

Extraction and Characterization of *Sesbania cannabina* (Retz.) Pers. (Dhaincha) Seed Oil for Potential Engineering Applications

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Abstract: *Sesbania cannabina* (Retz.) Pers. (Dhaincha) is a member of family Fabaceae spread over several countries in tropical and subtropical regions of the world. *Sesbania aculeata*, *Sesbania drummondii*, *Sesbania grandiflora*, *Sesbania rostrata*, *Sesbania sesban*, and *Sesbania speciosa* are other members of this family. The agricultural, nutritional and pharmaceutical applications of *Sesbania* species are known to farmers, villagers, and the tribes since ages and are well studied by researchers. However, the significance of *Sesbania* as an industrial crop has not been recognized till now. The objective of this study was extraction and characterization of *Sesbania cannabina* seed oil (SCSO) for potential engineering applications. The seed oil was extracted with hexane in a Soxhlet extractor. Yield was only 2.32% w/w due to long storage at high temperature in seed house. *Sesbania cannabina* seed oil methyl ester (SCSOME) was prepared via esterification and transesterification for analysis of fatty acid composition of extracted oil. SCSO has high iodine value (118 g I₂/100 g) and high saponification value (185.79 mg KOH/g) making the oil suitable for use as candle stocks or in soap making. However, these applications were ruled out on account of being insignificant for oil available in limited quantity. The oil has high viscosity index (174.19), high onset (382°C) and offset (450°C) decomposition temperatures, endothermic nature, and shear rate thickening behaviour. These properties make SCSO a good candidate for application as specialty lubricant required under severe operating conditions of high temperature and high shear rate or as insulating and cooling transformer oil.

Key words: *Sesbania cannabina*, free fatty acid, iodine value, saponification value, thermogravimetric analysis

1 Introduction

The genus *Sesbania* of family Fabaceae is comprised of around 60 species of annuals, perennials, herbs, shrubs and trees that are distributed over tropical and subtropical regions of the world. *Sesbania aculeata* (synonym *Sesbania bispinosa*, Prickly sesban, Dhaincha), *Sesbania cannabina* (common sesban, Yellow pea bush, Dhaincha), *Sesbania drummondii* (Rattlebox), *Sesbania grandiflora* (vegetable hummingbird, Agathi, Agasti), *Sesbania rostrata* (Manila Agathi, new Dhaincha), *Sesbania sesban* (Egyptian riverhemp, African *sesbania*), and *Sesbania speciosa* (Wisteria tree) are more popular among all *Sesbania* species and well studied by researchers too. *Sesbania* species are generally adaptable to terrains with alternate wet and dry climates than those with humid climate having

evenly distributed rainfall throughout the year¹. Quite interestingly, the *Sesbania* species are known for their remarkable tolerance to adverse soil, geographic and climatic conditions like saline and sodic soils, soil with high electrical conductivity (10 mS cm⁻¹)², high alkalinity (pH 10)³, drought, waterlogging⁴, high annual temperature (36–44°C) and rainfall (570–2210 mm)⁵ with little or no input.

The agricultural, nutritional and pharmaceutical applications of *Sesbania* species are known to farmers, rural people and tribal communities since ages particularly in Indian subcontinent. The major application of *Sesbania* is as a leguminous crop to increase the soil fertility. It is a fast-growing, succulent and easily decomposable green manure crop which on mulching with soil increases the

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quantity of organic matter and nitrogen in soil⁶⁾. This in turn results in higher yield for wheat, rice, maize, sorghum, sugar cane, etc.⁴⁾. The concurrent growing of *Sesbania* with rice significantly reduces the count of grass, weeds and sedges in the field resulting in higher yield of rice due to increased nutrient uptake from soil in a competition free environment⁷⁾. The other less important applications of *Sesbania* species in traditional agroforestry include as cover crop, shade plant, windbreak, live support fence, livestock feed, aquafeed, fibre, wood for light construction work and firewood^{2, 8, 9)}. The stems are used as poles in fishing and in fencing around agricultural fields and gardens. The stem wood has been reported to be used for mushroom cultivation in Mekong river delta of southern Vietnam¹⁰⁾. The fibre obtained from the stem is used in making high strength ropes and fishing nets¹¹⁾.

