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Article

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Review article

The potential of utilising papaya seed oil and stone fruit kernel oil as non-edible feedstock for biodiesel production in Australia—A review

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ABSTRACT

This paper reviews and discusses the potential of papaya seed and stone fruit kernel biodiesels — the two sources of 2nd generation transport biodiesels in Australia. The challenges associated with biodiesel production and their possible solutions, particularly on feedstock selection, oil extraction, conversion of oil into biodiesel, biodiesel storage and transport, costs of production and the information needs for commercialising these sources of biodiesels are discussed, along with the eco-friendly attributes of these biodiesels to Australian transport sector. Some researchers report that the use of papaya seed and stone fruit kernel biodiesels reduce engine power only 2 to 5%), however significantly reduce harmful engine emission such as HC reductions of 9 to 19%, PM reductions of 19.5 to 35% and CO reductions of 11 to 29%.

Contents

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1. Introduction

Australia's economy heavily depends on energy use, and this dependence will continue to grow into the future. At present, 94% of Australia's total energy consumption is catered by non-renewable sources of energy which includes coal, oil and gas. Fig. 1(a) shows leading primary energy sources in 2015–16, and their consumption by fuel type. As can be seen that oil was the primary source of energy and accounted for 37%, whereas coal was 32.2% followed by gas 24.8%. Over the last 10 years, Australia's energy consumption has increased by 0.6% a year (Department of the Environment and Energy, 2017). The renewable energy accounts for only 6% and the majority of bioenergy is sourced from biomass. Fig. 1(b) shows the percentage usage of renewable energy by various sources in 2015–16, of which biomass accounts for 55% whereas biofuel only 12%. Both biomass and biofuels are drawing larger attention in Australia as an alternative renewable source of energy.

The most significant primary energy-consuming sector in Australia in 2015–16 was electricity generation which accounted for 1755.7 PJ or 29% of the total national consumption, and had an annual growth of 3.4% in that year. The second large energy-consuming sector was the transport sector which accounted for 27%. Yearly growth for road and air transport sectors have increased by 1.7% in 2015–2016, and this trend is likely to continue. The share of energy consumption by the transport sector is projected to increase slightly from 29% to 32% over the period to 2049–50 (Australian Energy Projections, 2014). Table 1 shows the 2015–16 energy consumption details for Australia by sector.

Australian liquid fuel consumption has been static over the last 15 years, and the local refineries have produced 26 billion litres of fuels that include both petrol and diesel (80% together in 2016). Australia is heavily reliant on imported refined crude oil to meet its demand. Nearly 80% of the crude oil and other feedstocks were imported in 2016. The Australian production of crude oil has been declining, and about 76% of it was exported, as these oils are mostly unsuitable for local refineries. Furthermore, the number of Australian oil refineries has declined from seven to five since 2010, indicating limited scope for local supply fuel in Australia. The projection of diesel fuel usage by different sectors is shown in Table 2.

The Australian transportation sector is mostly reliant on petroleum fuels such as petrol and diesel. Generally, the light vehicle sector uses petrol as its dominant fuel, whereas the heavy vehicles use diesel. The share of diesel usage is increasing day-by-day even though the fuel efficiency and vehicle performance have improved. Nowadays, automobile manufacturers are focusing more on diesel-based vehicles than on petrol-based vehicles. Petrol, diesel and aviation fuel accounted for 90% energy usage in the transport sector in 2015. The share of petrol is declining, whereas the use of diesel and aviation fuels are continuing to increase due to mining and increased air transport activities, respectively. Biodiesel is attracting large attention throughout the world due to its similarity with diesel and its environmentally-friendly nature. As biodiesel production in Australia from its native plants has not yet fully exploited, a detailed review on biodiesel production from Australian native 2nd generation feedstocks and its potential as an alternative fuel for transport sector is therefore needed, and is presented in this paper.

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2. Biodiesel—an alternative source of energy in Australia

Biodiesel is becoming popular due to its environmentally-friendly nature, including its reduced environmental pollution and its potential to serve as an alternative source of energy (Rahman et al., 2015; Bhuiya et al., 2016). It is sulphur-free, non-toxic, renewable, biodegradable, clean burning, ester-based, and it is an oxygenated fuel (Dincer, 2008; Mosarof et al., 2016; Ganjehkaviri et al., 2016; Rahman et al., 2014). It is a mixture of alkyl esters of long chain fatty acids which are synthesised via esterification and transesterification of free fatty acids and triglycerides, respectively (Bhuiya et al., 2016; Atabani et al., 2013; Luque et al., 2008). Biodiesel is also known as fatty acid methyl ester (FAME), and is derived from vegetable oils (edible or non-edible) and animal fats (Azad et al., 2015; Rahman et al., 2016; Lin et al., 2011). The biodiesel fuel can be added directly into diesel engines, with no or minimal modification of the engine. Often biodiesel has proven to provide better engine performance and lubrication (Cornejo et al., 2017). It is a globally accepted fuel to reduce exhaust gas emissions and environmental issues. When synthesised appropriately, biodiesel will meet international fuel standards and is highly compatible for mixing with diesel. Biodiesel can be blended with diesel at any proportion, and the modern diesel engines can cope with this blended biodiesel–diesel fuel without any issues (Rahman et al., 2012). The USA, European Union, and Australia have set their own specifications and technical regulations for biodiesel. These include ASTM 6751—02, EN14214 and the Australian Fuel Standard (biodiesel), respectively (Table 3).

Potential biodiesel sources can be categorised into three major divisions, namely (i) first-generation biodiesel feedstocks, i.e., edible vegetable oil sources, (ii) second-generation biodiesel feedstocks, i.e., non-edible vegetable oil and animal fat sources, and (iii) third-generation biodiesel feedstocks, i.e., microalgae, algae, fungi, latexes, bacteria and terpenes (Atabani et al., 2013). While significant advances have been made for producing the first-generation biodiesel, the research on second and third-generation biodiesels is limited, particularly from the point of view of commercialisation. Furthermore, the usage of first-generation biodiesel has raised many concerns, for example, the food versus fuel debate, as well as severe environmental problems such as deforestation and vital soil loss due to land clearing for biodiesel production. The focus now has shifted to second-generation biodiesel production from non-edible vegetable oils due to their accessibility and low cost (Bhuiya et al., 2016; Jamil et al., 2016).

Some popular second-generation feedstocks include *Calophyllum inophyllum*, *Eruca sativa*, *Jatropha curcas*, papaya seed oil, *Pongamia pinnata (or glabra)* (karanja), *Madhuca indica*, *Salvadora oleoides*, cottonseed, tobacco, rubber seed, desert date, fish oil, jojoba, neem, apricot seed, *Moringa oleifera*, sal, chicken fat, pork lard, beef tallow and waste cooking oil (Rahman et al., 2012; Avinash et al., 2014; Baiju et al., 2009; Godiganur et al., 2009; Kaul et al., 2007; Aydin and Bayindir, 2010; Usta, 2005; Li et al., 2009; Özcanlımath et al., 2011; Atabani et al., 2012). Table 4 shows popular biodiesel feedstocks used in various countries around the world.

The biodiesel industry of Australia has significantly reduced its production in recent years due to lower crude oil prices, high feedstock prices and a changing policy framework (USDA, 2017). It is predicted that total production in 2018 will be 290 ML (250 ML of ethanol and 40 ML of biodiesel). This estimated production would be unchanged from 2017. However, biodiesel production had peaked at 400 ML in 2014 when the consumption had approached 800 ML that also included imported biodiesel. This biodiesel production has collapsed due to high costs of feedstocks and the low world crude oil price. Some of the Australian biodiesel processing facilities were closed in early 2016

Table 1
Australian primary energy consumption by sector (Department of the Environment and Energy, 2017).

Sector	2015–16 (PJ)	Share (%)	Average annual growth 2015–16 (%)	Average annual growth 10 years (%)
Electricity generation	1755.7	28.5	3.4	−0.5
Transport	1642.8	27.1	1.7	1.6
Manufacturing	1144.4	18.4	−1.8	−1.3
Mining	610.0	10.1	14.2	7.2
Residential	457.4	7.5	0.3	0.8
Commercial	321.5	5.6	1.0	2.0
Agriculture	110.3	1.8	5.6	1.8
Construction	23.4	0.4	−8.6	−1.3
Others	30.5	0.7	−18.4	−6.3
Total	6065.9	100.0	2.3	0.6

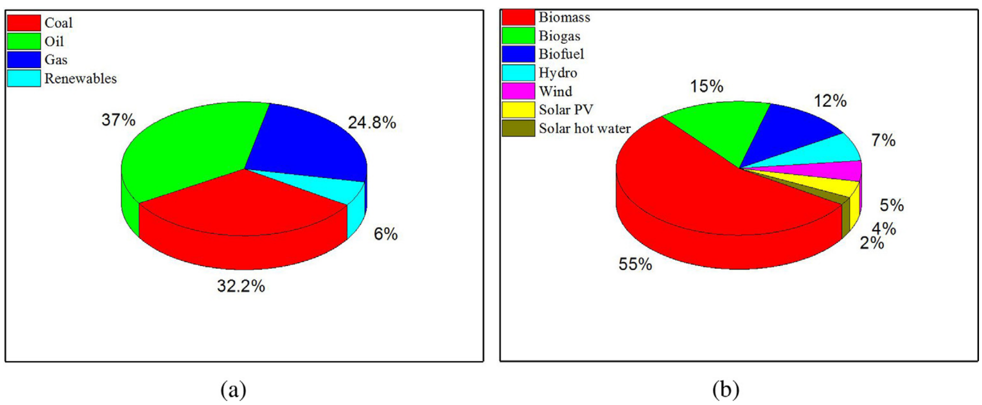

Fig. 1. Australian energy consumption (%) in 2015–2016 by: (a) Fuel type, and (b) Renewable energy type (Department of the Environment and Energy, 2017).

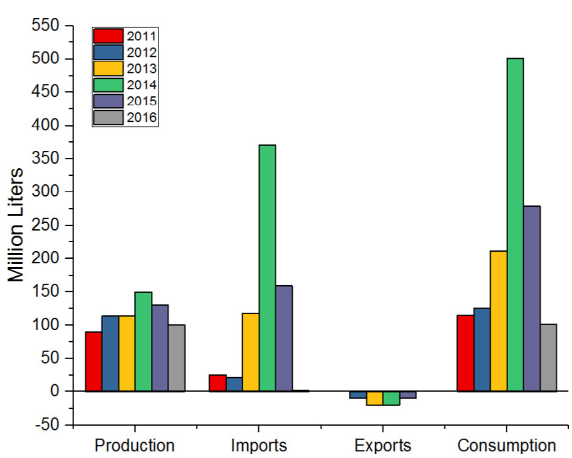

Fig. 2. Australian biodiesel scenario.
Source: Redrawn from USDA (2017).

due to uncompetitive prices with standard diesel. No commercial production of second and third-generation biodiesel occurs in Australia, and no subsidy scheme is being offered for commercial sales. Recently, the Queensland (Australia) Government has announced some programs aimed at making the state a centre of bio-manufacturing and biodiesel production. It is also expected that the commercial production of biodiesel will be used in the military, maritime and aviation sectors. Fig. 2 shows the Australian scenario of biodiesel production, imports, exports and consumption from 2011 to 2016. It can be seen that biodiesel consumption is much higher than production, therefore a significant amount import was needed.

Table 2
Australian fuel consumption projections — 2017 to 2024 (Million litres, ML) (USDA, 2017; Department of Industry, 2016).

Year	2017	2018	2019	2020	2021	2022	2023	2024
Diesel	24.0	24.0	24.2	24.4	24.6	24.8	25	25.2
On-road	7.7	7.9	8.1	8.3	8.6	8.8	9.0	9.2
Agriculture	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2
Construction/mining	7.9	8.1	8.3	8.6	8.8	9.0	9.3	9.5
Shipping/rail	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0
Industry	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6
Jet fuel	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5

The feedstocks used for producing second-generation biodiesel in Australia are primarily animal fats (tallow) and waste cooking oil (recycled yellow grease). Using these same feedstocks, renewable diesel can be produced. The difference between renewable diesel and biodiesel is noticeable. The renewable diesel is chemically balanced and fully compatible with diesel, whereas the biodiesel needs to meet range requirements specified in the ASTM and EU standards. Hydrogenated or hydrotreated vegetable oil (HVO) is the only type of renewable diesel that is available at a large commercial scale. So far, there is no commercial production of HVO biodiesel in Australia. Since 2012, Australia has imported and consumed small volumes of biodiesels. The first known shipment was 21.4 ML in 2013 from Singapore. Australia regularly exports tallow to Singapore which used to produce HVO. Table 5 shows the total biodiesel imports from various countries. The largest imports of biodiesels was from Singapore and Indonesia until 2015. Only 769 thousand litres of biodiesel was imported in 2016 and Indonesia supplied 89.2% (686 thousand litres) of it.

Australia has considered the addition of 5% biodiesel into diesel (B5) as a common blend due to its similar fuel properties with diesel. According to Australian Fuel Standard (biodiesel) Determination 2003, B5 is sold unlabelled whereas a 20% biodiesel

Table 3
ASTM D6751-2, EN 14214 and Australian fuel standard (biodiesel) determination 2003 specifications for biodiesel without blend (Rahman et al., 2012; Jayed et al., 2009; Singh and Singh, 2010; Atadashi et al., 2010; Murugesan et al., 2009).

