

Chapter 2

Physicochemical Assessment of Pumpkin (*Cucurbita pepo* L.) Seed Oil as a Viable Feedstock for Biodiesel Production

Bichitra Bikash, Nabajit Dev Choudhury, Dilip Kumar Bora
and Kalyan Kalita

Abstract Biodiesel is a renewable and sustainable alternative to fossil fuels which is derived from vegetable oils and animal fats. This paper presents the prospect of Pumpkin (*Cucurbita pepo* L.) seed oil, as a feedstock for biodiesel production because of its suitability for production in a variety of atmospheric condition, easy cultivation, high-fruit production rate, and low cost of cultivation. In this study, *C. pepo* L. seeds were collected, processed, and oil was extracted from the seeds by mechanical extraction process. The important physical and chemical properties of the extracted seed oil were experimentally analyzed. Fatty acid methyl ester (FAME) of the seed oil was produced corresponding to ASTM standards. The quality of biodiesel produced was assessed in terms of the physicochemical properties e.g., density, viscosity, heating value, flash point, acid value, and pour point, which are considered as the most important properties of a fuel for its application in C.I engines. The experimental findings of this study reveal that *C. pepo* L. seed can be a suitable feedstock for biodiesel production in commercial scale.

Keywords Biodiesel · *Cucurbita pepo* L. · Oil extraction · Physicochemical properties

2.1 Introduction

A vital segment of the growth of any civilization rests on the use of petroleum fuels in various fields, namely industry, power production, aviation, and transportation. However, the use of petroleum fuels needs to be reduced. The diesel burning that occurs in transport vehicles results in serious ecological changes, which include the

B. Bikash (✉) · N.D. Choudhury
Assam Down Town University, Guwahati 781026, Assam, India
e-mail: bichi1111@gmail.com

D.K. Bora · K. Kalita
Assam Engineering College, Guwahati 781013, Assam, India

© Springer Nature Singapore Pte Ltd. 2018
S. Kumar et al. (eds.), *Conference Proceedings of the Second International Conference on Recent Advances in Bioenergy Research*, Springer Proceedings in Energy, https://doi.org/10.1007/978-981-10-6107-3_2

increase in global surface temperature (global warming), as well as changes in rainfall patterns and in the frequency of extreme weather events. In addition, the demand for sustainable alternatives for crude oil has increased because of limited fossil fuels reserves, increasing prices of world crude oil, and environmental concerns [1].

One of the feasible solutions that have got popularity during last few decades is the use of the fatty acid methyl esters, termed as biodiesels as alternative fuels of diesel [2]. Biodiesel is a renewable and sustainable alternative to fossil fuel that is derived from vegetable oils and animal fats [3]. When burned in diesel engines, biodiesels offer a drop of carbonated emissions and no sulfurized emissions [4]. However, being oxidized fuels, biodiesels emit nitrogen oxide (NOx) emissions when burnt on diesel engines [5]. Thus, biodiesel can be a potential solution to the energy needs and emission reductions. In this study, *Cucurbita pepo* L. seed, which is grown abundantly in India, is considered as a new feedstock for biodiesel production.

2.1.1 Objectives of This Study

This paper presents the prospect of that *C. pepo* L. seed oil as a promising feedstock for biodiesel production. As *C. pepo* L. seed oil is new in the field of biodiesel, to achieve this, collection of seed and extraction of vegetable oil, quantification of fatty acid methyl esters, and characterization of physicochemical properties e.g., density, viscosity, heating value, flash point, acid value, pour point were analyzed and compared corresponding to ASTM standards. The experimental findings of this study reveal that *C. pepo* L. seed can be a suitable feedstock for biodiesel production.