The leaves, flowers, pods and seeds of *Sesbania* constitute a valuable source of livestock feed. *Sesbania* leaves contain 30% protein and good amino acid composition and are therefore considered a high quality fodder for livestock with reported increase in milk and meat production¹²⁾. *Sesbania* seeds contain 29–33% crude protein, 4.7–6% crude lipid, 11–16% crude fibre, and 44–47% carbohydrates¹³⁾. Some tribal sects of South India are reported to consume mature seeds after proper cooking^{14, 15)}.

Sesbania occupies a unique place in traditional Indian medicines for treatment of various health disorders on account of healing properties in different parts of the plant. The roots of *Sesbania* are used as alexiteric (against the effects of poison), anthelmintic (to destroy parasitic worms), carminative (to prevent formation of gas in the gastrointestinal tract and facilitate its expulsion), collyrium (medicated eyewash), contraceptive (to prevent pregnancy), diuretic (causing increased passing of urine), galactagogue (to promote the flow of mother's milk) and hepatoprotective (to protect damage to the liver). Some other pharmaceutical applications of roots include the treatment of dysuria (painful urination), leucoderma (loss of skin colour), fever, ulcer, and diabetes^{12, 16, 17)}. Similarly, barks are effective in treatment of anaemia, bronchitis, dysentery, inflammations, leucorrhoea, liver cirrhosis, tumour and hypertension¹²⁾.

The extract of *Sesbania* leaves in the form of tea is believed to contain anthelmintic, antibiotic, antispasmodic, antitumor, contraceptive^{14, 18)} and sedative properties. Leaf paste is often used in seeking relief from skin diseases and inflammatory rheumatism¹²⁾. Leaves wash is used as prevention to tsetse flies and is also given to infants against a whooping cough¹⁷⁾. *Sesbania* leaves have good concentration of antidiabetic (+)-pinitol or O-methyl inositol (1-methoxy-2,3,4,5,6-penta hydroxy cyclohexane)⁶⁾. Pinitol is also active against larval growth of major agricultural pest corn earworm moth (*Helicoverpa zea*)¹⁹⁾. *Sesbania* flowers are used as poultice to cure skin afflictions^{15, 16)}, whereas

the flowers smoke is an effective mosquito and insect repellent¹⁷⁾.

Sesbania seeds are good astringent (causes skin or other tissues to tighten), emmenagogue (promotes menstrual discharge) and stimulant. They are also used in treatment of diarrhoea, fever, spleen enlargement, ulcers and as purgative demulcent¹²⁾. Seed powder is extensively applied on infected area in the treatment of ringworm, skin diseases, wounds^{14, 16, 18, 20)} and headache¹⁵⁾. Seed powder is also given to stimulate appetite¹⁷⁾. The seed meal with about 53% protein is found as a suitable medium for production of antibiotic fungi *Penicillium*¹¹⁾. Seed oil is an effective pain reliever particularly in arthritis¹⁵⁾.

The fibre obtained from stem wood of annual *Sesbania* species can be used in paper industry for pulp making^{8, 20)}. *Sesbania* seed oil is used in the production of paints, varnishes, and printing inks due to its higher viscosity than other vegetable oils²¹⁾. *Sesbania* seeds are good source of non-toxic polysaccharide galactomannan (mannose-to-galactose M/G ratio: 1.8:1)²²⁾ that can be used for several applications in biomedical, cosmetics, food, pharmaceutical, paper and textile industries. In food industry the main applications of galactomannan are as stabilizer, thickener, emulsifier and firming agent in bakery mixes, baby milk formulations, coffee/tea whiteners, dairy and dietary products, fruit-based water gels, ice creams, powdered products, salad dressings, sauces and soups, canned meats and frozen and cured meat products²³⁾. In pharmaceutical industry galactomannan is used in manufacturing of tablets to improve their hardness and delivery to the large intestine without release into the upper gastrointestinal tract¹⁵⁾.