Properties	Unit	ASTM D6751-2		EN 14214		Australian fuel standard (biodiesel) determination 2003	
		Limit	Method	Limit	Method	Limit	Method
Density at 15 °C	kg/m^3	870–890	ASTM D4052–91	860–900	EN ISO 3675, EN ISO12185	860–890	ASTM D1298
Viscosity @ 40 °C	mm^2/s	1.9–6.0	ASTM D445	3.5–5.0	EN ISO 3140	3.5–5.0	ASTM D445
Flash point	°C	Min 130	ASTM D93	Min 101	EN ISO 3679	Min 120	ASTM D93
Cloud point	°C	–	ASTM D2500	–	EN ISO 23015	–	EN ISO 23015
Cetane number	–	Min 47	ASTM D613	Min 51	EN ISO 5165	Min 51	ASTM D613
Acid number	mg KOH/g	Max 0.5	ASTM D664	Max 0.5	EN 14104	Max 0.8	ASTM D664
Oxidation stability	Hour	Min 3	ASTM D6751/ D7467	Min 6	EN ISO 14112	Min 6	EN ISO 14112
Iodine number	g I/100 g	–	–	Max 120	EN 14111	Max 120	EN 14111
Water content and sediment	mg/kg	Max 0.05 (%v)	ASTM D2709	Max 0.05	EN ISO 12937	Max 0.05 (%v)	ASTM D2709
Free glycerine	% m/m	Max 0.02	ASTM D6584	Max 0.02	EN 14105/ 14016	Max 0.02	ASTM D6584
Total glycerol	% m/m	Max 0.24	ASTM D6548	0.25	EN 14105	Max 0.25	ASTM D6584
Methanol content	% m/m	Max 0.2	EN 14110	Max 0.2	EN 14110	Max 0.2	EN 14110
Sulfated ash	% m/m	Max 0.02	ASTM D874	Max 0.02	EN ISO 3987	Max 0.02	ASTM D874
Phosphorus	mg/kg	Max 10	ASTM D4951	Max 10	EN 14107	Max 10	EN 14107
Carbon residue	% wt	Max 0.05	ASTM D4530	Max 0.3	EN ISO 10370	Max 0.3	ASTM D4530
Calcium and Magnesium	ppm	Max 5	EN 14538	Max 5	EN 14538	Max 5	EN 14538

Table 4
Popular biodiesel feedstocks around the world (Azad et al., 2015; Avinash et al., 2014; Rahman et al., 2013; Damanik et al., 2018; Milano et al., 2018).

Country	Popular feedstocks	
	Edible feedstocks	*Non-edible feedstocks*
Argentina	Soybeans, corn, wheat, sugarcane	–
Australia	Canola oil	Beauty leaf, *Jatropha curcas*, pongamia, waste cooking oil, tallow
Bangladesh	–	Rubber seed, *pongamia pinnata*
Brazil	Soybeans, palm, corn, sugarcane	Castor, cotton oil
Canada	soybeans, mustard, flax	Rapeseed, animal fat, yellow grease, and tallow
China	Corn, soybeans, wheat, sugarcane	*Jatropha curcas*, waste cooking oil, rapeseed
Colombia	Sugarcane, palm	–
Cuba	Sugarcane	*Jatropha curcas*, moringa, neem,
France	Sunflower	Rapeseed
Germany	–	Rapeseed
Ghana	Palm	
Greece	–	Cottonseed
India	Soybean, sunflower, sugarcane	*Jatropha curcas, Pongamia glabra* (karanja), rapeseed
Indonesia	Palm, coconut	*Jatropha curcas*
Iran	Palm	*Jatropha curcas*, castor, algae
Ireland	–	Waste cooking oil, animal fats
Italy	Sunflower	Rapeseed
Japan	–	Waste cooking oil
Kenya	–	Castor
Malaysia	Palm	–
Mali	–	*Jatropha curcas*
Mexico	Sugarcane and corn	Animal fat, waste oil
New Zealand	–	Waste cooking oil, tallow
Norway	–	Animal fats
Pakistan	–	*Jatropha curcas*
Peru	Palm	*Jatropha curcas*
Philippines	Coconut	*Jatropha curcas*
Singapore	Palm	–
Spain	Soybeans, olive oil, palm, Linseed oil, sunflower	–
Sweden	–	Rapeseed
Thailand	Palm, coconut	*Jatropha curcas*
Turkey	Sunflower	Rapeseed
UK	–	Rapeseed, waste cooking oil
USA	Soybeans, peanut, corn	Poultry fat, animal fat, tallow, waste oil
Zimbabwe	–	*Jatropha curcas*

blend (B20) is labelled and sold for commercial operations. Most diesel fuel in Australia is sold in bulk on long-term contracts to commercial/industrial customers such as mining and transport companies, whereas only a quarter is sold through retail outlets.

Table 5
Australian imports of biodiesel by country, 2012–2016 ('000 litres) (USDA, 2017).

Country	2012	2013	2014	2015	2016
Singapore	858	39,741	209,583	139,355	0
Argentina	0	28,604	32,189	4,748	0
Indonesia	15,488	28,339	116,956	6,084	686
United States	0	11,352	0	1,105	1
Canada	5,018	5,482	1,057	0	0
Other	46	4,185	10,980	8,128	82
Total	21,410	117,703	370,765	159,420	769

Again, about 80% of this retail sale is bought by the long-haul trucking industry. Most diesel engine manufacturers limit the usage of biodiesel with conventional diesel to a maximum of 5% (B5 biodiesel blends), considering that this blend meets the Australian fuel standard. A limited number of engine manufactures encourage the use of higher than 5% blends in Australia. However, some local council trucks, i.e., fleet operations, are using biodiesel blends up to 99.9%.

Compared to other developed countries, Australian biodiesel production is very low (only 40 ML in 2017 and 2018). Several factors that have led to this low biodiesel production, include the closure of local biodiesel production facilities, continued unfavourable conditions of limited mandate support, higher feedstock prices, and lower international fuel prices. Although the current capacity of biodiesel production is 400 ML, only 10% of the capacity was utilised in both 2017 and 2018. Table 6 shows the total picture of Australian biodiesel use from 2009.

From 2016, biodiesel production declined significantly leading to insignificant export and import of biodiesels. Under new Australian excise and import duty arrangements, imported biodiesel became uncompetitive with diesel. Australia had imposed anti-dumping and countervailing duties on imported biodiesel from the United States in 2011. These duties were imposed due to a United States federal tax credit of US $1/gallon. Although the Australian government terminated the anti-dumping measure to imported biodiesel from the United States in 2016, no records were found of the imports of biodiesel from the USA.

In comparison with other developing countries, Australian biodiesel production facilities are growing slower than expected. Although some biofuel production companies were closed in 2016, three major biofuel facilities are still in operation, one 'Manildra facility' in Nowra (New South Wales), the other 'Sarina Distillery and the third 'Dalby Bio-Refinery' in Queensland (Puri et al., 2012). Among these, the Manildra group is the largest commercial biofuel producer in Australia. Biofuel mandates in different states encourage all companies to increase their production capacity to meet their state government's demand. Table 7 summarises the biodiesel production capacity scenario in Australia.

3. Australian native papaya and stone fruit-Sources of second-generation biodiesel

Biodiesel production from various feedstocks has been a popular area of research in recent times. Researchers have explored many types of feedstocks representing a variety of sources. These species are generally selected based on some key parameters such as reasonable plant yield, higher oil content, high conversion rate to biodiesel, local availability and cost-effectiveness. The plants that consume less water, require less maintenance, can grow in marginal soils, can grow in diverse climatic conditions, and are unsuitable for human consumption are ideal for biodiesel feedstocks. Again, physical and chemical properties such as density, kinematic viscosity, higher heating value, cetane number, iodine value, cold filter plugging point and the like can indicate a suitable biodiesel feedstock. Furthermore, a suitable biodiesel feedstock must be amenable for its production at the lowest possible price and in abundance, in comparison with the prices of diesel in the competitive market. A few researchers (Rahman et al., 2012; Lim and Teong, 2010) mention that the price and supply of feedstock will cost more than 75% of biodiesel production cost. Fig. 3 shows the overall cost breakdown for biodiesel production.

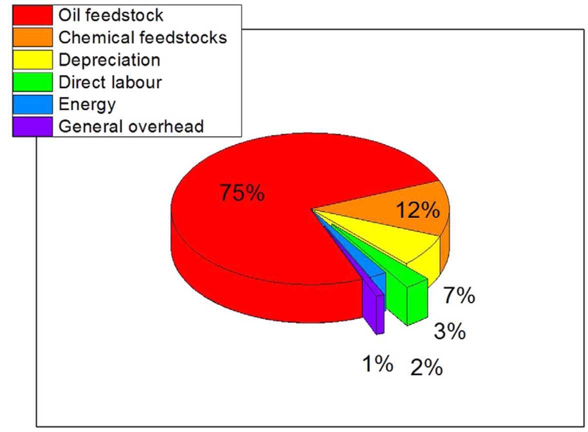

Fig. 3. Overall cost breakdown for biodiesel production (Lim and Teong, 2010).

Table 8 shows the Australian research that has examined optimised biodiesel production from specific feedstocks with regard to engine performance, emissions studies and combustion characteristics.

Some researchers have aimed to explore the potential of Australian native plants as a source of second-generation biodiesel. Ashwath (2010) evaluated more than 200 species and provenances and found that only four of the tested species were meeting the biodiesel production criteria. Amongst these, he found the beauty leaf tree (BLT; *Calophyllum inophyllum* L.) showing greater promise than other species (candlenut tree, pongamia, and coconut). Bhuiya et al. (2015) have investigated biodiesel from BLT, refined poppy oil, crude jojoba oil and waste cooking oil, comparing their results for biodiesel yield and physicochemical properties. Highest biodiesel conversion efficiency was achieved with poppy oil (93.4%) followed by BLT oil (92.3%). Bhuiya et al. (2015) concluded that both BLT and poppy biodiesels have the potential to become suitable second-generation biodiesels. Jahirul et al. (2014) investigated 11 Australian native and naturally-grown non-edible biodiesel feedstocks, namely Beauty leaf (BLT) (*Calophyllum inophyllum*), Candlenut (*Aleurites moluccana*), Blueberry lily (*Dianella caerulea*), Queen Palm (*Syagrus romanzoffiana*), Castor (*Ricinus communis*), bottle tree (*Brachychiton bidwillii*), Karanja (*Pongamia pinnata*), Whitewood (*Atalaya hemiglauca*), Cordyline (*Cordyline manners — suttoniae*), Flame tree (*Brachychiton acerifolius*) and Chinese rain tree (*Koelreuteria formosana*). They suggested that BLT biodiesel was the top-ranked candidate for second-generation biodiesel followed by Queen palm, Castor, and Karanja. Islam et al. (2015) investigated fatty acid profiles of nine microalgae species and examined their fuel properties to identify suitable microalgae for biodiesel production. They recommended that a blend of 10% to 20% marine microalgae biodiesel with diesel could achieve similar power and brake specific fuel consumption as pure diesel. Rahman et al. (2016) researched *Macadamia integrifolia* oil as a native plant source of biodiesel feedstock in Australia and suggested up to 20% macadamia biodiesel blends with diesel in a diesel engine were suitable without further engine modification.

Table 6
Summary of Australian biodiesel scenario (USDA, 2017).

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Production (ML)	85	85	90	114	114	150	130	100	40	40
Imports (ML)	11	9	25	21	118	371	159	1	0	0
Exports (ML)	0	0	0	10	20	20	10	0	0	0
Consumption (ML)	96	94	115	125	212	501	279	101	40	40
Number of bio-refineries	8	6	6	7	7	8	8	5	3	3
Production capacity (ML)	380	380	380	400	400	400	400	400	400	400
Capacity utilised (%)	22.4	22.4	23.7	28.5	28.5	37.5	32.5	25.0	10.0	10.0

Table 7
Biodiesel production capacity scenario in Australia, 2017 (USDA, 2017).

Biodiesel plant	Location	Capacity (ML)	Feedstock	Production start
Australian Renewable Fuels (ARF) largs bay	South Australia	45	Tallow, used cooking oil	2006 (closed 2016)
Australian Renewable Fuels (ARF) picton	Western Australia	45	Tallow, used cooking oil	2006 (closed 2016)
Biodiesel Industries Australia (BIA)	New South Wales	20	Used cooking oil, vegetable oil	2003
Australian Renewable Fuels (ARF) barnawartha	Victoria	60	Tallow, used cooking oil	2006 (closed 2016)
Ecotech biodiesel	Queensland	30	Tallow, used cooking oil	2006
Smorgon fuels biomax plant	Victoria	100	Tallow, Canola oil and Juncea oil	2005 (closed 2016)
Macquarie Oil	Tasmania	15	Poppy oil, waste vegetable oil	2008
Territory biofuels	Northern Territory	140	Palm oil, Tallow, used cooking oil	closed in 2009

Table 8
Summary of Australian biodiesel researches until 2018.

