCRITICAL METHANOL

For the use of waste animal fat as a feedstock two-step catalyzed process (esterification and transesterification) for the production of FAME and it requires large amount of water for washing and neutralization. These steps produces lower yield of FAME. Supercritical methanol method is simpler, catalyst free, eco-friendly and convert triglycerides into FAME within minutes [24]. The downstream process is simpler because of no catalyst is used. The yield of FAME doest affected by water and FFA content because, esterification and transesterification take place simultaneously [25], and there is possibility to scaling up at industrial level. In this process feedstock reacts with supercritical methanol (at high temperature more than 276^{0}C and high pressure above 100 atm) and increase the solubility of triglycerides [26].

V. METHODOLOGY FOR FATTY ACID METHYL ESTER PRODUCTION FROM WASTE ANIMAL FAT

Waste chicken fat was collected from slaughter house and cut into small pieces. The chicken fat was melted at 110^{0}C and after that it was centrifuged to obtain oil as well as to remove protein residues, gum and suspended particles. Generally, in feedstock, water content and FFA content should be less than 0.06 wt% [27] and 0.5% wt [7] respectively. Yellow grease and brown grease depends upon FFA content and FFA content is less than 15% it is called as yellow grease, while in brown grease FFA content is above 15% [28].FFA content is an important parameter for transesterification process. Extracted oil has high FFA and there is need to reduce less than 1% to avoid soap formation. Fatty acid methyl ester production is two-step catalyzed process, first acid-catalyzed esterification and second alkali-catalyzed transesterification for waste animal fat with high FFA content. The FFA level can be lowered by pre-treatment / esterification process. Extracted chicken oil has high FFA content (15%) and it was reduced by esterification using sulfuric acid (20% wt) as an acid catalyst. In second step process; after the removal of sulfuric acid, methanol and water, the mixture was transesterified with sodium hydroxide as an alkaline catalyst. These two steps process provided 87.4% yield of fatty acid methyl ester (FAME) [28].The water content in fat; inhibits esterification and transesterification, promotes soap formation, increases catalyst consumption, favors hydrolysis of triglycerides and FFA, lowers its efficiency and create the problems in separation of ester and glycerol [29]. The water content in feedstock should be lower than 0.06% (w/w) and it can be lowers by heating the waste animal fat at 100^{0}C to remove excess water present in feedstock.

V.I PRETREATMENT / ESTERIFICATION

To reduce the acid value of extracted oil in acceptable limit, oil is pre-treated or esterified with acid (H_2SO_4, HCl). Raw chicken fat have high acid value 22 mg KOH/g and it was reduced up to 4.7 mg KOH/g at optimized condition of 0.9 wt% sulphuric acid catalyst, 6:1 methanol to oil molar ratio, reaction time of 60 minute at 60^{0}C during esterification process [30]. Gurusala etal [21] conducted esterification of waste chicken fat to reduce the FFA content from 13.6 % to less than 1 % through ferric sulphate catalyst.

V.II Transesterification

Transesterification is reversible process due to which higher amount of methanol must be supplied to shift the equilibrium in forward direction thereby achieving higher yield of biodiesel. For transesterification of waste animal fat, base catalyst (KOH, NaOH, KOMe, NaOMe, MgO, Cao, ZnO, TiO_2) is most suitable due to faster reaction rate. Methoxide based catalyst (KOMe, NaOMe) produces higher yield as compared to hydroxide base catalyst [31]. Tranesterfication of chicken fat under the optimized conditions of ; 0.8 wt% KOH, methanol to oil molar ratio 8:1 , reaction time 60 min at 60^{0}C gives 97.68 % biodiesel yield process [30].

V.III PURIFICATION OF FATTY ACID METHYL ESTER

The quality of biodiesel depends upon its purity and it affects engine performance [32]. After transesterification process, crude FAME have impurities such as methanol, glycerol, catalyst, acylglycerol and others, and it reduces FAME quality. If methanol is present in biodiesel it; reduces density, viscosity and flash point, corrodes aluminum and zinc part, degrade the rubber seal and gasket. Methanol is recovered by flash evaporation. Glycerol has negative impact on biodiesel such as; deposition in fuel tank, durability of engine, higher emission of aldehyde and acrolein. Glycerol is recovered by centrifugation or gravitational separation and it can be further purified by vacuum distillation

VI. Factors affecting transesterification

VI.I Free fatty acid content and water content

Low cost feedstocks (waste animal fat and waste cooking oil) have high free fatty acid content (more than 13%) and reduces the yield of fatty acid methyl ester, due to soap formation during alkali-catalyzed transesterification process. To overcome this problem, these feedstocks are pretreated with sulphuric acid catalyst to reduced free fatty acid content less than 1% [33]. The higher water (moisture) content causes; microbial growth, hydrolysis of FAME and corrode fuel supply system [34]. According to US standard (ASTM D 6751), acceptable water content in biodiesel should be 0.050% [35].