2.2 Materials and Methods

Scinas et al. [6] has reported that Pumpkin seeds are rich in oil, and the major physicochemical properties of pumpkin seed oil make it an attractive alternative application of the existing feedstock for biodiesel production in Greece. Hence, the Indian variety of Pumpkin can also be a potential feedstock for biodiesel production. The materials and methods applied are as follows:

2.2.1 *Cucurbita pepo* L. Description

The biggest International producers of *C. pepo* L. include the USA, Canada, Mexico, India, and China. It is a warm-weather crop that is usually planted in early

July. *C. pepo* L. or pumpkin is fruit of the Cucurbitaceae family which is commonly known as ‘Pumpkin’ all around the world. The growth rate of pumpkin from sowing of seed to harvesting is around 85–90 days, which is very high. Also by sowing 1–1.5 kg seeds a hectare, we can get 20–30 tonnes/hectare (Source: KISSAN Kerala Operations Centre, IIITM-K, NILA, Techno park Campus, Thiruvananthapuram).

2.2.2 *Cucurbita pepo* L. Oil Seed Preparation

As *C. pepo* L. is available in almost all the vegetable market of India, it was not much difficult in collecting the seeds. The collection of seed process was started from September 2014. The seeds were collected from the local vegetable markets of Chandrapur, Kolongpar, Mackhowa, Garchuk, etc. in Guwahati, Assam. Table 2.1 shows the amount of seed collected from different location of Assam.

Also, the seeds were collected from the hostel canteens of ADTU campus. About 1 kg of oil seed was obtained from 15 kg of *C. pepo* L. A total of 13 kg of pumpkin seeds were collected.

The seeds of *C. pepo* L. were separated from the fruit by cutting the fruit and then separating the seeds from the pulp and fibrous strands of the fruit. The seeds were then cleaned with cloth and dried evenly at room temperature of about 28–32 °C for five days. Figure 2.1 shows seed preparation steps. After drying the seeds were stored in airtight containers at room temperature.

2.2.3 Oil Extraction

The extraction process carried out was the mechanical extraction. It was carried out in an oil expeller machine. The pumpkin seeds are crushed inside the machine, and the vegetable oil is flowing out through the outlet tray of the machine (Fig. 2.1). The oil is filtered and collected in a beaker. From 1 kg of pumpkin seed about

Table 2.1 Amount of seed collection and the location

S. No.	Location	Geographical coordinate	Amount in kg
1	Chandrapur	26° 13' 45"N 91° 55' 10"E	2
2	Kolongpar	26° 11' 44"N 91° 50' 57"E	3
3	Fancy Bazar	26° 13' 52"N 91° 44' 23"E	6
4	Gorchuck	26° 6' 57"N 91° 42' 31"E	2



Fig. 2.1 Flow chart of *Cucurbita pepo* L. seed preparation to oil extraction

480 gm of seed oil is extracted. The oil is filtered and collected. From 7 kg of pumpkin seeds about 3.2 l of pumpkin seed oil was extracted. The extraction process was carried out in an oil mill at Chandrapur (26° 13' 45"N–91° 55' 10"E) which is nearby the University campus. Figure 2.1 shows the seed preparation and oil extraction steps.

2.2.4 *Cucurbita pepo* L. Seed Oil Analysis

Table 2.2 shows the important properties of *C. pepo* L. seed oil.

The experiments were performed corresponding to ASTM standards. The oil content of *C. pepo* L. seed was found to be 48%. The method of finding oil content of the seed is given below:

Table 2.2 Properties of *Cucurbita pepo* L. seed oil

S. No.	Properties	<i>Cucurbita pepo</i> L. seed oil
1	Oil content	48%
2	Density (28 °C)	800 kg m ⁻³
3	Kinematic viscosity (40 °C)	35.6 mm ² s ⁻¹
4	FFA	0.88 mg g ⁻¹
5	Pour point	–12 °C
6	Water content	598 µg g ⁻¹

$$\text{Oil content (\%)} = (W_2 - W_1)/W \times 100$$

where, W = weight of sample; W_1 = weight of beaker with glass ball; W_2 = weight of beaker with glass ball and oil; and $W_2 - W_1$ = weight of the oil.

Density is the mass per unit volume of the oil. The density of *C. pepo* L. found out to be 800 kg m^{-3} at 28°C .