Biodiesel feedstocks used	Biodiesel production and optimisation	Engine performance	Emission studies	Combustion characteristics	Research conducted	Ref.
Evening-primroses (*Oenothera lamarckiana*)	√	√	√	X	2018	Hoseini et al. (2019)
Waste cooking oil	√	X	X	X	2018	Mowla et al. (2018), Gardy et al. (2018), Nabi and Rasul (2018), Zare et al. (2018) and Ming et al. (2018)
Waste cooking oil with additives	√	√	√	√	2018	Rahman et al. (2018a)
Grease trap waste	√	X	X	X	2018	Tran et al. (2018)
Microalgae	√	√	√	√	2018, 2017	Rahman et al. (2018a), Xie et al. (2018) and Sitepu et al. (2018)
Macadamia (*Macadamia integrifolia*)	√	√	√	√	2018, 2016,	Rahman et al. (2016) and Nabi and Rasul (2018)
Tree of heaven (*Ailanthus altissima*)	√	√	√	X	2018	Hoseini et al. (2018)
Canola oil	√	√	√	√	2018	Ming et al. (2018)
Rice bran biodiesel	√	√	√	X	2017	Rahman et al. (2018b)
Beauty leaf	√	√	√	√	2016	Azad et al. (2016), Bhuiya et al. (2015), Jahirul et al. (2014) and Jahirul et al. (2015)
Licella biofuel (*Pinus radiata*)	√	√	√	√	2015	Nabi et al. (2015)
Waste tyres	√	√	√	X	2018	Verma et al. (2018)
Essential oil (orange oil)	√	√	√	X	2017	Rahman et al. (2017a)
Palm oil	√	√	√	X	2011	Yusaf et al. (2011)
Diesel with additives	√	√	√	√	2018	Algayyim et al. (2018)
Poppy seed oil	√	√	√	X	2017	Bhuiya et al. (2017)

Azad et al. (2017) found a 5% macadamia biodiesel blend with diesel performed better compared to a 20% biodiesel blend. They revealed that the 5% biodiesel blend slightly increased BSFC and decreased BTE while reducing emissions (CO, HC, and PM) significantly. Azad (2017) also studied Mandarin peel waste, cramble, tamanu, borage, waste avocado flesh and bush nut for biodiesel production and found that mandarin biodiesel showed higher calorific value (44.66 MJ/kg) and higher flash point (52 °C), which closely matched with commercial jet fuel. Zare et al. (2017) used waste cooking biodiesel and triacetin (highly oxygenated additive) to analyse cold-start and hot-start operations. They found the use of oxygenated fuel during cold-starts increased harmful nucleation mode particles significantly. Rahman et al. (2018b) used a 20% blend of rice bran biodiesel with diesel to lower air pollution without affecting engine power significantly. In another

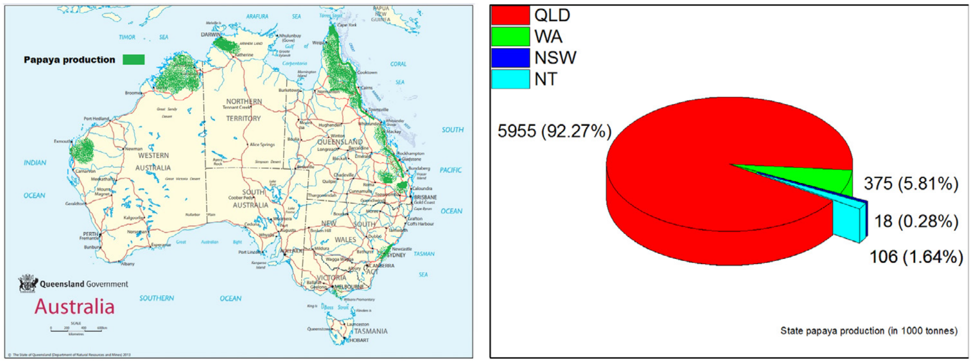

Fig. 4. Papaya production in Australia: Regional distribution (left) and State & Territory outputs in 2009 ('000 tonnes) (right).
Source: This figure has been modified from the Queensland Government Department of Natural Resources, Mines and Energy website (Department of Natural Resources, 2018).

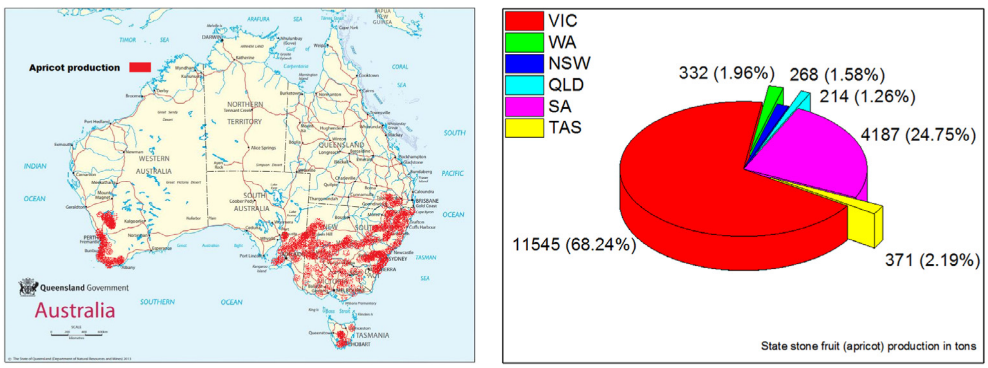

Fig. 5. Stone fruit (apricot) production in Australia: Regional distribution (left) and state outputs in 2008 (tons) (right).
Source: This figure has been modified from the Queensland Government Department of Natural Resources, Mines and Energy website (Department of Natural Resources, 2018).

study of fuel properties (physical, chemical and tribological), Rahman et al. (2017b) showed that palm biodiesel was the most suitable blending alternative followed by macadamia, moringa, jatropha and beauty leaf biodiesel. Rahman et al. (2018a) suggested that 10% blends of essential oils (orange, eucalyptus and tea tree) with diesel can be used in diesel engines.

The potentiality of waste papaya seed oil and stone fruit oil as second-generation biodiesel feedstocks have never been investigated in Australia. However, a very few researchers from other parts of the world have researched second-generation papaya seed oil (PSO) and stone fruit kernel oil (SFO) biodiesels (Gumus and Kasifoglu, 2010; Wang and Yu, 2012; Fadhil, 2017; Fan et al., 2016; Wang, 2013; Ullah et al., 2009; Jannatizadeh et al., 2008; Yadav et al., 2017; Wong and Othman, 2014; Agunbiade and Adewole, 2014; Mohan and Sen, 2015). The current study has reviewed the details of papaya and stone fruit biodiesel, and identified some challenges and solutions to use papaya and stone fruit as alternative sources of biodiesel for Australian transport sector.

3.1. Papaya seed oil

The papaya (*Carica papaya*) originates from the tropics of the Americas and is mainly cultivated in tropical climates of Asia, South America, Africa and Polynesia. Fig. 4 shows details of papaya production in Australia. Papaya being a tropical fruit, it grows well in sub-tropical regions. Papaya fruit can weigh from 200 g to more than 3000 g, and its seed content can be approximately 15%–20% of the wet weight of the fruit (Salunkhe and Kadam, 1995; Chan et al., 1978; Samaram et al., 2013; Hameed, 2009). Since the seeds are not consumed, 15%–20% of the biomass (i.e., the amount of seeds) is discarded (Chan et al., 1978; Daryono and Sinaga, 2017). These seeds contain 30%–34% oil with nutritional and functional properties similar to that of olive oil (Chielle et al., 2016; Puangsri et al., 2004; Lee et al., 2011). These seed oils can be utilised as the feedstocks for biodiesel synthesis.

3.2. Stone fruit oil

The stone fruit, particularly apricot (*Prunus armeniaca* L.), originates from India and Armenia, and is mainly cultivated in cool frost-free sites due to its early blooming properties (Salunkhe and Kadam, 1995). Its commercial cultivation is limited to humid climates due to fungal disease. This crop is now widely cultivated in Australia, especially in Victoria and South Australia. Australia produces about 100,000 tons of summer stone-fruits from October to April each year and, in 2008, about 16,917 tons of apricot were produced in all six mainland states in Australia. The apricot (*Prunus armeniaca*) belongs to the Rosaceae family and it is native to western Asia and possibly China. Two other species that are related to apricot are also cultivated, and they are *Prunus mandshurica* (from Manchuria, Korea) and *P. siberica* (from Siberia, Manchuria, and northern China). Another species that bears purple fruits (*P. dasycarpa*) and a Japanese apricot (*P. mume*) are also cultivated. The fruits are green and turn to orange or yellow–orange on maturity. The fruits contain soft flesh and hard seed (stone/kernel).

Fig. 5 shows apricot production and its growing regions in Australia (Salunkhe and Kadam, 1995). Stone fruit is similar to a small peach, generally 1.5–2.5 cm diameter, with its colour varying from yellow to orange or red. Its single seed is enclosed in a hard stony shell. The fruits yield 22 to 38% of kernels and 54.2%

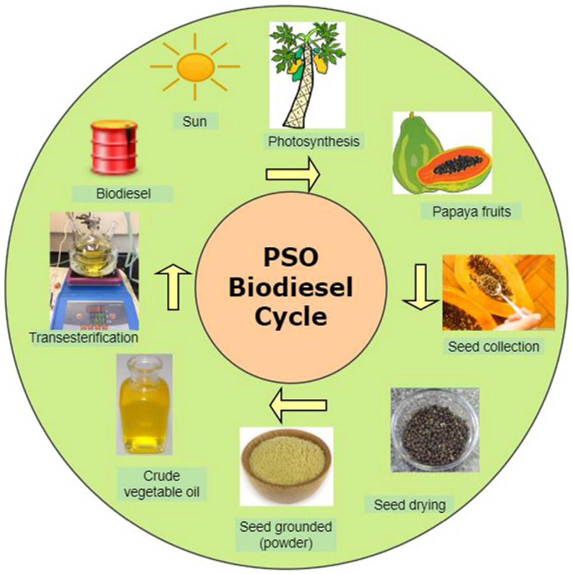

Fig. 6. Life cycle steps for biodiesel production from Papaya seed oil (Anwar et al., 2018a).

oil (Yadav et al., 2017; Kate et al., 2014). During fruit processing, for a variety of uses, the seeds are discarded as they are not edible due to the presence of hydro-cyanic acid (Sharma et al., 2012). The potentiality of this biomass as a biodiesel feedstock thus deserves investigation.

4. Life cycle steps for papaya and stone fruit biodiesel production

4.1. Cultivation

Fig. 6 shows various steps involved in biodiesel production from PSO. The details of the optimisation and conversion of PSO biodiesel was discussed in Anwar et al. (2018c). Papaya (*Carica papaya*; Caricaceae) is a giant herbaceous tree that originated in Central America and is cultivated in many parts of the tropics. The common name "papaya" or pawpaw also refers to the fruit of other *Carica* species (*C. pubescens* and *C. stipulata*) and the varieties derived from these species. The fruit shape varies from oval to round, and the size differs considerably amongst the cultivars, ranging from 0.5 kg to 9 kg. Fruit shape also differs from oval to cylindrical, and the length varies from 10 cm to 50 cm with a diameter of 5 cm to 20 cm. Green fruits produce copious amounts of white latex, and the mature fruits lack this latex. The flesh of the fruit varies from yellow to orange to red, and is thick and juicy. The central cavity of the fruit is filled with brown to black coloured seeds. Fruits differ in the seed content, and the seed content ranges from seedless to heavily seeded, depending on the way the cultivar has been bred (pure line or hybrid). The seed content of the fruit varies from nil (seedless) to 20% of the wet weight.

The apricot kernel is rich in protein and oil. The steps involved in producing biodiesel from apricot kernels are shown in Fig. 7. The details of optimisation and conversion of apricot kernels biodiesel was discussed in Anwar et al. (2018c).

4.2. Oil extraction system

Oil extraction is the first stage in biodiesel production. There are many methods of oil extraction from the original sources such as seeds, fruits, and other oil bearing materials. A simple mechanical press can be used for extracting the oil without further processing. This process is also known as cold pressing. Not all seeds are suitable for extraction using mechanical press; some of them involve a complex process such as a combination of pressing, cooking and solvent extraction. The oil extraction methods are described below for both papaya seed and apricot kernel.

4.2.1. Mechanical extraction

The mechanical extraction method is the conventional method of extracting oil from seeds. An expeller or ram press or engine driven screw press is used for expelling or pressing seeds. The oil extraction rate depends on the type of seeds and type of press. However, oil extracted by mechanical extraction needs further treatment of filtration and degumming.

4.2.2. Chemical extraction

Removing one constituent from a solid by means of a liquid solvent is known as chemical extraction. It is also known as solvent extraction process. The rate of extraction of oil depends on the type of liquid chosen, particle sizes, temperature and agitation of the solvent. The most common solvent used in the chemical extraction process is hexane due to its low cost and low toxicity (Mahanta, 2004).

4.2.3. Enzymatic extraction

Oil extraction through an enzymatic extraction method, using suitable enzymes while crushing, is gaining popularity due to its excellent environmental attributes and for not producing volatile organic compounds (Rosenthal et al., 2001; Shah et al., 2005; Vasco-Correa and Zapata Zapata, 2017). However, the main barrier of this method is enzyme cost and the need for a long processing time to liberate oil bodies (Mahanta, 2004).

Table 9 shows a summary of research undertaken into oil extraction from papaya seed and apricot kernel. It can be seen that most researchers have found the chemical extraction process was convenient to extract oil from both papaya seed and stone fruit seed.

5. PSO and SFO analysis

Both Papaya seed oil (PSO) and Apricot kernel oil (SFO) are characterised for viscosity, density, specific gravity, acid value, refractive index, angular rotation, stability oxidative, iodine value, calorific value and saponification number. PSO is reddish yellow in colour. Generally, solvent extracted oil tends to have more yellow and red colour than enzyme extracted oil (Puangsri et al., 2004). SFO is generally light yellow in colour. Depending on the variety and extraction process, its colour can change to slightly darker yellow, and there is a nutty aroma in this oil. Table 10 shows the properties of PSO and SFO along with diesel. These properties are compared with both measured value and reviewed value.