The use of *Sesbania* in agriculture as a leguminous green manure crop is so popular and established that it has overshadowed the horizon for other applications. For instance, the nutritional and pharmaceutical applications are confined to a few rural and tribal communities without much commercial value. *Sesbania* seed galactomannan is equivalent to guar gum and is less expensive¹⁵⁾, howbeit it has not received as much acceptance as guar gum in food industry. Several research groups in India²⁴⁾, Pakistan²⁵⁾, Bangladesh^{26, 27)} and Vietnam¹⁰⁾ have confirmed the potential of *Sesbania* fibre for pulp making, but it is hardly used as raw material in pulp and paper industry as compared to eucalyptus and poplar. Authors of this article observe that the importance of *Sesbania* as an industrial crop is not yet recognized and corresponding efforts in this direction are lacking. It would be difficult for our small research group to conduct research on all aspects of *Sesbania* with equal authority; henceforth we fix our attention on *Sesbania cannabina* seed oil (SCSO) for applications other than agricultural, nutritional and pharmaceutical. The main objective set for this study was to extract oil from *Sesbania cannabina* (retz.) pers. (Dhaincha) seeds with hexane by hot extraction in a Soxhlet extractor and its characteriza-

tion for potential engineering applications. This study might seek the attention of researchers towards this species for further studies culminating in increased commercial utilization.

2 Experimental

2.1 Materials

Sesbania cannabina (Dhaincha) seeds were purchased from local seed store in vicinity of Kanpur University. Hexane LR and Potassium hydroxide pellets LR were purchased from Avantor Performance Materials India Limited, Ankleshwar. Methanol GR and anhydrous Sodium sulphate were purchased from Merck Specialities Pvt. Limited, Mumbai. Sulphuric acid abt. 98% LR was purchased from S. d. Fine-chem Limited, Mumbai. Silicon high vacuum grease was purchased from Loba Chemie Pvt. Limited, Mumbai. Phenolphthalein indicator solution 1% was purchased from Central Drug House (P) Limited, New Delhi. All chemicals were used as obtained from vendor without any purification.

2.2 Plant Description

Sesbania cannabina (Fig. 1) is an annual erect plant that can grow up to a height of 3.5 m. The stem is green in colour that becomes somewhat woody and is much branched on the upper side. The mature leaves are 5–20 cm long and are in 12–30 pairs of leaflets. Each leaflet is 5–20 mm long and 2–4 mm wide with rounded leaflet tip. The raceme has 1–5 pea-like flowers which are yellow to yellowish orange with dark purple streaks on the corolla.



Fig. 1 *Sesbania cannabina* (a) plant, (b) flowers, and (c) seeds.

The pods are near cylindrical, straight or little bent 12–20 cm long and 2.5–4 mm in diameter containing 20–35 seeds. The seeds are smooth dark green cylindrical and 3–4 mm long. The plant is widely distributed over several countries of the world. A partial list includes India, Nepal, Bangladesh, Pakistan, Myanmar, Malaysia, Mauritius, Indonesia, Vietnam, Philippines, Ghana, Southern China, Australia, New Guinea, New Caledonia and South Pacific Islands^{28, 29}.

2.3 Experimental Setup

The extraction of SCSO was carried out in a 60 ml capacity Soxhlet extractor. The extractor capacity is the volume of the solvent held in the extractor to the cusp of the siphon tube. The various components of experimental setup are shown in Fig. 2. The inner joint at the bottom of the extractor was connected to the centre neck of a three-

