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Prospect of Moringa seed oil as a sustainable biodiesel fuel in Australia: A review

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Abstract

Moringa oleifera is one of the most widely cultivated crops in tropical and sub-tropical areas in the world. The common name is drumstick which contains 6 to10 seeds. The matured seeds yield 38 - 40% of colourless and odorless vegetable oil. The oil contains concentrated oleic acid which has the potential to be used as a biodiesel. The study reviewed the prospect of *moringa oleifera* seed oil as a source of alternative transport fuel in Australia. The distributions, habitat, growth, production, oil extraction and biodiesel conversion techniques are briefly discussed. The literatures available on engine performance test and emission studies are also summarized for better understanding of the prospect of the *moringa oleifera* as a sustainable and alternative source of transport fuel. A review of the literatures indicates that *moringa oleifera* oil could be one of the prospective sources of biodiesel in Australia. Further studies are recommended on issues such as engine combustion characteristics, emission parameters, environmental impact and economic analysis of the species before it can be considered for commercial application.

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Keywords: Biodiesel; Moringa oil; Transterification reaction; Alternative fuel; Transport fuel.

1. Introduction

Biodiesel is the fuel mainly derived from vegetable oils, animal fats, biomass etc. It is the fuel composed of mono-alkyl esters of long chain fatty acids designated as B100 and meeting the requirements of ASTM D6751 standard [1,

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2]. It is a liquid fuel generated from biological resources and a renewable source of energy [3, 4]. Different types of biodiesels are available (depending upon the source that they are extracted from) such as: bioethanol [5], karanja [6], jatropha [7], castor [8], sunflower and mustard [9] etc. According to the United State Energy Information Administration (USIA), biodiesel can serve as a substitute for petroleum-derived gasoline and diesel or distillate fuel [10]. Biofuels are low emission, non-toxic, safer and environmentally acceptable source of energy [11]. For these reasons the production and consumption of biodiesel has rapidly grown in the last few decade. At present biodiesel provides around 3% of the world total transport fuel on energy basis. Several factors can contribute to rise in biodiesel demand. Salient drivers are increasing oil prices over the past decade, environmental pollution and gradually decreasing the fossil diesel resources etc. These factors have led to increased public support for renewable fuels [12-14]. The sources of biodiesels were investigated and now the investigation is being continued to find new resources.

At present, world's majority of the biodiesels are produced from edible oil resources which lead to increase in food price and create pressure on land. For these reasons the world is moving towards such type of biodiesel resources which are nonedible, biodegradable, safer and low pollutant. In Australia, 90% of biodiesels are produced from non-edible resources [15]. Only 10% biodiesel produced from edible sources. Australia started producing biodiesel in 2004, 100 barrels per day and increasing demand it reached to 9100 barrel per day in 2011. Research in Australia is being focused on how its feedstocks can be used for biodiesel resolving the challenges associated with its production [16]. With continued efforts in this direction this study reviewed the potential of moringa seed oil as prospective feedstocks. The growth, habitat, distribution and production of biodiesel from the species are briefly discussed in this paper. The lifecycle of the moringa biodiesel has been developed in this study. The physical and chemical fuel properties of the biodiesel are compared with traditional fossil diesel. The study aimed to summarize the literature available on engine performance and emission study and briefly discussed for better understanding of the prospective species as a sustainable alternative source of transport fuel.

2. Moringa oleifera (growth, habitat, distribution)

Moringa oleifera is evergreen, fast growing, deciduous and widely cultivated species. It has some common English names such as moringa, drumstick tree, horseradish tree, benzoil tree etc. [17]. It grows in tropical and sub-tropical areas. It requires rainfall about 250-2000 mm depending on soil condition. It grows best in dry sandy soil and tolerates poor soil with *pH* range 5 to 9. It is distributed from Africa, Asia, Latin America and Oceana countries including Australia. The distribution map for moringa oleifera in Australia is presented in Figure 1. This species is widely distributed in Queensland, Northern Territory and Western Australia. The taxonomical or scientific classification of moringa oil tree is also presented in Table 1. Moringa oil has many medicinal usages and also has significant nutritional value [18]. Literature reported that moringa oil has good potential for biodiesel production based on a recent survey conducted on 75 indigenous plant derived non-traditional oils [19].