The fatty acid compositions were analysed by a gas chromatograph using the EN14103 standard. The compositional analysis set out in Table 11 shows that the PSO contains high proportion of unsaturated fatty acids (87.5%). Amongst these, the oleic acid (C18:1) was found to be the dominant fatty acid (47.7%). Linoleic acid (C18:2) was found at 37.3% and the saturated fatty acids, palmitic acid (C16:0), was found at 6.1%. SFO has a high level (89.7%) of unsaturated fatty acids such as polyunsaturated and monounsaturated fatty acids. Saturated fatty acids such as palmitic acid, stearic acid, and behenic acid were found at 5.9%, 2.51% and 0.66% respectively.

The fatty acid profiles of both PSO and SFO are compared in Fig. 8. Both PSO and SFO have higher oleic acid and linoleic acid as well as similar level of unsaturated fatty acids 87.5% and 89.7% for PSO and SFO respectively.

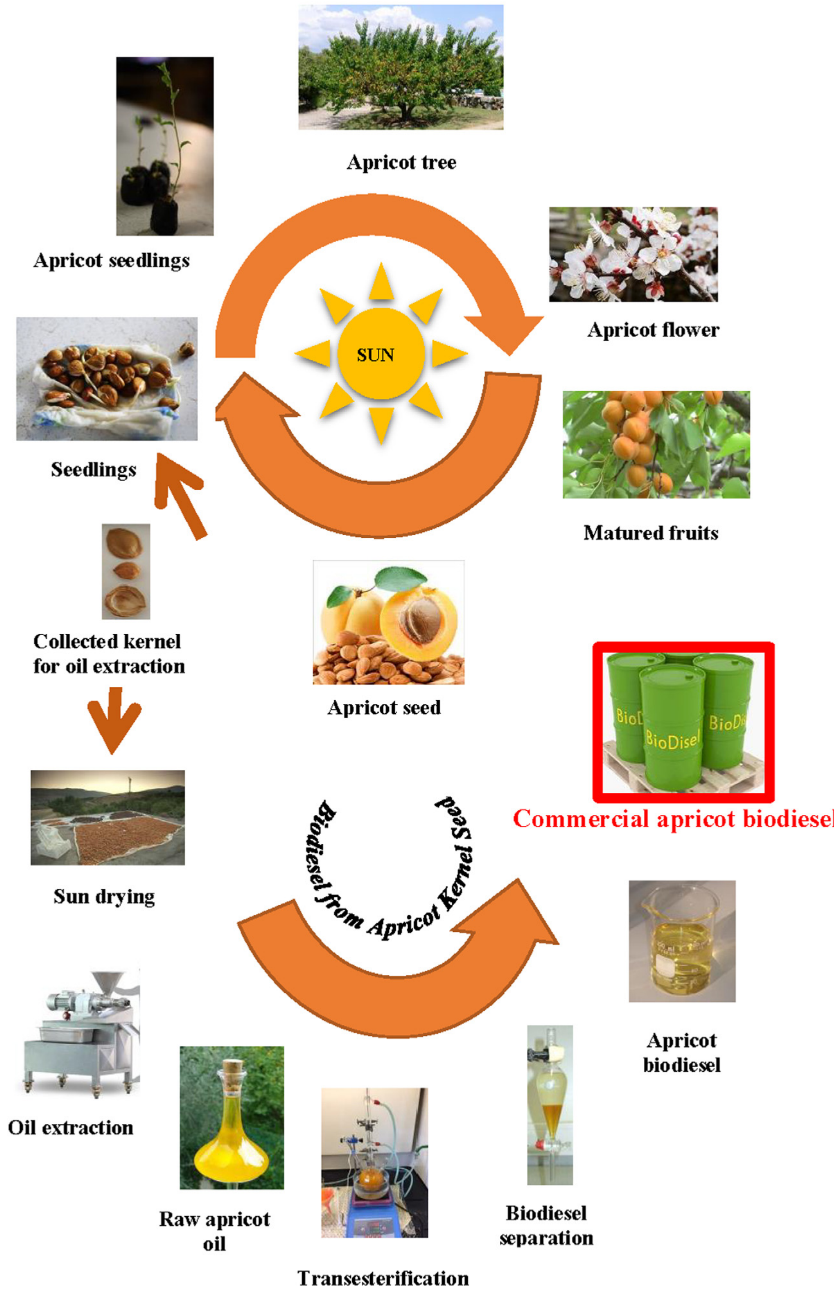

Fig. 7. Life cycle steps for biodiesel production from Apricot kernel oil (Anwar et al., 2018c).

6. PSO and SFO biodiesel production

Alkali catalysed transesterification reaction is the most widely used method for producing biodiesel due to its higher conversion efficiency in a short time (30–60 min), as compared to an acid catalysed process. Researchers have used both methanol and ethanol as alcohol in the transesterification process (Kaul et al., 2007). However, methanol is less costly and has better reactivity. Furthermore, the fatty acid methyl esters (FAMEs) produced from methanol are more susceptible to evaporation than those generated from ethanol (ethyl esters). On the other hand, ethanol is derived from renewable feedstocks and it is less toxic to humans than methanol (Kaul et al., 2007). De Melo et al. (2011) used alkaline transesterification with 0.5% sodium methoxide with a methanol:oil molar ratio of 8:1. Several process parameters such as reaction temperature, catalyst type, catalyst concentration, type of alcohol and their oil to molar ratio, reaction time and agitation speed, all affect biodiesel yield and quality. Therefore, the transesterification optimisation process is critical to produce high quality biodiesel at a low cost.

Papaya seed oil (PSO): A number of researchers have studied biodiesel production from various feedstocks, but very few researchers (Wong and Othman, 2014; Agunbiade and Adewole, 2014; Mohan and Sen, 2015; Daryono and Sinaga, 2017; Anwar et al., 2018a; Patel and Nayak, 2017; Sivasubramanian, 2017) have looked into papaya biodiesel production. Wong and Othman (2014) produced papaya biodiesel via enzymatic transesterification using lipase at a methanol:oil molar ratio of 6:1. Agunbiade and Adewole (2014) have shown that the crude papaya seed oil can be transesterified by two-stage catalysis using a methanol:oil molar ratio of 9:1. Mohan and Sen (2015) used CaO as the catalyst to produce 20% papaya biodiesel and 80% chicken biodiesel blend. Daryono and Sinaga (2017) used sodium hydroxide as an alkaline

Table 9
Research summary of oil extraction process of papaya seed and stone fruit seed (apricot kernel).

Source	Oil extraction	Method	Temperature	Process time	Results	Ref.
Papaya seed	Mechanical extraction	Heat generated by friction	–	–	Oil yield 142 g/kg.	Lee et al. (2011)
		Screw pressing	85–90 °C	–	Oil yield 152 g/kg	
		Roasting papaya seed at 160 °C, then screw pressing	100–105 °C	–	Oil yield 139 g/kg	
	Chemical extraction	– Solvent (n-hexane) extraction – Ultrasound-assisted extraction (UAE) method	– 25–50 °C – 50 °C	– 3, 6, 9 and 12 h – 30 min	UAE was quicker procedure resulting in higher extraction yield than conventional methods.	Samaram et al. (2013)
		Percolation method	70 °C	4 h	Oil yield 265 g/kg	Chielle et al. (2016)
		Four solvents (ethanol, acetone, ethyl acetate and n-hexane) extraction	–	–	Oil yield 151–300 g/kg	Lee et al. (2011)
		Solvent n-hexane	–	–	Oil yield 31.2%	Agunbiade and Adewole (2014)
		Solvent n- hexane	–	8 h	Oil yield 34.3%	Wong and Othman (2014)
		Solvent n- hexane	110 °C	2 h	Converted oil was collected by separating from benzene solution	Mohan and Sen (2015)
		Solvent n- hexane	40–60 °C	8 h	Oil yield 30.7%	Puangsri et al. (2004)
		Solvent n- hexane	27 °C	33 min	Oil yield 225.9 g/kg	Daryono and Sinaga (2017)
		Solvent n- hexane	40–60 °C	6 h	Oil yield 29.16%	Malacrida et al. (2011)
		Solvent n- hexane	–	–	Oil yield 280 ± 20 g/kg	De Melo et al. (2011)
		Solvent n- hexane	60 °C	8 h	Oil yield 30.1%	Syed et al. (2011)
	Enzymatic extraction	Protease, pectinase, α-amylase and cellulose enzymatic extraction			Enzymatic method produced less amount of oil than solvent extraction (30.7%).	Puangsri et al. (2004)
Apricot Kernel	Mechanical extraction	–	–	–	–	–
	Chemical extraction	Soxhlet extractor (using petroleum ether)	45–50 °C	6–8 h	Oil extracted 50.2%	Wang and Yu (2012)
		Soxhlet extractor (using petroleum ether)	–	–	Oil extracted 48.7%	Ullah et al. (2009)
		Solvent n- hexane	25 °C	–	Oil extracted 51.6%	Fan et al. (2016)
		Pyrolysis in a fixed bed reactor	450 °C	60 min	Oil extracted 43.7%	Fadhil (2017)
		Supercritical fluid extraction system	110 °C	25–90 min	Oil extracted 48%	Özkal et al. (2005)
	Enzymatic extraction	–	–	–	–	–

catalyst for the transesterification process to produce biodiesel from papaya seed. Anwar et al. (2018a) have shown that PSO can be transesterified by single-stage method using KOH catalyst and with a methanol:oil molar ratio of 10:1. Patel and Nayak (2017) have used 0.5% NaOH catalyst with methanol:oil molar ratio of 9:1 to obtain 96.7% biodiesel yield. Sivasubramanian (2017) used NaOH catalyst with methanol:oil molar ratio of 5:1 in a single-stage transesterification reaction for PSO biodiesel production. They have all claimed that the physicochemical properties of papaya seed oil biodiesel were very close to those of diesel.

Apricot kernel oil (SFO): Very few researchers (Gumus and Kasifoglu, 2010; Wang and Yu, 2012; Fadhil, 2017; Fan et al., 2016; Wang, 2013; Ullah et al., 2009; Jannatizadeh et al., 2008; Yadav et al., 2017; Anwar et al., 2018c) have investigated of SFO biodiesel. Among all the SFO biodiesel researchers, a handful of them (Gumus and Kasifoglu, 2010; Fadhil, 2017; Ullah et al., 2009; Yadav et al., 2017) focused their research on apricot (*Prunus armeniaca* L.). Other researchers have used either Siberian apricot kernel oil (*Prunus sibirica* L.) or Manchurian apricot kernel oil (Prunus mandshurica Skv.). Gumus and Kasifoglu (2010) and Anwar et al. (2018c) used alkali transesterification with methanol and potassium hydroxide catalyst for producing SFO methyl ester. Fadhil (2017) produced SFO biodiesel via alkali transesterification with 0.75% potassium hydroxide catalyst and at a methanol:oil molar ratio of 6:1. Ullah et al. (2009) have shown that the wild apricot kernel oil (*Prunus armeniaca* L.) can be transesterified by a single step via the use of sodium hydroxide catalyst and a methanol:oil molar ratio of 6:1, and reported a biodiesel yield of 93%. Yadav et al. (2017) performed single step alkali transesterification using 1% potassium hydroxide as a catalyst at 55 °C and 60 min reaction time with a constant stirring speed of 400 rpm and obtained a biodiesel yield of 96.5%. The above researchers have claimed that their SFO biodiesel quality and physicochemical properties had matched with ASTM and EN standards and were found to be very close to those of the diesel. Thus, several process parameters, including reaction temperature, catalyst type and catalyst concentration, type of alcohol used

Table 10
Comparison of the properties of PSO and SFO with diesel.

Sl. No.	Properties	PSO		SFO		Diesel
		Measured	Reviewed (Agunbiade and Adewole, 2014; Malacrida et al., 2011; Marfo et al., 1986)	Measured	Reviewed (Gumus and Kasifoglu, 2010; Fadhil, 2017; Yadav et al., 2017)	
1	Kinematic viscosity (mm^2/s) @ 40 °C	27.3	8.3–27.4	34.54	20.53–34.82	3.23
2	Density (kg/m^3)	885	890–926	910	913–919.9	830
3	Specific gravity @ 15 °C	0.885	0.89–0.926	0.91	0.91	0.83
4	Acid value (mg KOH/g)	0.98	2.91	1.65	0.68–2.60	0.05
5	Refractive Index @ 25 °C	1.457	1.45–1.4678	–	–	–
6	Angular rotation (°) @ 20 °C	−8.75	–	–	–	–
7	Stability oxidative (h)	77.97	77.97–78.86	–	–	–
8	Iodine value (g I 100 g^{-1})	79.95	74.8–86.7	103	90.3–101.32	–
9	Calorific value (MJ/kg)	–	40.23	38.45	31.47–39.64	45.3
10	Saponification number (mg KOH/g)	–	97.77–197	173	187.22–188.56	–

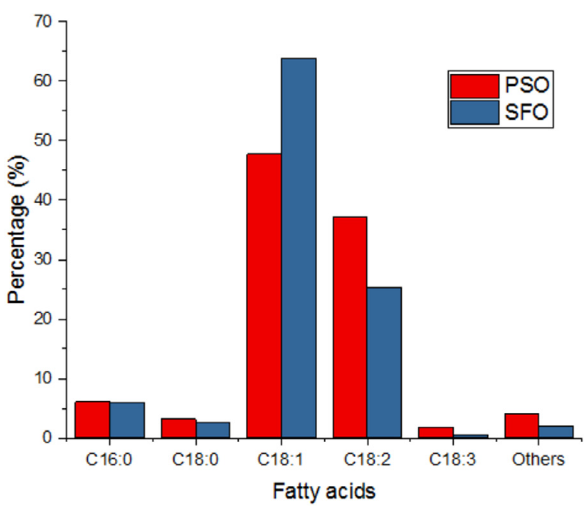

Fig. 8. Fatty acid profile of PSO and SFO.