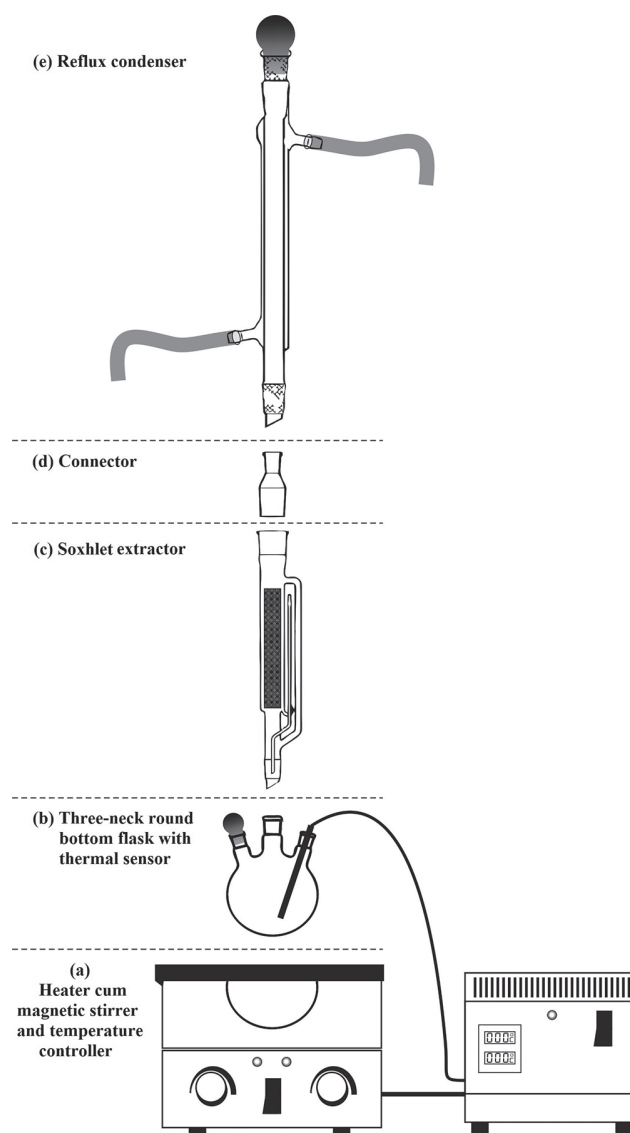


Fig. 2 Experimental setup for extraction of SCSO.

necked round bottom boiling flask. The outer joint at the top of the extractor was connected to the reflux condenser. The condenser refluxes the solvent vapours back to the extractor to prevent any solvent loss. The condenser is also useful in sustaining the atmospheric pressure inside the boiling flask³⁰⁾. An oil-filled thermowell was fitted in one side neck of boiling flask to put the thermal sensor for continuous temperature measurement. The other side neck was used as sampling port. REMI 2RML heater cum magnetic stirrer was used to provide necessary heat and stirring to feed material. PTFE coated magnetic stirrer bar was used in place of top mounted mechanical stirrer. A highly efficient custom-made PID controller manufactured by Blue Bell Industries, Kanpur was used to maintain the temperature in the boiling flask within $\pm 0.1^\circ\text{C}$ of the set values. An external tank equipped with a small capacity centrifugal pump supplied cold water to reflux condenser. Running tap water was not used in the study to prevent wastage of this valuable natural resource. The synthesis of *Sesbania cannabina* seed oil methyl ester (SCSOME) was carried out in the same experimental setup except that the Soxhlet extractor was displaced from the assembly.

Stainless steel (S.S.) sample holders were specifically designed for oil extraction. Three cylindrical sample holders, each of dimension 180 mm $\times$ 28 mm were made from 1 mm thick perforated S.S. sheet. The sample holders were then wrapped with multiple layered muslin cloth to prevent slippage of fine seed particles during extraction. These sample holders are highly economical, durable and are convenient to work with and easy to clean than conventional cellulose or glass fibre thimbles.

2.4 Oil Extraction

The seeds were manually cleaned to remove dust, dirt and other foreign particles chiefly the wheat and rice grains and seasonal pulses. The cleaned and dried seeds were grinded in a domestic grinder to produce powdered seed particles. Around 60 g of powdered seeds were extracted with 0.5 L of hexane in Soxhlet extractor at 68°C for 8 hours. Hexane condensation rate was fixed at 150 drops/min for the entire duration³⁾. After extraction the hexane was recovered from the oil by blank extraction. In blank extraction the experiment was run as usual but with empty extractor having no seeds. In this manner the pure solvent was collected in extractor and withdrawn carefully before running off the siphon. The residual traces of hexane were removed by heating the oil in water bath at 50°C ³¹⁾. The extracted oil was then dried over anhydrous sodium sulphate³²⁾ and stored at laboratory temperature in closed glass bottle. The average oil yield was merely 2.32% (w/w) that necessitated several batches to run in order to collect sufficient quantity of oil for characterization purpose. The oil extraction data for some experimental runs are given in Table 1.