Kinematic viscosity is the property of a fluid which resists the fluid to flow over a surface. Higher the viscosity of a fluid greater will be the resistance to flow. Generally, a vegetable oil is more viscous than diesel. The viscosity of *C. pepo* L. found out to be $35.6 \text{ mm}^2 \text{ s}^{-1}$.

FFA is the estimated amount KOH required to neutralize the soap formation. Higher the FFA value greater will be the soap formation during transesterification of the vegetable oil. The FFA of the *C. pepo* L. was found out to be $0.88 \text{ mg of KOH g}^{-1}$.

2.2.5 Biodiesel Production

Transesterification of was carried out in the chemistry lab of Assam down town University. Potassium hydroxide is taken as a catalyst in the reaction. The vegetable oil was first heated to 100°C to remove the water content in the vegetable oil. Heated oil is allowed to cooled to 65°C and put upon a magnetic stirrer. The alcohol which is methanol along with catalyst is poured in the heated oil. The catalyst used is potassium hydroxide (KOH). The molar ratio of methanol to oil is maintained at 6:1. The amount of catalyst i.e., KOH is determined by titration process. The mixture of the bio-oil and alcohol is kept in the magnetic stirrer for one hour keeping the temperature at 65°C . The process flow for biodiesel production is shown in Fig. 2.2.

2.2.6 Products of Transesterification

Transesterification process has two products. Major product is biodiesel and coproduct is glycerol. After stirring for an hour the mixture is kept in a cool place for gravity separation. Two phases of glycerol and biodiesel are appeared after 24 h in the container. Glycerol is appeared in lower phase and the biodiesel floats over glycerol due to low density of the biodiesel. The biodiesel and glycerol were separated by using a separating funnel.

After separation, the biodiesel was washed by adding 50% volume of warm distilled water and agitated gently for 5 min. The mixture was allowed to settle, and this gave a two-layer mixture from which the biodiesel was separated. The process



Fig. 2.2 The process flow of biodiesel production from *Cucurbita pepo* L. seed oil

was repeated two more times to give a clearer ester. The washing was done to remove impurities and any remaining residual methanol.

NMR analysis of FAME was analyzed by ^1H NMR and ^{13}C NMR. The ^1H and ^{13}C NMR spectra were recorded at 600 and 150 MHz, respectively, using Bruker Avance III 600 MHz NMR spectrometer using CDCl_3 as solvent. The ^1H and ^{13}C NMR spectra of FAME from *C. pepo* L. seed oil are depicted in Figs. 2.3 and 2.4.

The ^1H NMR spectrum of FAME from *C. pepo* L. seed oil is shown in Fig. 2.3. The multiplet at δ 5.240–5.398 ppm represents the olefinic protons ($-\text{CH}=\text{CH}-$). The triplet near $\sim \delta$ 2.763 ppm indicates the bis-allylic protons ($-\text{C}=\text{C}-\text{CH}_2-\text{C}=\text{C}-$) of the unsaturated fatty acid (like linoleic acid) [7]. The triplet at δ 2.290 ppm represents the α -methylene protons to ester ($-\text{CH}_2-\text{CO}_2\text{Me}$). The α -methylene protons to double bond ($-\text{CH}_2-\text{C}=\text{C}-$) appear as a multiplet near $\sim \delta$ 1.988–2.060 ppm. The β -methylene protons to ester ($\text{CH}_2-\text{C}-\text{CO}_2\text{Me}$) also appear as a multiplet at δ 1.592–1.612 ppm. The singlet signals at δ 1.249 are expected for the protons of backbone methylenes of the long fatty acid chain. The terminal methyl protons ($\text{C}-\text{CH}_3$) appears as a multiplet near δ 0.85–0.88 ppm. The ^{13}C NMR spectrum of biodiesel from *C. pepo* L. seed oil is shown in Fig. 2.4. The signals at δ 173.02–173.47 ppm represent the carbonyl carbon of the ester molecules of FAME, and the olefinic carbons appear at δ 128.09, 128.29, 129.58,