Table 1.Taxonomical classification of moringa oil tree.

Taxonomical classification	
Kingdom	*Plantae*
Sub-kingdom	*Angiosperms*
Phylum	*Charophyta*
Class	*Equisetopsida*
Subclass	*Magnoliidae*
Order	*Brassicales*
Family	*Moringaceae*
Genus	*Moringa*
Species	*Moringa oleifera*

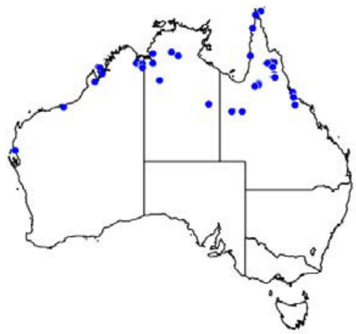

Figure 1. Distribution map for moringa species in Australia [20].

3. Life cycle for biodiesel production

3.1 Cultivation and harvesting

The biological life cycle of the moringa species and different steps for biodiesel production is presented in Figure 2. Moringa plant can be grown by direct seeding and cuttings. If water is available for irrigation, moringa trees can be seeded directly and grown anytime during the year. On the other hand, cuttings should be 45cm to 1.5m long and 10cm thick can be planted directly or planted in sacks in the nursery. The tree can reach a height of 10 to12m and the trunk can reach a diameter of 30 to 45cm.

When the plant is grown up from the cuttings the first harvest can already take place 6 to 8 months after the plantation. Often, the fruits are not yielded in the first year and the yield is generally low during the first years. By year 2 it produces around 300 pods, by year 3 around 400 to 500 kg. A good tree can yield 1000 pods or more.

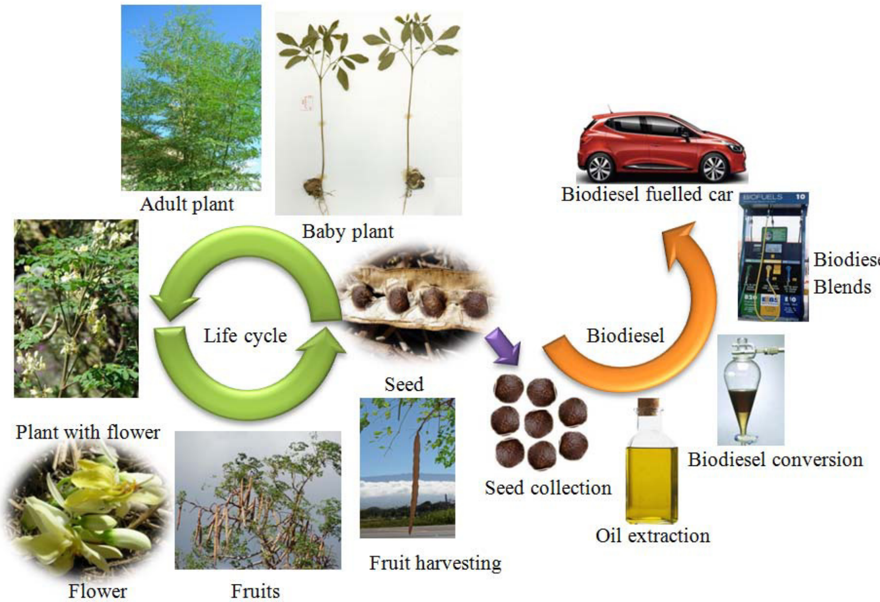

Figure 2. Life cycle of *moringa oleifera* and biodiesel production steps.

3.3 Seed collection and oil extraction

The seed contains 38-40% of oil and 25-30% of moister. After seed collection, the moister can be removed by drying. One estimate for yield of oil from kernels is 250 liters per hector [21]. Anwar and Bhanger [17] studied on moringa seed oil and analyzed different physical and chemical properties of the oil. The oil contents of moringa seed was found to be 38 to 42% using hexane extraction method. Protein, fiber and ash contents were found to be 26.5 to 32%, 5.8 to 9.29% and 5.6 to 7.5%, respectively. On the other hand, Rashid et al. [22] performed an experimental work on oil extraction from moringa seed and afford 35% in w/w crude moringa oil. The oil can also be extracted by traditional mechanical extraction method. Biodiesel can be converted by transesterafication reaction.

