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Study on biodiesel production from *Datura innoxia* and *Datura metel* seed oils from western Rajasthan, India

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ABSTRACT

The challenges associated with conventional fossil fuels have fueled the quest for alternative energy sources. In modern times alternative fuels have identified as a prominent problem in many countries has resulted in efforts to reduce emissions, which are currently imposing a substantial threat to the environment. In this context biodiesel is one of the best alternatives to the existing fossil fuel which is not only renewable but also non-toxic and environmentally sustainable. The purpose of this research was to compare the fatty acid profile and biodiesel potentials of *Datura innoxia* and *Datura metel* seed oils to develop eco-friendly and cheap bio-fuel from non-edible seed oils.. Their triglycerides were physicochemically characterized during the experiment. The seed oils were extracted using soxhlet apparatus and 40^0-60 ^{0}C petroleum ether as a solvent. The fatty acids methyl esters were prepared by base-catalyzed trans-esterification. The fatty acids compositions of both the seed oils were analyzed by GC-MS spectrophotometer. The fuel properties of both the Datura species biodiesel were compared with ASTM-D6751. The biodiesel obtained from *D. innoxia* and *D. metel* are found as a green alternative to diesel fuel due to its low cost, easy availability, and also do not cause any harmful effects on the environment.

***Key words**: Datura innoxia, Datura metel Physico-chemical properties, and Fuel Properties.*

Introduction

A significant proportion of the energy utilized in the modern world relies on fossil fuels. These are nonrenewable resources that take millions of years to build and whose deposits are diminishing more rapidly than they've regenerated. They are the main sources of greenhouse gas emissions, environmental damage, and global climate change. These fossil fuels release CO, CO_2, NOX, SOX, in complete combustion or partially burned hydrocarbons, and airborne contaminants, among other things. As a result of the emergence and use of these fossil fuels, environmental concerns have arisen (Wang, 2011). Numerous countries around the globe are rebooting biodiesel production to deal with the issue of continually increasing fuel and energy prices caused by the decline of exhaustible fossil fuels. This has stimulated research into alternative fuels to substitute hydrocarbon energy. Even though biodiesel has become more prevalent, edible oils contribute to far more than 95 percent of the renewable resources used in its production (Gui, 2008). However, the biodiesel production from edible oil increased the production costs and also the strain on current feedstuffs. The vegetable oils have several limitations to be used as biodiesel such as they are highly viscous in nature, increased cost of production, low volatility, and highly reactive towards unsaturated hydrocarbons (Demirbas, 2009a,b). As a result, it's critical to explore non-edible seed oils that are quite non-competitive with consumption and cheap. Castor and Jatropha seeds, and also microalgae oil, have been identified as some of the most encouraging non-edible oil fuel sources due to the higher seed oil composition (Sruthi, 2013). Non-edible oil crops can be grown in waste areas that aren't suitable for food crop production, and the cost of production is significantly lower because these crops can still produce a high output without requesting a lot more attention (Fatah, 2012). Non-edible oil species grow in the uncongenial desert and semi-arid environments with limited fertilizer and moisture prerequisites (Atabani *et al.,* 2013). Enormous amounts of non-edible oil plants could be found in the natural environment all over the world. The ideal vegetable oil for biodiesel must be widely accessible, have an effortless to grow the plant, and possess a large proportion of mono-unsaturated fatty acids (C16:1, C18:1) in its seed oil content (Wang, 2011). Several researchers worked on the production of biodiesel from non–edible seed oils such as *Madhuca indica, Jatropha curcas, Pongamia pinnata, Hevea brasiliensis, Ricinus communis*, Linseed, Cottonseed, *Azadirachta indica* under controlled laboratory conditions (Kulkarni *et al*., 2013; Senthil *et al.,* 2003; Meher *et al.,* 2006; Ikwuagwu *et al.,* 2000; Roy *et al*., 2020; Demirbas *et al.,* 2009; Nabi *et al*., 2009; Banu, Hd *et al.*, 2018). This research investigated the feasibility of employing *D. innoxia* and *D. metel* non-edible wild seeds in the arid zone of western Rajasthan with a potentially high proportion of oil in the seeds, as one of the prospective biodiesel feedstocks. *D. innoxia* and *D. metel* seed oils have been proven to be useful renewable feedstock for biodiesel production based on the above-mentioned parameters. The images of seeds of *D. innoxia* and *D. metel* were shown in Fig 1(a, b).