Table 11
Fatty acid composition of PSO and SFO.

Oil	Fatty acids (% w/w)						Ref.
	C16:0	C18:0	C18:1	C18:2	C18:3	Others	
PSO	6.07	3.13	47.73	37.25	1.78	4.04	
PSO[a]	16.16	4.73	71.30	6.06	–	1.75	Malacrida et al. (2011)
PSO[b]	16.6	1.90	79.10	2.57	–	–	Marfo et al. (1986)
PSO[c]	18.9	5.20	69.80	4.80	–	1.3	De Melo et al. (2011)
PSO[d]	16.2	5.0	74.3	0.4	–	4.1	Agunbiade and Adewole (2014)
PSOe	13.4	4.6	76.9	3.2	–	1.9	Puangsri et al. (2004)
SFO	5.85	2.51	63.84	25.34	0.51	1.95	
SFO[a]	5.62	1.27	67.31	24.68	0.08	1.04	Gumus and Kasifoglu (2010)
SFO[b]	4.20	2.32	71.00	20.15	1.20	1.13	Yadav et al. (2017)
SFO[c]	3.87	0.92	67.21	27.12	0.11	0.77	Wang (2013)
SFO[d]	3.79	1.01	65.23	28.92	0.14	0.91	Wang and Yu (2012)
SFO[e]	–	–	66.20	28.20	–	5.60	Kate et al. (2014)

Note: The superscripts a, b, c, d and e refer to other researchers' work as per the last column.

and the oil to methanol molar ratio, reaction time and agitation speed have been found to influence the optimum transesterification process (Atabani et al., 2012; Hamze et al., 2015; Atadashi et al., 2012; Banerjee and Chakraborty, 2009; Yaakob et al., 2013). However, the potential of both PSO and SFO biodiesel as source of future second-generation biodiesels are yet to be established due to limited knowledge on its consistent optimum production processes.

Biodiesel process optimisation: Traditional experimental methods of any process optimisation are time-consuming and labour intensive. Moreover, they cannot explain the actual interaction effects of variables of the experimental data which lead to misinterpretation of results. There are a few statistical approaches that can be used in experimental design to overcome the limitations of traditional methods. Both Taguchi methods and Response surface methodology (RSM) are very popular methods for biodiesel process optimisation. However, there was no literature on Taguchi methods for optimising biodiesel production process from PSO or SFO.

RSM is a set of mathematical and statistical methods used for modelling and problem solving, wherein the response is influenced by several operating or process parameters (Hamze et al., 2015). RSM is very effective when designing the experiments for maximising yield and minimising production cost. RSM not only simplifies the complex nature of many experimental runs but also studies the interactive effect of several operating parameters and the effects on the response (target). Many researchers have successfully worked with RSM methods and were able to optimise their production process parameters with both central composite design (CCD) and Box–Behnken design models. Researchers investigating optimisation of biodiesel production processes mainly used the RSM approach and their process parameters were: (1) methanol: oil molar ratio, (2) catalyst concentration, (3) reaction temperature, (4) reaction time, and (5) agitation speed. Bello et al. (2016) used a RSM approach with a central composite experimental design (CCD) model for optimising waste frying biodiesel production by varying five process parameters. A CCD method for optimising safflower biodiesel production process parameters and their combined effects were investigated using RSM by Math and Chandrashekhara (Math and Chandrashekhara, 2016). A *Madhuca indica* oil to biodiesel conversion process was optimised using a RSM approach with a CCD model by Muthukumaran et al. (2017). The RSM approach with a CCD model was used for the biodiesel conversion process from various feedstocks or oils such as camelina oil (Yang et al., 2015), sunflower oil (Mansourpoor, 2012), a mixture of edible and nonedible vegetable oils (thumba oil, karanja oil, linseed oil and palm oil) (Gupta et al., 2016), refined cottonseed (Onukwuli et al., 2017), waste cooking oil (Babaki et al., 2017), lard oil (Ezekannagha et al., 2017), soybean oil (Rahimi et al., 2014), date pits (Jamil et al., 2016), *Thevetia peruviana* seed oil (Ogaga et al., 2017) and crambe oil (Vieira Silveira et al., 2017). The optimisation of biodiesel production from other bio-oils or feedstocks, namely microalgae (Makareviciene et al., 2014), waste cooking oil (Hamze et al., 2015), karanja oil (Verma et al., 2016), mixed nonedible oils (*Jatropha curcas* and *Ceiba pentandra* oil) (Dharma et al., 2016), *Brucea javanica* seed oil (Hasni et al., 2017), were investigated using the RSM approach with Box–Behnken design and fractional factorial design. Anwar et al. (2018a) used RSM approach with Box–Behnken design to optimise PSO biodiesel production process and they demonstrated that 96.5% biodiesel was obtained with the reaction conditions to be a methanol:oil molar ratio 10:1, KOH catalyst concentration of 1 wt% and reaction temperature of 45 °C. In another study by Anwar et al. (2018c) showed that maximum SFO biodiesel yield of 95.8% was obtained at a methanol: oil molar ratio of 6:1, KOH catalyst concentration of 0.5 wt% and a reaction temperature of 55 °C.

7. PSO and SFO biodiesel properties- a comparison with selected second-generation biodiesels

The converted biodiesel properties are characterised by major physicochemical properties such as density, viscosity, calorific value, flash point, cetane number, iodine value, and oxidation stability. A selection of properties for various nonedible biodiesel are shown in Table 12.

Silitonga et al. (2014) mentioned that the density of a fuel influences the fuel atomisation efficiency in airless combustion system. The density of biodiesel should be 860–900 kg/m^3 as per both ASTM and EU standard. The density of diesel was measured as 827.2 kg/m^3, whereas PSO and SFO densities were recorded as 840 kg/m^3 and 855 kg/m^3 respectively. The density of karanja biodiesel was found to be the highest (931 kg/m^3). The viscosity of PSO and SFO ranged from 1.9 to 6 mm^2/s. Higher acid value of biodiesel can cause corrosion of engine and other metal parts. Both ASTM and EU standard limits the maximum acid value of 0.5 mg KOH/g. Calorific value is another important property and all biodiesels have slightly less calorific values than diesel, as expected. Cetane number, flashpoint, iodine value and oxidation stability of both PSO and SFO are found to be within the range of ASTM/EU standard.

8. Engine performance and emission studies of PSO and SFO biodiesel

Most biodiesels have lower calorific values than diesel which narrows their usage in compression ignition (CI) i.e. diesel engines. Some challenges include higher brake specific fuel consumption (BSFC), lower brake thermal efficiency (BTE), and higher particulate matter (PM) and nitrogen oxides (NOx) emissions. Very limited literature has been found regarding the use of PSO and SFO biodiesel to examine engine performance and emission studies. Prabhakaran et al. (2016) have done engine performance analysis of a single cylinder Kirlosar-TV1 diesel engine with PSO biodiesel blends of B25, B50, B75 and B100. They also studied the emissions of biodiesel blends. They concluded that the BTE of PSO blends was lower than that of diesel at all load conditions. They also found that the BSFC of B25 was lower than that for all other blends. They recommended B25 blend as a suitable biodiesel blend due to lower carbon monoxide (CO) and NOx emissions. Raj and Karthikayan (2016) have undertaken diesel engine (single cylinder) performance analysis with papaya diesel blends of B25 and B25 with additives (B25A), B100 and B100 with additives (B100A). They found that the PSO diesel blends with additives have better combustion and emission characteristics with reductions in the NOx emissions compared with PSO diesel blends as well as lower smoke density compared with the diesel. Prabakaran et al. (2015) have done the engine performance analysis of a single cylinder diesel engine with papaya diesel blends such as B25, B50, B75 and B100. They found that the PSO biodiesel B50 with standard injection timing showed slight improvement (3%) in BTE compared to diesel. Anwar et al. (2018b) have done the engine performance analysis of a four cylinder diesel engine with papaya diesel blends B5, B10 and B20 and found average BP value reduction of 2.88%, 3.87% and 5.13% respectively. Furthermore, they reported that reduction in HC emissions of 9 to 19%, PM it emissions of 19.5 to 35% and CO emissions of 11 to 29%can be achieved. They suggested that B5 and B10 biodiesel–diesel blends can be used to diesel engine without further engine modification. Mohan and Sen (2015) used CaO as the catalyst and analysed the emissions of a single cylinder diesel engine using 20% papaya biodiesel and 80% chicken biodiesel blend. Although the NOx emissions showed a marginal increase, other emission characteristics such as CO, hydrocarbon (HC) and smoke were reduced compared with diesel.

Gumus and Kasifoglu (2010) have used SFO biodiesel–diesel blends of B5, B20, B50 and B100 in a Lombardini 6LD400 single cylinder diesel engine and found that B5 and B20 gave better engine power and lower BSFC. The B50 and B100 blends produced less CO, HC and smoke density; however they produced higher NOx emissions and lower engine performance characteristics than diesel. Kumar et al. (2018) have conducted engine performance and emission studies of SFO biodiesel with B20 and B20, with BHA and PG antioxidants. They found that B20 has lower CO, HC emissions than diesel. With B20/BHA4000, both HC and CO emissions were recorded at their lowest at full load. CO emission with the B20/PG4000 blend was found to be similar to that of diesel at full load conditions. NOx emissions were also found to be lower at low load for B20 blend, but these were raised when the load was increased. Table 13 shows the summary of engine performance and emissions studies for PSO and SFO biodiesels.

9. Combustion characteristics of PSO and SFO biodiesel

Prabhakaran et al. (2016) investigated the combustion characteristics of PSO biodiesel and reported that the addition of PSO biodiesel to diesel fuel considerably decreased the ignition delay period and resulted in maximum in-cylinder pressure due to higher cetane number and oxygen contents of biodiesel. It was reported that the peak pressure of the biodiesel blend B25 was higher than those of all other blends. Again, the heat release rate of B25 blend was found to be higher than those of other blends due to reduced viscosity and improved spray formation. The higher viscous biodiesel leads to a reduction in air fuel mixing rates which end up producing a lower heat release rate compared to diesel. Raj and Karthikayan (2016) reported that PSO biodiesel blends ignited earlier and finished combustion earlier than diesel. It was also reported that PSO biodiesel with Di-tert butyl peroxide (DTBP) additive produced higher peak pressure due to oxygen buffer character of the additive which enhanced complete combustion process. The heat release rate was also improved with the use of DTBP additive by 13.7% and 39% respectively, on biodiesel

Table 12
Some non-edible biodiesels and their properties.

Non-edible biodiesels	Density (kg/m^3)	Viscosity at 40 °C (mm^2/s)	Acid value (mg KOH/g)	Cetane number (CN)	Calorific value (MJ/kg)	Flash point (°C)	Iodine value (IV) (mg I_2/100 g)	Oxidation stability (OS) (h)
Diesel	827.2	3.23	0.05	48.00	45.30	68.5	38.3	39.0
PSO (Anwar et al., 2018a)	840.0	3.53	0.42	48.29	38.49	112	115.89	5.61
SFO (Anwar et al., 2018c)	855.0	4.26	0.25	50.45	39.64	105	104.70	7.15
Tobacco (Atabani et al., 2012; Hasni et al., 2017)	888.5	4.23	–	51.60	–	165.4	136	0.80
Jatropha (Hasni et al., 2017)	879.5	4.80	0.40	51.60	39.23	135	104	2.30
Rapeseed (Atabani et al., 2012)	882.0	4.43	–	54.40	37.00	170	–	7.60
Cottonseed (Atabani et al., 2012)	875.0	4.07	0.16	54.13	40.43	150	–	1.83
Neem (Atabani et al., 2012; Hasni et al., 2017)	868.0	5.21	0.65	–	39.81	76	–	7.10
Karanja (Hasni et al., 2017)	931.0	6.13	0.42	55.00	43.42	95	–	–
Moringa (Atabani et al., 2012)	883.0	5.00	0.18	67.1	–	160	74	2.3
ASTM D6751	880.0	1.9–6.0	max 0.5	min. 47	–	100–170	–	min. 3
EN14214	860–900	3.5–5.0	max 0.5	min. 51	35	>120	max 120	min. 6

blends B25 and B100 respectively, compared to diesel. Prabakaran et al. (2015) have shown that the peak cylinder pressure was slightly higher for B50 blend. They also reported that the heat release rate of diesel is slightly lower than that of PSO biodiesel B50 blend. To the best of our knowledge, there is no substantial work previously undertaken on an engine combustion using SFO biodiesel.

10. Discussion

Biodiesel is drawing vast attention as an alternative fuel source, but in reality, it is facing some challenges not only in Australia but also in many parts of the world. This study has identified some specific challenges for PSO and SFO biodiesels. Some challenges are associated with biodiesel feedstock selection, optimisation and production processes, the oil extraction and conversion process, fuel characterisation and property analysis, storage and transport. The study also identified some ways to overcome these challenges.