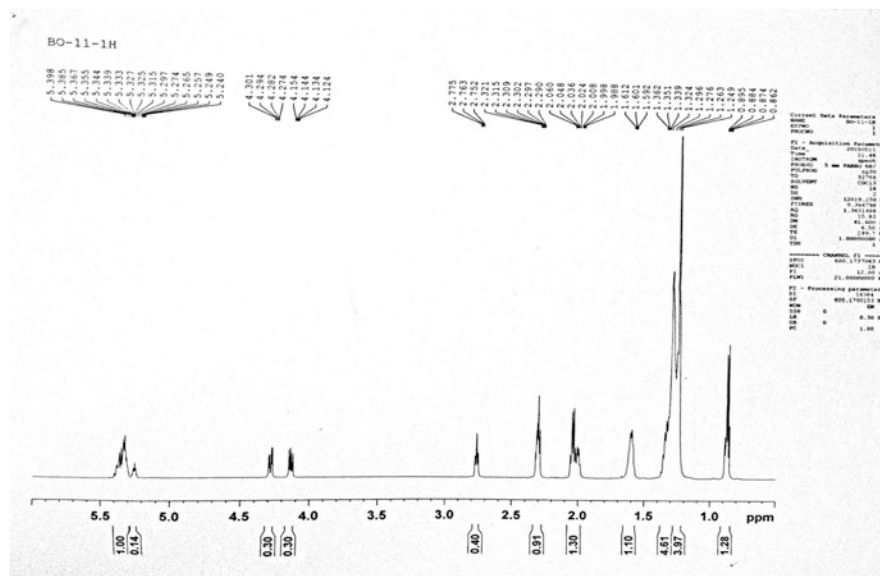


Fig. 2.3 ¹H NMR of FAME

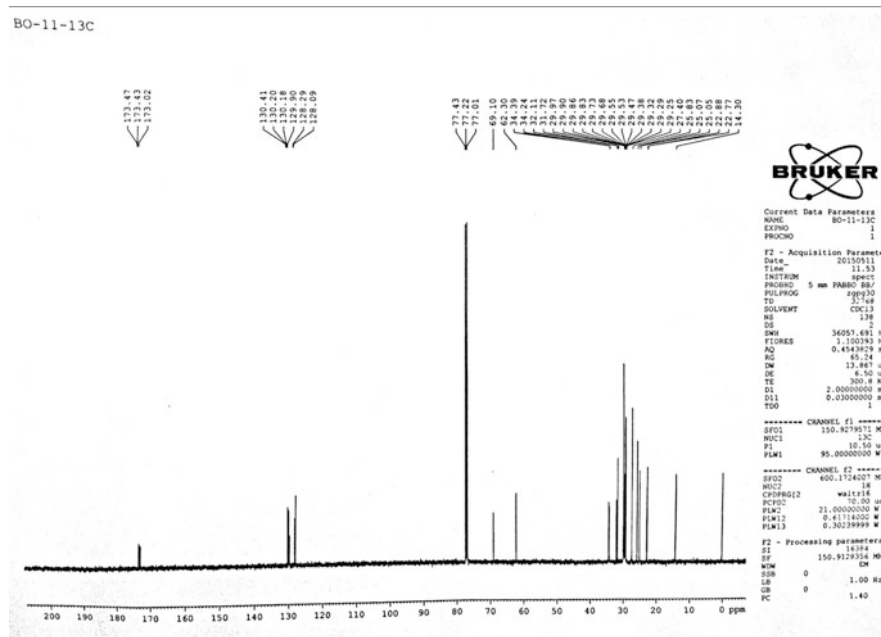


Fig. 2.4 ¹³C NMR of FAME

129.90, 130.18, 130.20, and 130.41 ppm. The methylene and methyl carbons of fatty acid moiety appear in the range from δ 14.30 to 34.39 ppm.