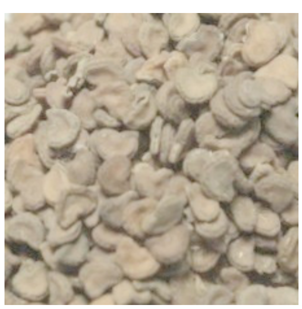

Fig. 1. (a) *Datura innoxia* seeds (b) *Datura metel* seeds

Materials and Methods

The seeds of *D. innoxia* and *D. metel* were collected from different locations in Rajasthan. The seeds were dried in shade and grounded with mortar. The oil was extracted with soxhlet apparatus using petroleum ether as solvent. A base-catalyzed trans-esterification reaction was employed to produce biodiesel from the oil sample recovered. To produce biodiesel one-fifth of its weight or volume of alcohol would be required for treating oils (Gerpen *et al.*, 2005). The fatty acids methyl esters so (FAMEs) obtained were transferred to a separating funnel to separate the glycerol (by-product). The dried biodiesel was obtained by treating it with Na_2SO_4 crystals (Dalai *et al.,* 2004). The physicochemical properties of seed oils were determined by using standard AOCS methods (AOCS., 1997). The iodine value was determined by using the wijs method. The Refractive index of the seed oils was measured by using Abbe's refractometer. The GC-MS spectrophotometer Thermo scientific TSQ 8000 was used to determine the fatty acids composition of seed oils. A polysilphenylene-siloxane capillary column having dimensions (BPX 70 TM; length: 25 m; diameter: 0.22 mm; film thickness: 0.25 m) was used. Helium was used as the carrier gas, and its flow velocity was 1 ml/min. The temperature of the injector was 240 °C, and the temperature of the detector was 250 °C. The oven temperature began at 60 °C and was gradually increased to 150 °C at a rate of 6 °C/min for 15 minutes before being increased to 200 °C at a rate of 8 °C/min for 15 minutes. FAMEs, which included retention indices, were used for comparison. The readings were measured in triplicate, and the average data are used in the results. The fuel properties such as density, kinematic viscosity, acid value, cloud point, pour point, flash point, and other properties were all measured by the standard methods. The calorific values of both the seed oils were obtained by using a bomb-calorimeter. The percentage of Biodiesel yield was calculated by the formula given below.

$$\text{Biodiesel yield (\%)} = \frac{\text{Weight of Biodiesel (in g)}}{\text{Weight of Datura oil (in g)}} \times 100$$

Results and Discussion

The physico-chemical properties of *D. innoxia* and *D. metel* were shown in Table 1. The oil yield obtained from *D. innoxia* and *D. metel* was 48.24% and 42.51% respectively. The oil content of both the Datura species was highly appreciable, especially when compared to the oil content of other biodiesel crops. The moisture content of *D. metel* was quite higher as compared to *D. innoxia*. The low moisture content of *D. innoxia* favors the biodiesel potential of seed oil. Both the *Datura* species have low free fatty acids (FFA) content. *Datura innoxia* seed oil has 1.12% FFA and *Datura metel* has 1.18% FFA. The FFA content of seed oil is a significant parameter that influences the efficient conversion of seed oils to fatty acids methyl esters and identifies the selectivity of an appropriate catalyst for the transesterification process (Deshmukh and Bhuyar, 2009). The FFA values for *D. innoxia* and *D. metel* fall into the category of the seed oils that could yield FAMEs in a single-step base-catalyzed trans-esterification process (Sokoto, M.A. 2013). Iodine values obtained for *D. innoxia* and *D. metel* were 70.45 and 74.45. The low iodine value shows that both these oil are chemically stable. The fatty acids composition of *D. innoxia* and *D. metel* FAMEs were determined by GC-MS shown in Table 2. The GC-MS spectra for D. innoxia and *D. metel* were given in Fig. 2 and 3. Both the seed oils were found to have a higher amount of mono-unsaturated fatty acid (oleic acid). The *D.innoxia* FAMEs contained 36.7% whereas *D. metel* FAMEs 38.1% Oleic acid. The non-edible seed oils characterized by high levels of mono-unsaturated fatty acids enhance their utility from a biodiesel perspective. Because oil with a high polyunsaturated fatty acid content has relatively low oxidation stability resulting in declination in fuel properties such as kinematic viscosity and deteriorate fuel quality (Emil *et al.*, 2010; Saravanan and Nagarajan, 2011; Ejikeme *et al.*, 2008). The fuel properties of the biodiesel obtained from the *Datura* species were compared with ASTM D6751 American Society for Testing and Materials) were shown in Table 3. The viscosity values for the FAMEs of *D. inoxia* and *D. metel* were 2.5 mm^2/s and 3.5 mm^2/s shown in Fig.