Table 1 SCSO extraction data for different experimental runs.

S. No.	Seed quantity (g)	Oil extracted (g)	Yield (%)
1	62.62	1.35	2.16
2	68.97	1.74	2.52
3	62.65	1.64	2.62
4	57.20	1.27	2.22
5	69.04	1.53	2.22
6	67.00	1.54	2.30
7	62.85	1.37	2.18
8	69.65	1.67	2.40
9	55.15	1.20	2.18
10	67.82	1.76	2.60
11	63.16	1.53	2.42
12	57.95	1.33	2.30
13	65.88	1.56	2.37
14	62.75	1.35	2.15
15	53.20	1.16	2.18

2.5 Oil Characterization

2.5.1 Physicochemical analysis

The density, acid value, free fatty acid, saponification value, iodine value, peroxide value, unsaponifiable matter, moisture content, colour, and refractive index of *Sesbania cannabina* oil were determined following Indian Standard Methods of Sampling and Test for Oils and Fats Part I Sampling, Physical and Chemical Tests (Revised) IS: 548 (Part I)–1964. The viscosity index (VI) value was determined on the basis of known viscosities of oil at 40 and 100°C using ASTM D2270 standard method. The higher heating value (HHV) (also called gross calorific value) of the oil was determined non-calorimetrically using equation (1) involving saponification value and iodine value of the oil³³⁾.

$$\text{HHV} = 49.43 - 0.041(\text{SV}) - 0.015(\text{IV}) \quad (1)$$

2.5.2 Methyl ester preparation for GC-MS

SCSOME was synthesized via two stage esterification and transesterification protocol on account of acid value of SCSO exceeding the threshold limit of 2 mg KOH/g oil. First the acid-catalyzed esterification of SCSO was carried out with sulphuric acid as catalyst. After successful completion of first stage reaction, base-catalyzed transesterification was initiated with potassium hydroxide as catalyst. At the end of the process a clear emerald green liquid methyl ester was formed. A detailed description of two stage process for vegetable oil methyl ester formation can be found elsewhere³⁰⁾.

2.5.3 GC-MS analysis

The fatty acid profile of SCSOME was determined using an Agilent gas chromatograph (GC-FID) Model 6890, inte-

grated with non-polar HP-5 MS fused silica capillary column having (5%-phenyl) methylpolysiloxane stationary phase (30 m × 0.25 mm i.d., 0.25 µm film thickness). The column temperature was programmed initiating from 30°C with 3 min initial hold to 270°C at 4°C/min and then held isothermally at 270°C for 6 min. The injector and flame ionization detector temperatures were 250 and 300°C, respectively. The oil was diluted in acetone 3.5% (v/v) and 1 µL sample injected in split mode (1/12) with solvent delay time of 1 min. Helium was used as a carrier gas (1.0 mL/min). Each outbound component of the column reached directly into the ionization field of the coupled Agilent mass spectrometer (MS) Model 5975. The mass spectrometer operated in electron impact mode at 70 eV and the electron multiplier voltage was 2200 V. The ion source temperature was 230°C and MS quadrupole temperature was 180°C. Mass spectral data were obtained in the scan mode in the m/z range 25–400. The identification of the oil constituents was done by matching their mass spectra and retention times (RT) with those of reference compounds in NIST 14 mass spectral library³⁴.