2.3 Result and Discussion

2.3.1 Biodiesel Analysis

The chemical composition of biodiesels is very important for determining their suitability for diesel engine application. Chemically, all biodiesels are mono alkyl esters of fatty acids, commonly referred to as fatty acid methyl or ethyl esters [8]. The analysis of the physicochemical properties are shown in Table 2.3.

Density is the mass per unit volume of the oil. The density of *C. pepo* L. methyl ester was found out at chemistry laboratory of Assam down town University by bottle method. The density was found out to be 787 kg m^{-3} at 28°C .

Kinematic viscosity is the property of a fluid which resists the fluid to flow over a surface. Higher the viscosity of a fluid greater will be the resistance to flow. The test for viscosity of *C. pepo* L. methyl ester was performed at Indian Institute of Technology, Guwahati (IITG). It was found out to be $4.41 \text{ mm}^2 \text{ s}^{-1}$.

Flash point is the temperature at which the fuel particles get burned. Flash point of the *C. pepo* L. methyl ester was found to be 138°C .

Calorific value is the amount of energy released from complete combustion of a specified amount of fuel. It is measured by MJ kg^{-1} of oil or fuel. The test for calorific value was performed at Indian Institute of Technology, Guwahati (IITG).

Moisture content test of *C. pepo* L. ester was carried out at Indian Institute of Technology, Guwahati. It is defined as the amount of water contained in the oil. The moisture content of *C. pepo* L. methyl ester was found out to be $598 \mu\text{g g}^{-1}$.

The temperature at which a liquid becomes a semi solid is called pour point of the liquid. At this point, the liquid loses its flow ability and becomes stationary. The pour point of oil as low as possible to consider the oil as an IC engine fuel. The *C. pepo* L. methyl ester pour point was found out to be -13°C .

Test for FFA level was performed at Chemistry laboratory of Assam down town University by the method of titration. The FFA level of *C. pepo* L. vegetable oil by

Table 2.3 Properties of *Cucurbita pepo* L. methyl ester

S. No.	Properties	Biodiesel
1	Density (28°C)	787 kg m^{-3}
2	Kinematic viscosity (40°C)	$4.41 \text{ mm}^2 \text{ s}^{-1}$
3	Flash point	138°C
4	Calorific value	$42.128 \text{ MJ kg}^{-1}$
5	Moisture content	$530 \mu\text{g g}^{-1}$
6	Pour point	-13°C
7	Acid value, KOH	0.12 mg g^{-1}

Table 2.4 Physicochemical properties comparison

Properties	^b Diesel	^a <i>Cucurbita pepo</i> L. biodiesel	^b Soybean biodiesel	^b Jatropha biodiesel
Oil content	–	48%	15%	30–35%
Density (28 °C)	840 kg m ⁻³	787 kg m ⁻³	907.3 kg m ⁻³	620 kg m ⁻³
Kinematic viscosity (40 °C)	4.0 mm ² s ⁻¹	4.41 mm ² s ⁻¹	4.3745 mm ² s ⁻¹	4.9476 mm ² s ⁻¹
Calorific value	45 MJ kg ⁻¹	42.128 MJ kg ⁻¹	39.579 MJ kg ⁻¹	39.5 MJ kg ⁻¹
Pour point	–14 °C	–13 °C	1 °C	–10 °C
Cloud point	–13 °C	–6 °C	1 °C	–3 °C

^aExperimental^bLiterature: Kumar et al. [9]; Bwade et al. [10]

percentage was 0.88. After transesterification, the FFA level of the *C. pepo* L. methyl ester was found out to be 0.68%.

2.3.2 Comparison with Diesel and Other Feedstock

A comparison of the physicochemical properties of *C. pepo* L. seed oil methyl ester with petroleum diesel and other feedstock for biodiesel production is shown in Table 2.4.