Table 1. Physico-chemical properties of *D. innoxia* and *D. metel* seed oils.

Parameters	D. innoxia	D. metel
Oil (%)	48.24	42.51
Moisture content	0.06	0.56
Saponification value	188	167
Iodine value	70.45	74.45
Refractive index	1.466	1.475
Free fatty acids (FFA)	1.12	1.18

Table 2. Fatty acids composition of *D. innoxia* and *D. metel* (uncorrected weight percent) determined by GC-MS

Fatty acids	*D. innoxia*	*D. metel*
Palmitic acid ($C_{16:0}$)	15.2	13.5
Stearic acid ($C_{18:0}$)	4.5	6.9
Oleic acid ($C_{18:1}$)	36.7	38.1
Linoleic acid ($C_{18:2}$)	24.7	23.8
Linolenic acid ($C_{18:3}$)	12.1	12.5
Arachidic acid ($C_{20:0}$)	2.1	2.9
Others	4.7	2.3

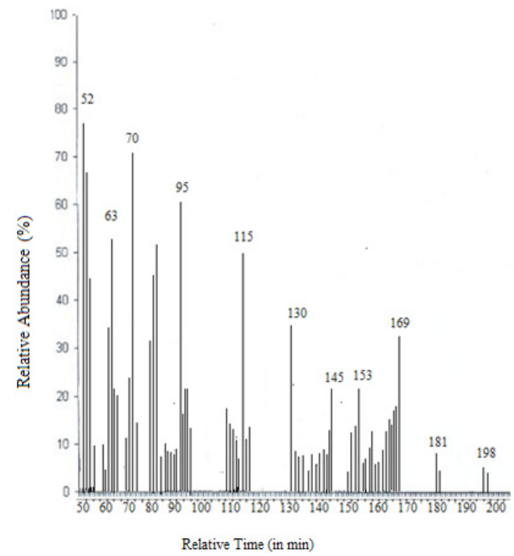

Fig. 2. GC-MS spectrum of *Datura innoxia*

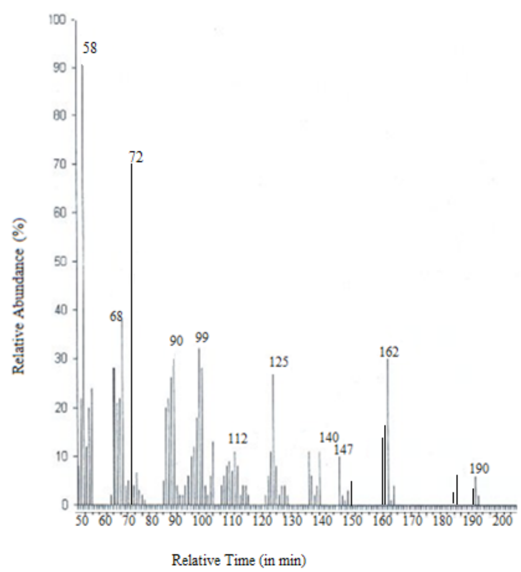

Fig. 3. GC-MS spectra of *Datura metel*

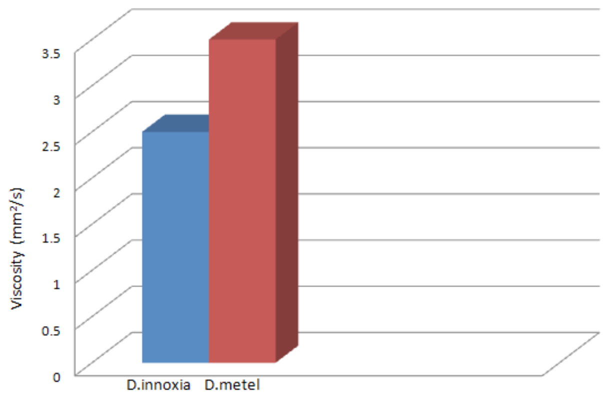

Fig. 4. Viscosity (mm^2/s) of *D. innoxia* and *D. metel* Biodiesel

4. The low viscosity of biodiesel obtained from both the Datura species favors easy pumping and atomization which results in finer droplets (Islam and Beg, 2004). The flashpoint is the temperature at which fuel ignites when it is exposed to a flame. The Flash Point is being used to evaluate the flammability threat of fuels while moving or storing them. The flashpoints of the biodiesel obtained from *D. innoxia* (110 ^{0}C) and *D. metel* (102 ^{0}C) are comparable with the ASTM-D6751 biodiesel specification. The acid values for *D. innoxia* and *D. metel* were 0.30 and 0.35 which were within the limits specified by ASTM-D6751. The low acid value of biodiesel obtained for both the *Datura* species suggested that they do not affect the engine parts. The biodiesel with high acid values causes corrosion in different engine parts and sometimes resulted in engine failure. The cetane number is a crucial parameter that determines the ignition quality of fuel as well as FAMEs composition. The cetane number decides the promptness of diesel to ignite automatically when it has been injected into the fuel engine (Bamgboye and Hansen, 2008). The cetane number for *D. innoxia* and *D. metel* were 52 and 54 respectively. The cloud point and pour point of biofuel are two critical factors for low-temperature implementations which depend mainly on the fatty acids compositions of FAMEs obtained from non-edible seed oils. (Atabani *et al.