2.5.4 Thermogravimetric analysis

Thermogravimetric analysis (TGA) of SCSO was performed using a Mettler Toledo TG/SDTA851e model thermogravimetric analyzer under nitrogen at a temperature range of 35–800°C and heating rate of 10°C/min. The oil sample of size 55.1960 mg was taken in an open alumina pan and the nitrogen flow rate was set at 50 ml/min. The resulting TGA curve was applied to figure out the onset and offset degradation temperatures of the oil sample. The onset degradation temperature determines the resistance

of the sample against thermal degradation. The higher onset degradation temperature is therefore indicative of higher thermal stability of the product and vice versa³⁵.

2.5.5 Viscosity analysis

The viscosity of SCSO was measured using TA instruments' Discovery Hybrid Rheometer model HR-3 Peltier plate and cone geometry (diameter 60 mm, angle 1/2 degree) under air at varying shear rates.

3 Results

SCSO characteristics were determined following Indian standard IS: 548 (Part I) – 1964 methods and the results are summarized in **Table 2**. The acid value of oil indicates its degree of purity, aging and quality upon storage²¹. The iodine value is an indication of the degree of unsaturation (DU) or the average number of C–C double bonds in its constituent fatty glycerides. The saponification value is an assessment of average molecular weight or carbon chain length of all the fatty acids present in test sample as triglycerides. Higher saponification value corresponds to smaller average molecular weight and the smaller average fatty acid carbon chain length (means higher percentage of short carbon chain fatty acids) of triglycerides and vice versa³⁶. Peroxide value is a measure of lipid oxidation and determines the oil quality. Freshly refined oils have peroxide value less than 0.05³⁷. VI is a dimensionless scale used to determine the dependence of viscosity on temperature³⁸. High VI corresponds to a small change in viscosity over a large temperature range³⁹ and the other way around

Table 2 Analytical values of SCSO.

S. No.	Test parameter	Value
1	Density at 27°C (g/cm ³)	0.9256
2	Acid value (mg KOH/g)	18.72
3	Free fatty acid (w/w % Oleic acid)	9.41
4	Iodine value (g I ₂ /100 g)	118
5	Saponification value (mg KOH/g)	185.79
6	Peroxide value (milli-equivalents per gram sample)	0.04398
7	Unsaponifiable matter (w/w %)	1.5
8	Moisture content (w/w %)	0.14
9	Color (1/4 inch)	85 (Y + 5R)
10	Refractive index at 40°C	1.4619
11	Viscosity at 40°C	39.9723 cSt
12	Viscosity at 100°C	16.7983 cSt
13	Viscosity index	174.19
14	Higher heating value (MJ/kg)	40.04261
15	Surface tension (mN/m)	37.5324

for low VI⁽⁴⁰⁾.

On the basis of GC-MS analysis of SCSOME, the percentage compositions of component fatty acids were calculated and are given in Table 3. SCSO is found to contain 41.36% saturated fatty acids, 51.69% monounsaturated fatty acids and 6.95% polyunsaturated fatty acids. The seed oil is rich in oleic acid (41.34%) along with moderate proportions of palmitic acid (13.85%), stearic acid (8.65%) and lauric acid (6.35%) acid. SCSO contains 1.44% omega-3 alpha linolenic acid which is greater than several commercial oils such as safflower (0.15%), sunflower (0.16%), rice bran (0.45%), and wheat germ and rapeseed (1.2% each)⁽⁴¹⁾. The oil is also a rich source of omega-6 linoleic acid (1.89%). The DU for SCSO was estimated using the following equation⁽⁴²⁾: Degree of unsaturation (DU) = (monounsaturated fatty acid C_n :1 wt.%) + 2 (polyunsaturated fatty acid C_n :2 wt.%) + 3 (polyunsaturated fatty acid C_n :3 wt.%).

DU was calculated to be 70.65 wt.%. Density, viscosity and HHV are correlated with the DU. Researchers have determined that the density of vegetable oils increases with reducing chain length and increasing DU; on the contrary, the viscosity increases with chain length and decreases as

the DU increases. The HHV of vegetable oils increases with the DU⁽⁴³⁾.