2.4 Conclusion

In this study, Pumpkin (*C. pepo* L.) seed oil was considered as a feedstock for biodiesel production because of its suitability for production in a variety of atmospheric condition, easy cultivation, high fruit production rate, and easy availability in markets. Here, the physicochemical properties of *C. pepo* L. seed oil and *C. pepo* L. seed oil methyl ester was experimentally analyzed and compared with other established feedstock for biodiesel production along with petroleum diesel and found that its properties are comparable to petroleum diesel. It was found that the oil content of *C. pepo* L. seed around 48% which is higher than the Soybean and Jatropha seed. Here, we have produced biodiesel from *C. pepo* L. seed oil by transesterification process and determined the various properties like density, kinematic viscosity, calorific value, pour point, and cloud point corresponding to ASTM standard and found it slightly better than the biodiesel produced from Soybean and Jatropha seed oil. The calorific value of *C. pepo* L. seed oil methyl ester was 42.128 MJ kg⁻¹, which is almost equivalent to the calorific value of normal diesel. Since the oil content of *C. pepo* L. seed is higher than some established feedstock, and physicochemical properties are comparable to petroleum

diesel hence, we can conclude that *C. pepo* L. seed oil can be a viable feedstock for production of biodiesel in India.

Acknowledgements The authors would like to express their thanks to Mr. Debarshi Baruah, Technical Officer, Centre for Energy, Indian Institute of Technology, Guwahati (IITG) for the technical and laboratory support and Mr. Neelkamal Basumatary of AdtU for his valuable contribution.

References

1. Masum BM, Masjuki HH, Kalam MA, Rizwanul Fattah IM, Palash SM, Abedin MJ (2013) Effect of ethanol–gasoline blend on NO_x emission in SI engine. *Renew Sustain Energy Rev* 24:209–222
2. Van Gerpen J (2005) Biodiesel processing and production. *Fuel Process Technol* 86:1097–1107
3. Murugesan A, Umarani C, Subramanian R, Nedunchezian N (2009) Bio-diesel as an alternative fuel for diesel engines—a review. *Renew Sustain Energy Rev* 13:653–662
4. Rizwanul Fattah IM, Masjuki HH, Liaquat AM, Ramli R, Kalam MA, Riazuddin VN (2013) Impact of various biodiesel fuels obtained from edible and non-edible oils on engine exhaust gas and noise emissions. *Renew Sustain Energy Rev* 18:552–567
5. Hoekman SK, Robbins C (2012) Review of the effects of biodiesel on NO_x emissions. *Fuel Process Technol* 96:237–249
6. Schinas P, Karavalakis G, Davaris C, Anastopoulos G, Karons D, Zannikos F, Stournas S, Lois E (2009) Pumpkin (*Cucurbita pepo* L.) seed oil as an alternative feedstock for the production of biodiesel in Greece. *Biomass Bioenerg* 33:44–49
7. Moser BR, Vaughn SF (2010) Coriander seed oil methyl ester as biodiesel fuel: unique fatty acid composition and excellent oxidative stability. *Biomass Bioenerg* 34(4):550–556
8. Jahirul MI, Brow RJ, Senadeera W, Ashwath N, Rasul MG, Rahman MM, Hossain FM, Moghaddam L, Islam MA, O'Hara IM (2015) Physio-chemical assessment of beauty leaf (*Calophyllum inophyllum*) as second-generation biodiesel feedstock. *Energ Rep* 1:204–215
9. Kumar S, Singh J, Nanoti SM, Garg MO (2012) A comprehensive life cycle assessment of jatropha biodiesel production in India. *Bioresour Technol* 110:723–729
10. Bwade KE, Aliyu B, Kwaji AM (2013) Physicochemical properties of seed oil relevant to biodiesel production and other industrial applications. *Int J Environ Eng Manag* 13:72–78

Conference Proceedings of the Second International
Conference on Recent Advances in Bioenergy Research
ICRABR 2016

Kumar, S.; Sani, R.K.; Yadav, Y.K. (Eds.)

2018, VIII, 192 p. 83 illus., 63 illus. in color., Hardcover

ISBN: 978-981-10-6106-6