Research shows that correct feedstocks selection and their ongoing availability are the major challenges for biodiesel production (Biswas et al., 2011). Biodiesel feedstocks are generally selected based on some key parameters such as higher oil content, high conversion rate to biodiesel, local availability and cost-effectiveness. Again, availability of feedstocks depends on different climatic conditions and growing seasons. Thus supplying continuous feedstock may be difficult (Zhu and Ketola, 2012). As Australia is a huge size country with several different climate zones, right feedstocks selections for its different climate zones are big challenges. Again, some parts of Australia is quite warm and dry in winter whereas some parts are hot and humid in the summer, prolonged drought is also a common phenomenon in some part of Australia. Therefore, the plants that consume less water, require less maintenance, less fertile soil, can grow in diverse climatic conditions and are unsuitable for human consumption are ideal for biodiesel feedstock.

One of the most challenging issues is to identify a cost-effective and higher biodiesel yielding strategy that can be used on a commercial scale (Puri et al., 2012). Extensive research and knowledge is required to optimise any biodiesel production process. Oil extraction and conversion processes may cause environmental pollution hazards, e.g., chemical oil extraction processes may involve chemical contamination of water source while washing and drying processes take place (Jayed et al., 2009; Hoekman, 2009). Sustainable and environmentally-friendly chemicals and technologies are a focus globally to mitigate these oil extraction challenges. Combined and collaborative research projects are ongoing with different Universities in Australia focusing on sustainable biodiesels and their production.

Storage of feedstocks can be challenging as they are biodegradable and can produce gum (Mukherjee et al., 2011). Biodiesel is non-flammable and is safe to store. However, prolonged storage can result in acidity problems due to easy oxidisation with oxygen at ambient temperature. Odour can occur due to prolonged storage of biodiesel. Strong Government policy is needed to ensure continuous consumption of biodiesel and their blends to minimise storage and transportation issues. State Government of Australia such as Queensland and New South Wales have introduced biofuel mandates to promote biodiesel consumption.

There is no generalised technique that can be applied to all feedstocks for converting to biodiesel. This is a major technical challenge (Greenwell et al., 2010; Santacesaria et al., 2012). For instance, different equipment and testing facilities are required in the biodiesel production processes and some of that equipment may not be needed for all feedstocks; thus, production cost per unit of biodiesel can be higher than for ordinary techniques (Vasudevan and Briggs, 2008; Mettler et al., 2012; Goldemberg, 2008). Some feedstocks, i.e. bio-oils, may have toxic acids that require advanced techniques and longer processing times, and this would lead to higher costs for fuel processing (Liu et al., 2012). To overcome technical challenges, advanced and organised research and development efforts are required among various universities, biodiesel producing companies and the state

Table 13
Summary of engine performance and emission studies for PSO and SFO biodiesels.

Parameters	Papaya seed oil (PSO) biodiesel	Apricot kernel oil (SFO) biodiesel
Engine performance		
BSFC increase	Blend B50, B75 and B100 (Prabhakaran et al., 2016); B5, B10, B20 (Anwar et al., 2018b)	Blend B100 (Gumus and Kasifoglu, 2010)
BSFC decrease	Blend B25 (Prabhakaran et al., 2016); B25 (Raj and Karthikayan, 2016)	Blend B5 and B20 (Gumus and Kasifoglu, 2010); Blend B20, B20/BHA4000, B20/PG4000 (Kumar et al., 2018)
BTE increase	Blend B25 (Prabhakaran et al., 2016); Mixed B25 and B25A (Raj and Karthikayan, 2016); B25, B50 (Prabakaran et al., 2015); B5, B10, B15 (Sivasubramanian, 2017)	–
BTE decrease	Blend B50, B75 and B100 (Prabhakaran et al., 2016); B5, B10, B20 (Anwar et al., 2018b)	Blend B20, B20/BHA4000, B20/PG4000 (Kumar et al., 2018)
Brake power increase	–	–
Brake power decrease	B5, B10, B20 (Anwar et al., 2018b)	–
Emission parameters		
CO increased	Blend B50, B75 and B100 (Prabhakaran et al., 2016); B75, B100 (Prabakaran et al., 2015)	Blend B20, B20/PG4000 (Kumar et al., 2018)
CO decreased	Blend B25 (Prabhakaran et al., 2016); B25, B50 (Prabakaran et al., 2015)	Blend B5, B20, B50 and B100 (Gumus and Kasifoglu, 2010); B20/BHA4000 (Kumar et al., 2018)
CO_2 increased	–	Blend B5, B20, B50 (Gumus and Kasifoglu, 2010)
CO_2 decreased	–	B100 (Gumus and Kasifoglu, 2010)
NO_x increased	Blend B25 (Prabhakaran et al., 2016); B25, B50 (Prabakaran et al., 2015)	Blend B5, B20, B50 and B100 (Gumus and Kasifoglu, 2010)
NO_x decreased	Blend B50, B75 and B100 (Prabhakaran et al., 2016); mixed B25 and B25A (Raj and Karthikayan, 2016); B75. B100 (Prabakaran et al., 2015)	Blend B20/BHA4000, B20/PG4000 (Kumar et al., 2018)
HC increased	Blend B25, B50, B75 and B100 (Raj and Karthikayan, 2016); B75, B100 (Prabakaran et al., 2015)	Blend B20, B50 and B100 (Gumus and Kasifoglu, 2010); B20/PG4000 (Kumar et al., 2018)
HC decreased	Blend B25 (Prabhakaran et al., 2016); B25, B50 (Prabakaran et al., 2015); B5, B10, B15 (Sivasubramanian, 2017)	Blend B5 (Gumus and Kasifoglu, 2010); B20/BHA4000 (Kumar et al., 2018)
EGT increased	B5, B10, B15 (Sivasubramanian, 2017)	–
EGT decreased	–	–
Smoke opacity increased	Blend B50, B75 and B100 (Prabhakaran et al., 2016); B25 and B100A (Raj and Karthikayan, 2016); B75, B100 (Prabakaran et al., 2015)	–
Smoke opacity decreased	Blend B25 (Prabhakaran et al., 2016); B25 and B100 (Raj and Karthikayan, 2016); B25, B50 (Prabakaran et al., 2015)	Blend B5, B20, B50 and B100 (Gumus and Kasifoglu, 2010)

Note: EGT refers to exhaust gas temperature; B25A and B100A refer to additives added to B25, and B100; B20/BHA4000 refers to B20 blend with butylated hydroxyl anisole (BHA) antioxidants at 4000 ppm; B20/PG4000 refers to B20 blend with propyl gallate (PG) antioxidants at 4000 ppm.

governments. Strong and favourable government policy and end user (public) support can help produce and maintain production efficiencies (Azad et al., 2015).

Most people are not aware of the benefits of biodiesel usage in their vehicles (Santacesaria et al., 2012). Lack of knowledge about the benefits of biodiesel prevents the public from using more biodiesel in their vehicles to enhance engine life as well as save the environment (Lin et al., 2011; Hannon et al., 2010). Increased publicity and attractive incentives to use biodiesel eliminate lack of awareness problem (McKone et al., 2011; Wang et al., 2009). Australian Government has initiated public awareness programs including advertisement on daily news, bill board poster, social media, radio, and television commercials to promote biofuel usage.

Generally, the production cost of biodiesel is higher than that of diesel. This is the biggest challenge, as the customers are not willing to pay extra for biodiesel. Customers are not focusing on long-term benefits of biodiesel usage in their vehicles such as increasing engine life. They are more inclined to take some savings at present (Lim and Teong, 2010; Santacesaria et al., 2012; Daniel et al., 2012; Ajanovic and Haas, 2010). Mass scale production and strong Government support, price compensation, i.e., incentives, can encourage customers to use biodiesel (Sulaiman, 2007; Li et al., 2011). Strong positive renewable energy policy is vital to promote biodiesel usage and mitigate increasing energy demands as well as decrease environmental emissions (Lin et al., 2011; Chu and Majumdar, 2012). Australian Government organisations such as Australian Renewable Energy Agency (ARENA) and Australian Competition and Consumer Commission (ACCC) are promoting biodiesel industry by satisfying all stakeholders.

11. Conclusions

This study reviewed both papaya and stone fruits as biodiesel feedstocks, and their biological life cycles. The study covers oil extraction methods, oil properties, biodiesel conversion process, biodiesel properties and their compliance to international standards, engine performance and emission studies, and combustion characteristics. Biodiesels from newer sources cannot be verified easily due to a lack of confidence, i.e., hesitation of users and engine manufacturers to accept unproven products. Since biodiesel production in Australia is not extensive, the potential of second-generation biodiesel from Australian native plants, in particular from PSO and SFO, is not fully exploited. An extensive literature review has been conducted to identify research problems and challenges in using PSO and SFO. Salient fuel properties of both PSO and SFO biodiesels have been investigated and compared with other popular non-edible biodiesels and diesel. While engine performance and emission analysis of both PSO and SFO biodiesels have been reported, there is insufficient research conducted on combustion analysis of SFO biodiesel. Further research on combustion, corrosion, tribo-corrosion, long-term engine durability testing and tribological performance analysis of PSO and SFO would be required before recommending them as future alternative energy sources in Australia.

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References

Agunbiade, F.O., Adewole, T.A., 2014. Methanolysis of carica papaya seed oil for production of biodiesel. J. Fuels 2014, 6.
Ajanovic, A., Haas, R., 2010. Economic challenges for the future relevance of biofuels in transport in EU countries. Energy 35 (8), 3340–3348.
Algayyim, S.J.M., Wandel, A.P., Yusaf, T., Al-Lwayzy, S., Hamawand, I., 2018. Impact of butanol-acetone mixture as a fuel additive on diesel engine performance and emissions. Fuel 227, 118–126.
Anwar, M., Rasul, M.G., Ashwath, N., 2018a. Production optimization and quality assessment of papaya (Carica papaya) biodiesel with response surface methodology. Energy Convers. Manage. 156, 103–112.
Anwar, M., Rasul, M., Ashwath, N., 2018b. A systematic multivariate analysis of carica papaya biodiesel blends and their interactive effect on performance. Energies 11 (11), 2931.
Anwar, M., Rasul, M., Ashwath, N., Rahman, M., 2018c. Optimisation of second-generation biodiesel production from Australian native stone fruit oil using response surface method. Energies 11 (10), 2566.
Ashwath, N., 2010. Evaluating biodiesel potential of australian native and naturalised plant species. In: Rural Industries Research and Development Corporation, (Canberra). p. 96.
Atabani, A.E., Silitonga, A.S., Badruddin, I.A., Mahlia, T.M.I., Masjuki, H.H., Mekhilef, S., 2012. A comprehensive review on biodiesel as an alternative energy resource and its characteristics. Renew. Sustain. Energy Rev. 16 (4), 2070–2093.
Atabani, A.E., Silitonga, A.S., Ong, H.C., Mahlia, T.M.I., Masjuki, H.H., Badruddin, I.A., Fayaz, H., 2013. Non-edible vegetable oils: a critical evaluation of oil extraction, fatty acid compositions, biodiesel production, characteristics, engine performance and emissions production. Renew. Sustainable Energy Rev. 18 (Supplement C), 211–245.
Atadashi, I.M., Aroua, M.K., Abdul Aziz, A.R., Sulaiman, N.M.N., 2012. The effects of water on biodiesel production and refining technologies: a review. Renew. Sustain. Energy Rev. 16 (5), 3456–3470.
Atadashi, I.M., Aroua, M.K., Aziz, A.A., 2010. High quality biodiesel and its diesel engine application: A review. Renew. Sustain. Energy Rev. 14 (7), 1999–2008.
Australian Energy Projections to 2049-50, BREE, Canberra, 2014.
Avinash, A., Subramaniam, D., Murugesan, A., 2014. Bio-diesel—A global scenario. Renew. Sustain. Energy Rev. 29, 517–527.
Aydin, H., Bayindir, H., 2010. Performance and emission analysis of cottonseed oil methyl ester in a diesel engine. Renew. Energy 35 (3), 588–592.
Azad, A., 2017. Biodiesel from mandarin seed oil: a surprising source of alternative fuel. Energies 10 (11), 1689.
Azad, A.K., Rasul, M., Khan, M.M., Sharma, S., 2017. Macadamia biodiesel as a sustainable and alternative transport fuel in australia. Energy Procedia 110, 543–548.
Azad, A.K., Rasul, M.G., Khan, M.M.K., Sharma, S.C., Hazrat, M.A., 2015. Prospect of biofuels as an alternative transport fuel in Australia. Renew. Sustain. Energy Rev. 43 (Supplement C), 331–351.
Azad, A.M., Rasul, M.G., Khan, M.M.K., Sharma, S.C., Mofijur, M., Bhuiya, M.M.K., 2016. Prospects, feedstocks and challenges of biodiesel production from beauty leaf oil and castor oil: A nonedible oil sources in Australia. Renew. Sustain. Energy Rev. 61, 302–318.
Babaki, M., Yousefi, M., Habibi, Z., Mohammadi, M., 2017. Process optimization for biodiesel production from waste cooking oil using multi-enzyme systems through response surface methodology. Renew. Energy 105 (Supplement C), 465–472.
Baiju, B., Naik, M.K., Das, L.M., 2009. A comparative evaluation of compression ignition engine characteristics using methyl and ethyl esters of Karanja oil. Renew. Energy 34 (6), 1616–1621.
Banerjee, A., Chakraborty, R., 2009. Parametric sensitivity in transesterification of waste cooking oil for biodiesel production—A review. Resour. Conserv. Recycl. 53 (9), 490–497.
Bello, Emmanuel I., Labunmi Lajide, I.T.I.O., Daniyan, Ilesanmi A., 2016. Daniyan optimization of process parameters for biodiesel production using response surface methodology. Amer. J. Energy Eng. 4 (2), 8–16.
Bhuiya, M., Rasul, M., Khan, M., Ashwath, N., 2017. Performance and emission characteristics of binary mixture of poppy and waste cooking biodiesel. Energy Procedia 110, 523–528.
Bhuiya, K.M.M., Rasul, M.G., Khan, M.M.K., Ashwath, N., Azad, A.K., 2016. Prospects of generation biodiesel as a sustainable fuel—Part: 1 selection of feedstocks, oil extraction techniques and conversion technologies. Renew. Sustain. Energy Rev. 55, 1109–1128.
Bhuiya, K.M.M., Rasul, M.G., Khan, M.M.K., Ashwath, N., Azad, A.K., Mofijur, M., 2015. Optimisation of oil extraction process from australian native beauty leaf seed (Calophyllum Inophyllum). Energy Procedia 75, 56–61.
Biswas, B., Scott, P.T., Gresshoff, P.M., 2011. Tree legumes as feedstock for sustainable biofuel production: opportunities and challenges. J. Plant Physiol. 168 (16), 1877–1884.
Chan, H.T., Heu, R.A., Tang, C.S., Okazaki, E.N., Ishizaki, S.M., 1978. Composition of papaya SEEDs. J. Food Sci. 43 (1), 255–256.
Chielle, D.P., Bertuol, D.A., Meili, L., Tanabe, E.H., Dotto, G.L., 2016. Convective drying of papaya seeds (Carica papaya L.) and optimization of oil extraction. Ind. Crops Prod. 85 (Supplement C), 221–228.
Chu, S., Majumdar, A., 2012. Opportunities and challenges for a sustainable energy future. Nature 488, 294.