TGA-DSC thermograms of SCSO are shown in Fig. 3. It is evident from the TGA plot that thermal decomposition of SCSO took place in a single stage. As the temperature was increased from 50 to 100°C, a loss of 0.4616% in weight was observed indicating the presence of small moisture in the oil. The sample displayed remarkable thermal stability by retaining 97% of its initial weight until 223°C, 95% until 258°C, and 90% until 313°C. At 400°C, the weight loss was about 40%. This result is attributed to the flash point of oil under study. The onset (T_{onset}) and offset decomposition (T_{offset}) temperatures were analyzed graphically from the thermogram at 382°C and 450°C, respectively, where a weight loss of 63% occurred over a thermal interval of 68°C. The maximum decomposition temperature was observed at 409.583°C with 0.1592 mg weight loss. The temperature plateau starting at 488.93°C showed no further significant weight loss indicating the fire point of oil sample. The weight loss profile for SCSO is given in Table 4.

The results of viscosity analysis are plotted as shear rate

Table 3 Fatty acid composition of SCSO.

Common name	Systematic name	weight %
Saturated fatty acid		41.36
Lauric acid (C12:0)	Dodecanoic acid	6.35
Myristic acid (C14:0)	Tetradecanoic acid	0.90
Palmitic acid (C16:0)	Hexadecanoic acid	13.85
Stearic acid (C18:0)	Octadecanoic acid	8.65
Arachidic acid (C20:0)	Eicosanoic acid	3.98
Behenic acid (C22:0)	Docosanoic acid	3.65
Lignoceric acid (C24:0)	Tetracosanoic acid	3.98
Monounsaturated fatty acid		51.69
5-Dodecenoic acid (C12:1 ω-7)	cis-5-Dodecenoic acid	0.23
Palmitoleic acid (C16:1 ω-7)	cis-9-Hexadecenoic acid	1.56
Paullinic acid (C20:1 ω-7)	cis-13-Eicosenoic acid	3.22
Elaidic acid (C18:1 ω-9)	trans-9-Octadecenoic acid	3.95
Oleic acid (C18:1 ω-9)	cis-9-Octadecenoic acid	41.34
Gondoic acid (C20:1 ω-9)	cis-11-Eicosenoic acid	0.57
Erucic acid (C22:1 ω-9)	cis-13-Docosenoic acid	0.53
Nervonic acid (C24:1 ω-9)	cis-15-Tetracosenoic acid	0.29
Polyunsaturated fatty acid		6.95
Linoleic acid (C18:2 ω-6)	cis,cis-9,12-Octadecadienoic acid	1.89
α-Eleostearic acid (C18:3)	cis,trans,trans-9,11,13-Octadecatrienoic acid	3.62
α-Linolenic acid (C18:3 ω-3)	cis,cis,cis-9,12,15-Octadecatrienoic acid	1.44

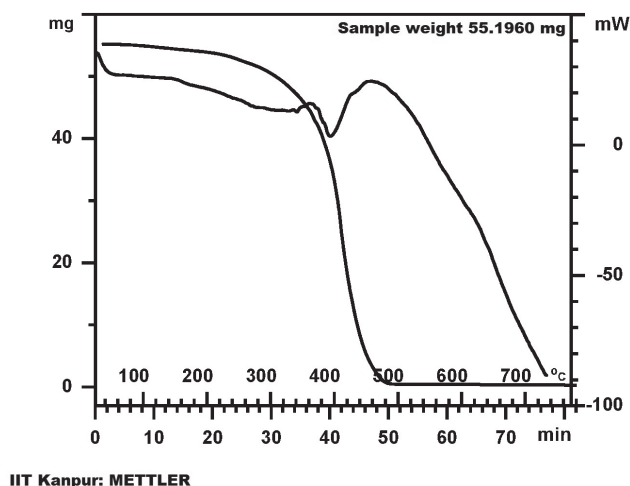


Fig. 3 TGA-DSC thermogram of SCSO.

vs. viscosity in Fig. 4. The plot shows a rise in viscosity of SCSO with increase in shear rate, which is indicative of shear rate thickening behaviour for test oil.