VI.II Catalyst loading

In pre-treatment of chicken fat, acid catalyst shows faster reaction rate than base catalyst [33], while, base-catalyzed reaction is faster than acid-catalyzed reaction in transesterification process. The higher concentration of catalyst reduces the yield of biodiesel [11].

VI.III Methanol to oil ratio

For biodiesel production, 6:1 molar ratio of methanol to oil is used for transesterification reaction [36]. Acid-catalyzed esterification requires; higher methanol to oil ratio, higher temperature and higher reaction time [17] to reduced FFA content. The FFA content of chicken fat was reduced from 13.45 % to 1.04% during esterification process with optimum conditions of methanol to oil ratio (30:1), sulphuric acid (35 % wt) and reaction temperature (60^0C) [11]. Transesterification of duck tallow produced 97 % of FAME at optimized condition of methanol to oil ratio 6:1 at reaction temperature 65^0C [37]. Therefore, it is required to optimize the molar ratio of methanol to reduce the consumption of it. In transesterification, methanol is generally used, because of its low cost, highly reactive and minimizing the hydrolysis and soap formation as well as it produces glycerol as by product. In place of methanol, methyl acetate can be used and it produces triacetin (triacetylglycerol) and has higher value than glycerol. Triacetin is used as perfumery fixative.

VI.IV Reaction temperature

The temperature is important parameter for homogeneous/ heterogeneous catalyzed reaction. The reaction temperature should be maintained below the boiling point of alcohol and greatly influences the rate of reaction. The optimum temperature is temperature at which it produces maximum yield of FAME. As the temperature increases, FAME yield also increases due to acceleration of the reaction, but above the optimum temperature, yield decreases due to loss of alcohol (methanol) [38]. The reaction temperature for transesterification of chicken fat, waste cooking oil and beef should be fixed at 65^0C [39].

VII. Physiochemical properties of fatty acid methyl ester

The physiochemical properties of fatty acid methyl ester (biodiesel) should be similar to biodiesel standard of US (ASTM D 6751) and European (EN14214). The viscosity of biodiesel is an important fuel property because, biodiesel production from animal fat has high viscosity, it will degrade the fuel vaporization, atomization and directly reduces the engine efficiency during combustion process [40]. Kinematic viscosity of fatty acid methyl ester produced from chicken fat was 5.4-5.6 m2/s [11, 33]. The density of fuel affects the fuel injection properties such as atomization and injection time [40]. With increase in reaction time and temperature, it decreases the density of chicken fat methyl ester [33]. The density of fatty acid methyl ester produced from chicken fat was 0.849-870 Kg/L [19, 11]. Flash point is important fuel property for storage, safety and transportation [41]. It is the lowest temperature of flammable liquid at which it can form ignitable mixture in air. In literature it was reported that the flash point of chicken fat methyl ester was 170-174^0C [19, 11]. Cetane number, an indicator of biodiesel quality, related to ignition quality and combustion behavior. High cetane number indicates that easy run of engine [42]. Calorific value of fuel can be defined as, the amount of energy release during the complete combustion of fuel and minimum calorific value of fuel should be 35 MJ/Kg. The calorific value (heating value) of biodiesel produced from chicken fat was 39.4 MJ/Kg [43].

VIII. Conclusion

This study analyses the various methods for biodiesel production from waste chicken fat, parameters affecting its production and the properties of biodiesel obtained. The study concludes that from technological point of view, it is possible to use waste chicken fat to produce good quality biodiesel. This will also help in addressing

the issue of high cost for the production which is the bottleneck of biodiesel production.

ACKNOWLEDGMENT

Author thanks to Amity Institute of Biotechnology, Amity University Haryana, Gurugram, India for supporting the research work.