Cornejo, A., Barrio, I., Campoy, M., Lázaro, J., Navarrete, B., 2017. Oxygenated fuel additives from glycerol valorization. main production pathways and effects on fuel properties and engine performance: a critical review. Renew. Sustain. Energy Rev. 79, 1400–1413.

Damanik, N., Ong, H.C., Tong, C.W., Mahlia, T.M.I., Silitonga, A.S., 2018. A review on the engine performance and exhaust emission characteristics of diesel engines fueled with biodiesel blends. Environ. Sci. Pollut. Res. 25 (16), 15307–15325.

Daniel, K.-M., Piotr, O.-P., A, S.B., W, B.H., 2012. The challenge of enzyme cost in the production of lignocellulosic biofuels. Biotechnol. Bioeng. 109 (4), 1083–1087.

Daryono, E.D., Sinaga, E.J., 2017. Rapid in situ transesterification of papaya seeds to biodiesel with the aid of co-solvent. Int. J. Renewable Energy Res. 7 (1), 379–385.

De Melo, L.M.S., Santos, N.A., Rosenhaim, R., Souza, A.G., Athayde Filho, P.F., 2011. Use of thermal analysis techniques for evaluation of the stability and chemical properties of papaya biodiesel (Carica Papaya L.) at low temperatures. J. Thermal Anal. Calorimetry 106 (3), 831–836.

Department of Industry, Innovation and Sceience (2016), Australian energy update 2016, Canberra, September.

Department of Natural Resources, Mines and Energy, 2018 [cited 16 2018]; available from https://www.dnrm.qld.gov.au/mapping-data/maps.

Department of the Environment and Energy (2017), Australian Energy Update 2017, Canberra, August.

Dharma, S., Masjuki, H.H., Ong, H.C., Sebayang, A.H., Silitonga, A.S., Kusumo, F., Mahlia, T.M.I., 2016. Optimization of biodiesel production process for mixed Jatropha curcas–Ceiba pentandra biodiesel using response surface methodology. Energy Convers. Manage. 115, 178–190.

Dincer, K., 2008. Lower emissions from biodiesel combustion. Energy Sour. A 30 (10), 963–968.

Ezekannagha, C.B., Ude, C.N., Onukwuli, O.D., 2017. Optimization of the methanolysis of lard oil in the production of biodiesel with response surface methodology. Egyptian J. Petroleum.

Fadhil, A.B., 2017. Evaluation of apricot (Prunus armeniaca L.) seed kernel as a potential feedstock for the production of liquid bio-fuels and activated carbons. Energy Convers. Manage. 133, 307–317.

Fan, S., Liang, T., Yu, H., Bi, Q., Li, G., Wang, L., 2016. Kernel characteristics, oil contents fatty acid compositions and biodiesel properties in developing siberian apricot (Prunus sibirica L.) seeds. Ind. Crops Prod. 89, 195–199.

Ganjehkaviri, A., Mohd Jaafar, M., Hosseini, S., Musthafa, A., 2016. Performance evaluation of palm oil-based biodiesel combustion in an oil burner. Energies 9 (2), 97.

Gardy, J., Osatiashtiani, A., Céspedes, O., Hassanpour, A., Lai, X., Lee, A.F., Wilson, K., Rehan, M., 2018. A magnetically separable SO4/Fe-Al-TiO2 solid acid catalyst for biodiesel production from waste cooking oil. Appl. Catal. B 234, 268–278.

Godiganur, S., Suryanarayana Murthy, C.H., Reddy, R.P., 2009. 6BTA 5.9 G2-1 Cummins engine performance and emission tests using methyl ester mahua (Madhuca indica) oil/diesel blends. Renew. Energy 34 (10), 2172–2177.

Goldemberg, J., 2008. The challenge of biofuels. Energy Environ. Sci. 1 (5), 523–525.

Greenwell, H.C., Laurens, L.M.L., Shields, R.J., Lovitt, R.W., Flynn, K.J., 2010. Placing microalgae on the biofuels priority list: a review of the technological challenges. J. R. Soc. Interface 7 (46), 703–726.

Gumus, M., Kasifoglu, S., 2010. Performance and emission evaluation of a compression ignition engine using a biodiesel (apricot seed kernel oil methyl ester) and its blends with diesel fuel. Biomass Bioenergy 34 (1), 134–139.

Gupta, J., Agarwal, M., Dalai, A.K., 2016. Optimization of biodiesel production from mixture of edible and nonedible vegetable oils. Biocatal. Agric. Biotechnol. 8 (Supplement C), 112–120.

Hameed, B.H., 2009. Evaluation of papaya seeds as a novel non-conventional low-cost adsorbent for removal of methylene blue. J. Hazardous Mater. 162 (2), 939–944.

Hamze, H., Akia, M., Yazdani, F., 2015. Optimization of biodiesel production from the waste cooking oil using response surface methodology. Process Safety Environ. Protection 94, 1–10.

Hannon, M., Gimpel, J., Tran, M., Rasala, B., Mayfield, S., 2010. Biofuels from algae: challenges and potential. Biofuels 1 (5), 763–784.

Hasni, K., Ilham, Z., Dharma, S., Varman, M., 2017. Optimization of biodiesel production from Brucea javanica seeds oil as novel non-edible feedstock using response surface methodology. Energy Convers. Manage. 149 (Supplement C), 392–400.

Hoekman, S.K., 2009. Biofuels in the U.S. – challenges and opportunities. Renew. Energy 34 (1), 14–22.

Hoseini, S.S., Najafi, G., Ghobadian, B., Mamat, R., Ebadi, M.T., Yusaf, T., 2018. Novel environmentally friendly fuel: The effects of nanographene oxide additives on the performance and emission characteristics of diesel engines fuelled with Ailanthus altissima biodiesel. Renew. Energy 125, 283–294.

Hoseini, S.S., Najafi, G., Ghobadian, B., Mamat, R., Ebadi, M.T., Yusaf, T., 2019. Characterization of biodiesel production (ultrasonic-assisted) from evening-primroses (Oenothera lamarckiana) as novel feedstock and its effect on CI engine parameters. Renew. Energy 130, 50–60.

Islam, M.A., Brown, R.J., Brooks, P.R., Jahirul, M.I., Bockhorn, H., Heimann, K., 2015. Investigation of the effects of the fatty acid profile on fuel properties using a multi-criteria decision analysis. Energy Convers. Manage. 98, 340–347.

Jahirul, M.I., Brown, R.J., Senadeera, W., Ashwath, N., Rasul, M.G., Rahman, M.M., Hossain, F.M., Moghaddam, L., Islam, M.A., O'Hara, I.M., 2015. Physio-chemical assessment of beauty leaf (Calophyllum inophyllum) as second-generation biodiesel feedstock. Energy Rep. 1, 204–215.

Jahirul, M., Koh, W., Brown, R., Senadeera, W., Hara, I., Moghaddam, L., 2014. Biodiesel production from non-edible beauty leaf (Calophyllum inophyllum) oil: process optimization using response surface methodology (RSM). Energies 7 (8), 5317.

Jamil, F., Al-Muhtaseb, A.A.H., Al-Haj, L., Al-Hinai, M.A., Hellier, P., Rashid, U., 2016. Optimization of oil extraction from waste date pits for biodiesel production. Energy Convers. Manage. 117 (Supplement C), 264–272.

Jannatizadeh, A., Naderi-Boldaji, M., Ghasemi Varnamkhasti, F.R.M., Tabatabaeefar, A., 2008. Some postharvest physical properties of Iranian apricot (Prunus armeniaca L.) fruit. Vol. 22.

Jayed, M.H., Masjuki, H.H., Saidur, R., Kalam, M.A., Jahirul, M.I., 2009. Environmental aspects and challenges of oilseed produced biodiesel in southeast asia. Renew. Sustain. Energy Rev. 13 (9), 2452–2462.

Kate, A.E., Lohani, U.C., Pandey, J.P., Shahi, N.C., Sarkar, A., 2014. Traditional and mechanical method of the oil extraction from wild apricot kernel: a comparative study. Res. J. Chem. Environ. Sci 2, 54–60.

Kaul, S., Saxena, R.C., Kumar, A., Negi, M.S., Bhatnagar, A.K., Goyal, H.B., Gupta, A.K., 2007. Corrosion behavior of biodiesel from seed oils of indian origin on diesel engine parts. Fuel Process. Technol. 88 (3), 303–307.

Kumar, S., Kumar, R., Kumar, M., 2018. Experimental investigations of oxidation stability of biodiesel produced from prunus armeniaca oil (apricot oil) and effect of various antioxidants on stability, engine performance and emissions. Fuel 216 (Supplement C), 861–869.

Lee, W.-J., Lee, M.-H., Su, N.-W., 2011. Characteristics of papaya seed oils obtained by extrusion–expelling processes. J. Sci. Food Agric. 91 (13), 2348–2354.

Li, S., Wang, Y., Dong, S., Chen, Y., Cao, F., Chai, F., Wang, X., 2009. Biodiesel production from Eruca sativa gars vegetable oil and motor, emissions properties. Renew. Energy 34 (7), 1871–1876.

Li, Y.-G., Xu, L., Huang, Y.-M., Wang, F., Guo, C., Liu, C.-Z., 2011. Microalgal biodiesel in China: Opportunities and challenges. Appl. Energy 88 (10), 3432–3437.

Lim, S., Teong, L.K., 2010. Recent trends, opportunities and challenges of biodiesel in Malaysia: An overview. Renew. Sustain. Energy Rev. 14 (3), 938–954.

Lin, L., Cunshan, Z., Vittayapadung, S., Xiangqian, S., Mingdong, D., 2011. Opportunities and challenges for biodiesel fuel. Appl. Energy 88 (4), 1020–1031.

Liu, C.-Z., Wang, A.R., Guo, C., 2012. Ionic liquids for biofuel production: opportunities and challenges. Appl. Energy 92, 406–414.

Luque, R., Herrero-Davila, L., Campelo, J.M., Clark, J.H., Hidalgo, J.M., Luna, D., Marinas, J.M., Romero, A.A., 2008. Biofuels: a technological perspective. Energy Environ. Sci. 1 (5), 542–564.

Mahanta, P.S.A., 2004. Technology development of bio-diesel as an energy alternative. pp. 1–19.

Makareviciene, V., Skorupskaite, V., Levisauskas, D., Andruleviciute, V., Kazancev, K., 2014. The optimization of biodiesel fuel production from microalgae oil using response surface methodology. Int. J. Green Energy 11 (5), 527–541.

Malacrida, C.R., Kimura, M., Jorge, N., 2011. Characterization of a high oleic oil extracted from papaya (Carica papaya L.) seeds. Food Sci. Technol. 31, 929–934.

Mansourpoor, M.S.A., 2012. Optimization of biodiesel production from sunflower oil using response surface methodology. J. Chem. Eng. Process. Technol. 3 (141).

Marfo, E.K., Oke, O.L., Afolabi, O.A., 1986. Chemical composition of papaya (Carica papaya) seeds. Food Chem 22, 259–266.

Math, M.C., Chandrashekhara, K.N., 2016. 2016 optimization of alkali catalyzed transesterification of safflower oil for production of biodiesel. J. Eng. 7.

McKone, T.E., Nazaroff, W.W., Berck, P., Auffhammer, M., Lipman, T., Torn, M.S., Masanet, E., Lobscheid, A., Santero, N., Mishra, U., Barrett, A., Bomberg, M., Fingerman, K., Scown, C., Strogen, B., Horvath, A., 2011. Grand challenges for life-cycle assessment of biofuels. Environ. Sci. Technol. 45 (5), 1751–1756.

Mettler, M.S., Vlachos, D.G., Dauenhauer, P.J., 2012. Top ten fundamental challenges of biomass pyrolysis for biofuels. Energy Environ. Sci. 5 (7), 7797–7809.