4 Discussion

Low oil content in *Sesbania cannabina* seeds and high free fatty acid in crude oil is attributed to longer storage time and higher temperature at seed storage facility⁴⁴⁾. High iodine value (118 g I₂/100 g) of oil makes it useful for applications such as salad oil, cooking grease, candle stock,

etc, whereas its high saponification value (185.79 mg KOH/g) makes the oil useful for soap making industries³⁶⁾. High VI (174.19) of SCSO favours its application preferably as a quality lubricant for high temperature operating conditions.

SCSO is rich in omega-3 alpha linolenic acid (1.44%) and omega-6 linoleic acid (1.89%), both of which are considered essential to human body as they are important structural components of cell membranes, but are not synthesized by human body. The higher saturated fatty acid content (41.36%) of oil is largely responsible for high oxidative and thermal stability in oil leading to a slower deterioration rate of oil characteristics²¹⁾.

TGA observations further confirmed the higher thermal stability of SCSO. The corresponding DSC plot confirms the endothermic nature of SCSO and infers that SCSO can be used in high temperature engineering applications such as insulating fluid in transformers²¹⁾. Such oils are ideal for those applications which involve high speed rotation of machine components, like automobile engines, aircraft engines, power generation turbines, as these oils will retain their lubricity under severe operating conditions³⁰⁾.

5 Conclusion

In this study, SCSO was characterized for applications other than agricultural, nutritional and pharmaceutical. The average crude oil yield extracted from *Sesbania can-*

Table 4 SCSO weight loss profile.

Sample	Heating rate (°C/min)	Temperature for weight loss (°C)			
		1%	10%	50%	90%
SCSO	10	129.682	313.086	408.493	449.26

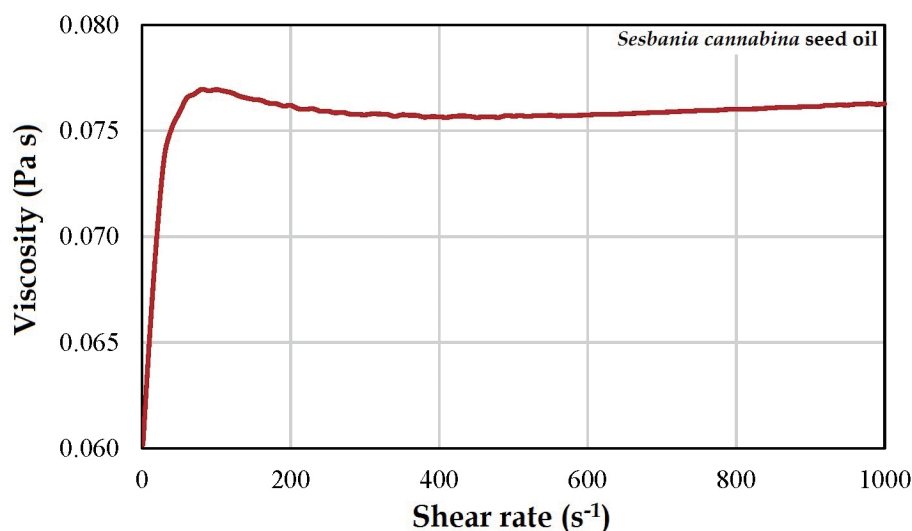


Fig. 4 Shear rate vs. viscosity behaviour of SCSO.

cabina seeds was low, whereas the free fatty acid content was high, both due to longer storage time and higher temperature at seed house facility. The study found SCSO to have high iodine value, saponification value, and VI, excellent thermal stability, good endothermic nature, and shear rate thickening property. High iodine value and saponification value make the oil suitable for use as candle stocks or in soap industries. But since the oil content in *Sesbania cannabina* seeds is very low, use of SCSO for such trivial applications is strongly ruled out. High thermal stability and endothermic nature makes the oil suitable for use as an insulating and cooling liquid in transformers replacing currently applied mineral oils. High thermal and oxidative stability along with high VI and shear rate thickening behaviour of oil indicate towards its potential use as a quality lubricant for severe operating conditions of high temperature, pressure, and shear rate.

Conflicts of Interests

All the authors declare to have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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