3.4 Biodiesel conversion by transesterification

Transesterification is one of the efficient ways for biodiesel conversion from vegetable oil. It can be performed in several ways such as catalytic and non-catalytic transesterification [23] depending on the properties of the crude vegetable oil. The total reaction is presented in Figure 3. Several studies have been conducted on transesterification reaction at different temperature. For example, Rashid et al. [24] studied on biodiesel conversion from crude moringa oil and got expected results. The results of the reaction are presented in Table 2.

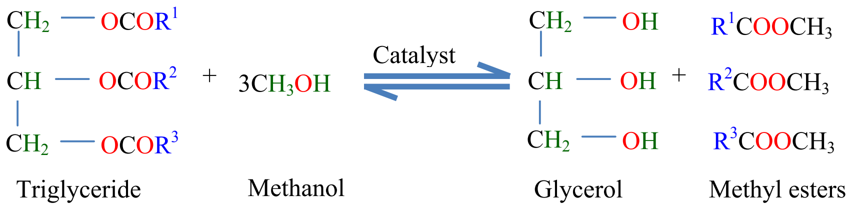

Figure 3. Transesterification reaction for biodiesel conversion from crude moringa oil [24]

Table 2. Transesterification reaction results for biodiesel conversion from moringa oil [24].

Standard order	Molar ratio	Catalyst concentration (%)	Temperature (°C)	Reaction time (min)	Observed methyl esters (wt.%)	Predicted methyl esters (wt.%)	Residual values
1	5.2:1	1.00	35	73	86.35± 0.88	86.72	- 0.37
2	5.2:1	0.50	55	73	87.30 ± 1.25	87.23	0.07
3	7.5:1	1.25	45	55	81.00 ± 1.40	79.42	1.58
4	7.5:1	0.75	45	90	93.50 ± 1.41	92.95	0.55
5	7.5:1	0.75	45	55	91.20 ± 1.15	90.87	0.33
6	7.5:1	0.75	45	55	91.73 ± 1.74	90.87	0.86
7	7.5:1	0.75	45	55	91.00 ± 1.26	90.87	0.13

3.5 Fatty acid profile of the moringa oil

Several researchers investigated the fatty acid profile of moringa oil and found that more than 70% of oleic acid. Rashid et al. [22] and Silva et al. [25] etc. studied the fatty acid profile of the moringa oil separately their combined results are presented in Table 3. The Table compared the fatty acid profile of the moringa oil with soybean, palm, sunflower and rapeseed oil. It has been found that the oleic acid content of moringa oil is 72.2% which is the highest level with respect to other oils.

Table 3. Fatty acid profile of moringa oil compared with soybean, palm, sunflower and rapeseed oil.

Fatty acid	Chemical name	Structure	Moringa oil	Soybean oil	Palm oil	Sunflower oil	Rapeseed oil
Palmitic	Hexadecanoic	16:0	6.5	11.0	44.1	6.4	3.6
Palmitoleic	9-hexadecanoic	16:1	2.0	-	-	-	-
Stearic	Octadecanoic	18:0	6.0	4.0	4.4	4.5	1.5
Oleic	cis-9-Octadecanoic	18:1	72.2	23.4	39.0	24.9	61.6
Linoleic	cis-9, cis-12-Octadecanoic	18:2	1.0	53.2	10.6	63.8	21.7
Arachidic	Eicosanoic	20:0	4.0	-	0.2	-	-
Gadoleic	11- eicosanoic	20:1	2.0	-	-	-	1.4

3.6 Characterization of the fuel properties

The fuel properties of the biodiesel are very important to consider as an engine fuel. The fuel properties of the moringa oil compared other biodiesels and the standard values are presented in Table 4. The flashpoint temperature of the moringa oil is 162ºC. This value is higher than the minimum requirements of ASTM D975 standards. The high flashpoint temperature of the moringa oil is a beneficial safety feature, as this fuel can safely be stored at room temperature. One of the major problems associated with the use of biodiesel is its poor temperature flow property, measured in terms of cloud point, and pour point temperatures. It has high values of cloud and pour points, both are 17ºC, like those reported for palm oil biodiesel (14 to 15ºC). Moringa oil contains unsaturated fatty acid of 72.2% expects to possess good cloud, flash and pour point. However, the relatively high content of behenic acid, C22 (7.2%), which possesses an even higher melting point than palmitic acid, C16:0 (6.5%) or stearic acid, C18:0 (6.0%) is likely to exert a greater effect on the cloud, flash and pour point. Other properties are within acceptable range to consider it as a biodiesel.