*, 2013). The cloud point for *D. innoxia* and *D. metel* were -5 and -8. The pour point for *D. innoxia* and *D. metel* were -14 and -12. Biodiesel obtained from non-edible seed oils has a higher density than standard diesel. This could be indicative of the presence of triglycerides with a higher molecular weight. (Hotti and Hebbal, 2015). The density for biodiesel of *D.innoxia* and *D.metel* were found as 980kg/m^3 and 995kg/m^3. The calorific values for *D. innoxia* and *D. metel* were obtained at 37.57 mJ/Kg and 36.77 KJ/Kg which were in close agreement with the calorific values evaluated for *Jatropha curcas* biodiesel (Singh and Saroj,

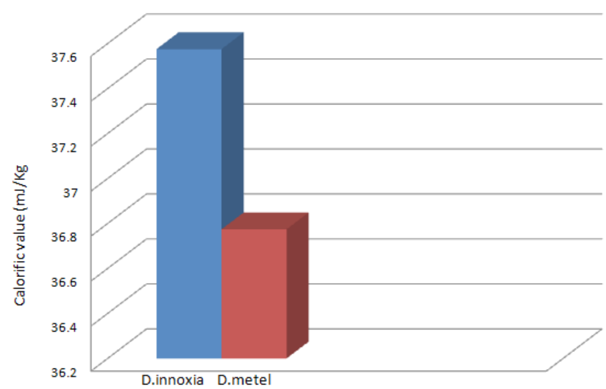

Fig. 5. Calorific values (mJ/Kg) for *D. innoxia* and *D. metel* Biodiesel

Table 3. Fuel characteristics of D.innoxia and *D.metel* Biodiesel compared with ASTM-D6751

Fuel properties	*D. innoxia*	*D. metel*	ASTM D6751
Cloud point (^{0}C)	-5	-8	"3 to "12
Pour point (^{0}C)	-14	-12	"15 to "16
Density (Kg/m^3)	980	995	880
Flash point (^{0}C)	110^{0}C	105^{0}C	130^{0}C
Kinematic Viscosity (mm^2/s)	2.8	3.2	1.9–6.0
Viscosity (mm^2/s)	2.5	3.5	
Specific gravity (g/cm^3)	0.865	0.855	
Ash content	.018	.021	
Acid value	0.30	0.35	0.50 max mg KOH/g
Cetane no.	70	77	47 min
Calorific value (mJ/Kg)	37.57	36.77	

ASTM-American society for testing materials

2009). The calorific values graph for D.innoxia and D.metel were shown in Fig. 5.

Conclusion

The oils extracted from the seeds of *D. innoxia* and D.metel could be a viable source of for the production of biodiesel from base catalyzed transesterification. Because of the presence of toxic compounds, non-edible seeds oils such as D.innoxia and *D. metel* are unsuitable for human consumption. Further these non-edible seeds are cost-effective, easily available and also don't burden on existing food sources. The findings revealed that the both Datura species studied contained significant oil content, and analyses of their FAMEs revealed that they possessed fuel properties acceptable within the ASTM-D6751 standard specification for biodiesel. As a result, the seed oil from *D. innoxia* and *D. metel* studied could be a great source of feedstock for the production of biodiesel as a alternative diesel fuel.

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