REFERENCES

[1] N. Srivastava and K. Gaurav, Jour. Environ. Sci. Pollu. Res. 4 268(2018).
[2] D. Kumar, S.Sharma, N. Srivastava, S. Shukla and K. Gaurav, Jour. Nano. Tech. 4 374 (2018).
[3] S. Zullaikah, C.C. Lai, S.R. Vali and Y.H. Ju, Bioresour. Technol. 96 1889 (2005).
[4] J. Xue , T.E. Grift and A. C. Hansen, Rene. Sustain. Ener. Rev. 15 1098 (2011).
[5] K. Gaurav, R. Srivastava and R. Singh, Inter. Jour. Gre. Ener. 10 775(2013).
[6] M.M. Gui, K.T. Lee and S. Bhatia, Energy 33 1646 (2008).
[7] B. Freedman, E.H. Pryde and T.L. Mounts, Jour. Amer. Oi. Chem. Soci. 61 1638 (1984).
[8] K. Gaurav, R. Srivastava, J.G. Sharma, R. Singh and V. Singh, Inter. Jour. Gre Ener. 13 320 (2016).
[9] A. Gnanaprakasam, V.M. Sivakumar, A. Surendhar, M. Thirumarimurugan and T. Kannadasan, Jour. Energ. 1 (2013).
[10] A.K. Tiwari, A. Kumar and H. Raheman, Bio. Bioener. 31 569 (2007).
[11] T.M. Mata, N. Cardoso, M. Ornelas , S. Neves and N.S. Caetano, Ener. Fue. 25 4756 (2011).
[12] R. Chakraborty and H. Sahu, Appl. Ener. 114 827(2014).
[13] R. Yahyaee, B. Ghobadian and G Najafi, Rene. Sustain. Ener. Rev. 17 312 (2013).
[14] M.E. D. Cunha, L.C. Krause, M.S.A. Moraes, C.S. Faccini, R.A. Jacques, S.R. Almeida, M.R.A. Rodrigues and E.B. Caramao, Fuel Process. Tech. 90 570 (2009).
[15] M. Berrios, M.C. Gutierrez, M.A. Martín and A. Martín, Fuel Process. Tech. 90 1447 (2009).
[16] K.H. Chung, J. Kim and K.Y. Lee, Bio. Bioener. 33 155 (2009).
[17] H.N. Bhatti, M.A. Hanif, M. Qasim and A.U. Rehman, Fuel 87 2961 (2008); https://doi.org/10.1016/j.fuel.2008.04.016.
[18] R. Behcet, H. Oktay, A. Çakmak and H. Aydin, Rene. Sustain. Ener. Rev. 46 157 (2015).
[19] E. Arnaud, G. Trystram, P. Relkin and A. Collignan, Jour. Food Engg. 72 390 (2006).
[20] M. Guru, A. Koca, O. Can, C. Cınar and F. Sahin, Rene. Ener. 35 637 (2010).
[21] N. K. Gurusala and V.A.M. Selvan, Clean Techn. Environ. Poli. 17 681 (2015).
[22] J.A. Melero, M.M. Clavero, G. Calleja, A.G.R. Miravalles and T. Galindo, Energy Fuel 24 707 (2010).
[23] T. Hua, L. Chunyi, Y. Chaohe and S. Honghong , Alternative processing technology for converting vegetable oils and animal fats to clean fuels and light olefins. Chinese Jour. Chem. Engg. 16 394 (2008).
[24] D. Kusdiana and S. Saka, Methyl esterification of free fatty acids of rapeseed oil as treated in supercritical methanol, Jour. Chemi. Engg. of Japan 34 383 (2001).
[25] D. Kusdiana and S. Saka, Fuel 80 693 (2001).
[26] G. Madras, C. Kolluru and R. Kumar, Fuel 83 2029 (2004).
[27] F. Ma, L.D. Clements and M.A. Hanna, Trans. of ASAE 41 1261 (1998).
[28] E. Alptekin and M. Canakci, Fuel 89 4035 (2010).
[29] M. Canakci, Bioresour. Techn. 98 183 (2007).
[30] S.B. Chavan, M. Yadav , R. Singh , V. Singh , R. R. Kumbhar and Y.C. Sharma, Environ. Progr. Sustain. Energ. 36 1 (2017).
[31] A. Singh, B. He, J. Thompson and J.V. Gerpen, Appl. Engg. Agri. 22 597 (2006).
[32] S. Banga and P.K. Varshney, Jour. Sci Indust. Res. 69575(2010).
[33] E. Alptekin and M. Canakci, Fuel 90 2630 (2011).
[34] B.R. Moser, In vitro cellul. develop. Biol. plant 45 229 (2009).
[35] M.A. Wakil, M.A. Kalam, H.H. Masjuki, A. Atabani and I.M. R. Fattah Energ. Conver. Manage. 94 51 (2015).
[36] M. H. Yuan, Y.H. Chen, J.H. Chen and Y.M. Luo, Fuel 195 59 (2017).
[37] K. H. Chung, J. Kim, K. Y. Lee, Bio. Bioener. 33 155 (2009).
[38] A.S. Ramadhas, S. Jayaraj and C. Muraleedharan, Fuel 84 335 (2005).
[39] M.E. Hoque, A. Singh and Y.L. Chuan, Bio. Bioeneg. 35 1582 (2011).
[40] B. Bankovic-ilic , I .J. Stojkovic , O.S. Stamenkovic , V.B. Veljkovic and Y.T. Hung, Rene. Sustain. Ener. Rev. 32 238 (2014).
[41] P.S.D. Caro, Z. Mouloungui, G. Vaitilingom and J. C. Berge, Fuel 80 565 (2001).
[42] S.K. Sinha, A. Gupta and R. Bharalee, Biofuels 7 105 (2016).
[43] T.M. Mata, A.M. Mendes , N.S. Caetano and A.A. Martins, Chem. Engg. Trans. 38 175 (2014).