Table 4. Fuel properties of moringa oil compared with other biodiesel and ASTM standards [24].

Fuel property	Unit	Moringa oil	BLT oil	Castor oil	Palm oil	Fossil diesel	ASTM test method	Limit	References
Density at 15ºC	Kg/m^3	875	869-888	913-920	879.3	820-860	ASTM D1298	880.0	[26]
Viscosity at 40ºC	cSt	4.80	7.724		4.9	2.0 to 4.5	ASTM D445	1.9-6.0	[23, 27]
Calorific value	MJ/kg	43.28	41.397	38.70	40.2	44.8	-	-	[23, 27]
Cetane number	-	67.0	57.3	-	52	46	ASTM D4737	47 min	[23]
Flash point	ºC	162	151	> 160	181	60 to 80	ASTM D975	130	[23]
Pour point	ºC	17.0	4.3	-	14	-35 to -15	ASTM D975	-15-16	[23, 27]
Cloud point	ºC	17.0	13.2	-13.4	15	-15 to 5	ASTM D975	-3-12	[23, 27]
Ash content	% (m/m)	0.010	0.026	-	0.0066	100 max^m	ASTM D482	-	[23, 28]
Lubricity	HFRR;µm	139.0	-	-	-	0.460mm	IP 450	520	[23, 28]

4. Engine performance test

Engine testing can be categorized based on performance parameters such as brake power (BP), brake specific fuel consumption (BSFC), brake thermal efficiency (BTE) etc. Emission study is one of the most relevant tasks for complete study of a biodiesel which is attributed to NO_x, CO, CO_2, HC and PM emissions. Summary of some of relevant studies pertaining to performance and emission products is presented in Table 5. The Table shows that in all experimental studies BP decreases, BSFC slightly increases and BTE goes down for moringa biodiesel when compared with the fossil diesel. In case of emission studies, Raghu et al. [29] found that the only parameter NO_x increases and all other parameters such as CO, CO_2, PM and HC are decreased. They found that NO_x decreases and other parameters increases because they used different combustion strategies.

Table 5. Summary of the engine performance and emission study using moringa biodiesel compared with fossil diesel.

Experimental setup	Blend used	Performance parameters			Emission parameters					Reference
		BP	BSFC	BTE	NO_x	CO	CO_2	PM	HC	
1-C, 4-S, diesel engine	B10, B25	-	↑ Slightly higher	Slightly lower	↑	↓	-	↓	↓	[30]
4-C, 4-S, diesel engine	B10, B20	Decrease	5.13-8.39% ↑	Lower	↑	↓	-	-	↓	[31]
4-C, 4-S, diesel engine	B0, B10	4% lower	Slightly higher	-	↑	↓	↑	-	↓	[32]
4-C, 4-S, diesel engine	B5, B10	Lower	Higher about 5%	Lower	-	↓	↓	-	↓	[33]

Note: The symbol used B5, B10 and B20 as biodiesel 5%, 10% and 20% respectively. Other symbols like ↑ refer to increase, ↓ denoted as decrease and – represents not measured the parameter.

5. Conclusions

The study concluded that *moringa oleifera* is one of the prospective industrial crops for biodiesel production in Australia. The species is widely distributed in Queensland, Northern Territory and Western Australia where there is suitable weather and soil condition which may help grow faster. It has many acceptable fuel properties within ASTM standard limits and comparable fatty acid profile with respect to other species except oleic acid (72.2%). This high level of oleic acid content appears to result in its good cloud, flash and pour point. The results on engine performance and emission study show that the biodiesel extracted from this source has lower performance and slightly higher NO_x emission with respect to fossil fuel. But this biodiesel has lower emissions of CO, CO_2, PM and HC compared to fossil diesel. The scant studies on emission show that further studies are needed on engine performance and emission studies by applying different combustion strategies.

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