Milano, J., Ong, H.C., Masjuki, H.H., Silitonga, A.S., Chen, W.-H., Kusumo, F., Dharma, S., Sebayang, A.H., 2018. Optimization of biodiesel production by microwave irradiation-assisted transesterification for waste cooking oil-Calophyllum inophyllum oil via response surface methodology. Energy Convers. Manage. 158, 400–415.

Ming, C., Rizwanul Fattah, I.M., Chan, Q.N., Pham, P.X., Medwell, P.R., Kook, S., Yeoh, G.H., Hawkes, E.R., Masri, A.R., 2018. Combustion characterization of waste cooking oil and canola oil based biodiesels under simulated engine conditions. Fuel 224, 167–177.

Mohan, A., Sen, S., 2015. Emission analysis of the biodiesel from papaya and chicken blends. Int. J. Informative Futuristic Res. 2 (7), 2258–2264.

Mosarof, M.H., Kalam, M.A., Masjuki, H.H., Alabdulkarem, A., Ashraful, A.M., Arslan, A., Rashedul, H.K., Monirul, I.M., 2016. Optimization of performance, emission, friction and wear characteristics of palm and Calophyllum inophyllum biodiesel blends. Energy Convers. Manage. 118, 119–134.

Mowla, O., Kennedy, E., Stockenhuber, M., 2018. In-situ FTIR study on the mechanism of both steps of zeolite-catalysed hydroesterification reaction in the context of biodiesel manufacturing. Fuel 232, 12–26.

Mukherjee, P., Varshney, A., Johnson, T.S., Jha, T.B., 2011. Jatropha curcas: a review on biotechnological status and challenges. Plant Biotechnol. Rep. 5 (3), 197–215.

Murugesan, A., Umarani, C., Chinnusamy, T.R., Krishnan, M., Subramanian, R., Neduzchezhain, N., 2009. Production and analysis of bio-diesel from non-edible oils—A review. Renew. Sustain. Energy Rev. 13 (4), 825–834.

Muthukumaran, C., Praniesh, R., Navamani, P., Swathi, R., Sharmila, G., Manoj Kumar, N., 2017. Process optimization and kinetic modeling of biodiesel production using non-edible madhuca indica oil. Fuel 195, 217–225.

Nabi, M.N., Rahman, M.M., Islam, M.A., Hossain, F.M., Brooks, P., Rowlands, W.N., Tulloch, J., Ristovski, Z.D., Brown, R.J., 2015. Fuel characterisation, engine performance, combustion and exhaust emissions with a new renewable Licella biofuel. Energy Convers. Manage. 96, 588–598.

Nabi, M.N., Rasul, M.G., 2018. Influence of second generation biodiesel on engine performance, emissions, energy and exergy parameters. Energy Convers. Manage. 169, 326–333.

Ogaga, I.B., Adeleke, I.A., Damus, M., Adeola, H.J., Ernest, K.O., Betiku, E., 2017. Optimization of biodiesel production from thevetia peruviana seed oil by adaptive neuro-fuzzy inference system coupled with genetic algorithm and response surface methodology. Energy Convers. Manage. 132 (Supplement C), 231–240.

Onukwuli, D.O., Emembolu, L.N., Ude, C.N., Aliozo, S.O., Menkiti, M.C., 2017. Optimization of biodiesel production from refined cotton seed oil and its characterization. Egyptian J. Petroleum 26 (1), 103–110.

Özcanlımath, M., Keskin, A., Aydın, K., 2011. Biodiesel production from terebinth (Pistacia Terebinthus) oil and its usage in diesel engine. Int. J. Green Energy 8 (5), 518–528.

Özkal, S.G., Yener, M.E., Bayındırlı, L., 2005. Mass transfer modeling of apricot kernel oil extraction with supercritical carbon dioxide. J. Supercrit. Fluids 35 (2), 119–127.

Patel, K.A., Nayak, M.G., 2017. Production of FAME using waste papaya seeds by different experimental conditions in a batch system. Int. J. Adv. Eng. Res. Dev. (IJAERD) 4 (1), 244–248.

Prabakaran, P., Saravanan, C.G., Yadav, S.P.R., Aalam, C.S., 2015. Experimental investigation of papaya methyl ester on performance, combustion and emission characteristics of DI diesel engine. Int. J. Innovative Res. Creative Technol. 1 (4).

Prabhakaran, P., Saravanan, C.G., Aalam, C.S., 2016. Effects of papaya methyl ester on DI diesel engine combustion, emission and performance characteristics. Int. Res. J. Eng. Technol. (IRJET) 3 (2).

Puangsri, T., Abdulkarim, S.M., Ghazali, H.M., 2004. Properties of Carica papaya L. (papaya) seed oil following extractions using solvent and aqueous enzymatic methods. J. Food Lipids 12, 62–76.

Puri, M., Abraham, R.E., Barrow, C.J., 2012. Biofuel production: Prospects, challenges and feedstock in Australia. Renew. Sustain. Energy Rev. 16 (8), 6022–6031.

Rahimi, M., Aghel, B., Alitabar, M., Sepahvand, A., Ghasempour, H.R., 2014. Optimization of biodiesel production from soybean oil in a microreactor. Energy Convers. Manage. 79, 599–605.

Rahman, M.M., Hassan, N.M.S., Hyde, J., 2016. Prospects of biodiesel production from macadamia oil as an alternative fuel for diesel engines. Energies 9 (403).

Rahman, M.M., Hazrat, M.A., Rasul, M.G., Mahmudul, H.M., 2015. Comparative evaluation of edible and non-edible oil methyl ester performance in a vehicular engine. Energy Procedia 75, 37–43.

Rahman, A.M.S., Hossain, F.M., Van, T.C., Dowell, A., Islam, M.A, Rainey, T.J., Ristovski, Z.D., Brown, R.J., 2017a. Comparative evaluation of the effect of sweet orange oil-diesel blend on performance and emissions of a multi-cylinder compression ignition engine. AIP Conf. Proc. 1851 (1), 020007.

Rahman, S.M.A., Masjuki, H.H., Kalam, M.A., Abedin, M.J., Sanjid, A., Rahman, M.M., 2014. Assessing idling effects on a compression ignition engine fueled with Jatropha and Palm biodiesel blends. Renew. Energy 68, 644–650.

Rahman, M.M., Masjuki, H.H., Kalam, M.A., Atabani, A.E., Shahabuddin, M., Palash, S.M., Hazrat, M.A., 2013. Effect of biodiesel from various feedstocks on combustion characteristics, engine durability and materials compatibility: A review. Renew. Sustain. Energy Rev. 28, 441–455.

Rahman, M.M., Masjuki, H.H., Kalam, M.A., Hazrat, M.A., Liaquat, A.M., Shahabuddin, M., Varman, M., 2012. Prospects of biodiesel from Jatropha in malaysia. Renew. Sustain. Energy Rev. 16 (7), 5007–5020.

Rahman, S.M.A., Nabi, M., Van, T.C., Suara, K., Jafari, M., Dowell, A., Islam, M.A., Marchese, A.J., Tryner, J., Hossain, M.F., Rainey, T.J., Ristovski, Z.D., Brown, R.J., 2018a. Performance and combustion characteristics analysis of multi-cylinder ci engine using essential oil blends. Energies 11 (4), 738.

Rahman, M.M., Rasul, M.G., Hassan, N.M.S., Khan, M.M.K., Rashedul, H.K., 2018b. Gaseous and particle emissions from a compression ignition engine fueled with biodiesel–diesel blends. In: Khan, A.A., Hassan, N.M.S. (Eds.), Application of Thermo-fluid Processes in Energy Systems: Key Issues and Recent Developments for a Sustainable Future. Springer Singapore, Singapore, pp. 35–56.

Rahman, M.M., Rasul, M.G., Hassan, N.M.S., Masjuki, H.H., Kalam, M.A., Mahmudul, H.M., 2017b. Chapter fourteen - assessment of physical, chemical, and tribological properties of different biodiesel fuels. In: Rasul, M.G., Azad, A.k., Sharma, S.C. (Eds.), Clean Energy for Sustainable Development. Academic Press, pp. 441–463.

Raj, C.S., Karthikayan, M., 2016. Effect of additive on the performance, emission and combustion characteristics of a diesel engine run by diesel-papaya methyl ester blends. Int. J. Chem. Sci 14 (4), 2823–2834.

Rosenthal, A., Pyle, D.L., Niranjan, K., Gilmour, S., Trinca, L., 2001. Combined effect of operational variables and enzyme activity on aqueous enzymatic extraction of oil and protein from soybean. Enzyme Microb. Technol. 28 (6), 499–509.

Salunkhe, D.K., Kadam, S.S., 1995. Handbook of Fruit Science and Technology: Production, Composition, Storage, and Processing. Taylor & Francis.

Samaram, S., Mirhosseini, H., Tan, C., Ghazali, H., 2013. Ultrasound-assisted extraction (Uae) and solvent extraction of papaya seed oil: yield, fatty acid composition and triacylglycerol profile. Molecules 18 (10), 12474.

Santacesaria, E., Vicente, G.M., Di Serio, M., Tesser, R., 2012. Main technologies in biodiesel production: state of the art and future challenges. Catalysis Today 195 (1), 2–13.

Shah, S., Sharma, A., Gupta, M.N., 2005. Extraction of oil from jatropha curcas l. seed kernels by combination of ultrasonication and aqueous enzymatic oil extraction. Bioresour. Technol. 96 (1), 121–123.

Sharma, R., Gupta, A., Abrol, G.S., Joshi, V.K., 2012. Value addition of wild apricot fruits grown in north-west himalayan regions: a review. J. Food Sci. Technol.

Silitonga, A.S., Ong, H.C., Mahlia, T.M.I., Masjuki, H.H., Chong, W.T., 2014. Biodiesel conversion from high FFA crude jatropha curcas, calophyllum inophyllum and ceiba pentandra oil. Energy Procedia 61 (Supplement C), 480–483.

Singh, S.P., Singh, D., 2010. Biodiesel production through the use of different sources and characterization of oils and their esters as the substitute of diesel: a review. Renew. Sustain. Energy Rev. 14 (1), 200–216.

Sitepu, E.K., Corbin, K., Luo, X., Pye, S.J., Tang, Y., Leterme, S.C., Heimann, K., Raston, C.L., Zhang, W., 2018. Vortex fluidic mediated direct transesterification of wet microalgae biomass to biodiesel. Bioresour. Technol. 266, 488–497.

Sivasubramanian, H., 2017. Performance and emission characteristics of papaya seed oil methyl ester–n-butanol–diesel blends on a stationary direct-injection Ci engine. Biofuels 1–10.

Sulaiman, A.-Z., 2007. Production of biodiesel: possibilities and challenges. Biofuels, Bioprod. Biorefin. 1 (1), 57–66.

Syed, H.M., P, K.S., Jadhav, B.A., Salve, R.V., 2011. Extraction and characterization of papaya seed oil Elixir Agriculture, 37A: 4102-4105.

Tran, N.N., Tišma, M., Budžaki, S., McMurchie, E.J., Gonzalez, O.M.M., Hessel, V., Ngothai, Y., 2018. Scale-up and economic analysis of biodiesel production from recycled grease trap waste. Appl. Energy 229, 142–150.

Ullah, F., Nosheen, A., Hussain, I., Bano, A., 2009. Base catalyzed transesterification of wild apricot kernel oil for biodiesel production. Afr. J. Biotechnol. 8 (14), 3289–3293.

USDA Foreign Agricultural service: Australia Biofuels Annual 2017, Canberra.

Usta, N., 2005. Use of tobacco seed oil methyl ester in a turbocharged indirect injection diesel engine. Biomass Bioenergy 28 (1), 77–86.

Vasco-Correa, J., Zapata Zapata, A.D., 2017. Enzymatic extraction of pectin from passion fruit peel (Passiflora edulis f. flavicarpa) at laboratory and bench scale. LWT - Food Sci. Technol. 80, 280–285.

Vasudevan, P.T., Briggs, M., 2008. Biodiesel production—current state of the art and challenges. J. Ind. Microbiol. Biotechnol. 35 (5), 421.

Verma, P., Sharma, M.P., Dwivedi, G., 2016. Prospects of bio-based alcohols for karanja biodiesel production: an optimisation study by response surface methodology. Fuel 183 (Supplement C), 185–194.

Verma, P., Zare, A., Jafari, M., Bodisco, T.A., Rainey, T., Ristovski, Z.D., Brown, R.J., 2018. Diesel engine performance and emissions with fuels derived from waste tyres. Sci. Rep. 8 (1), 2457.

Vieira Silveira, E., Santos Vilela, L., de Souza Castro, C.F., Morais Lião, L., Fernandes Gambarra Neto, F., Santos Mello de Oliveira, P., 2017. Chromatographic characterization of the crambe (Crambe abyssinica Hochst) oil and modeling of some parameters for its conversion in biodiesel. Ind. Crops Prod. 97 (Supplement C), 545–551.

Wang, L., 2013. Properties of manchurian apricot (Prunus mandshurica Skv.) and siberian apricot (Prunus sibirica L.) seed kernel oils and evaluation as biodiesel feedstocks. Ind. Crops Prod. 50 (Supplement C), 838–843.
Wang, F., Xiong, X.-R., Liu, C.-Z., 2009. Biofuels in china: opportunities and challenges. Vitro Cellular Dev. Biology - Plant 45 (3), 342–349.
Wang, L., Yu, H., 2012. Biodiesel from siberian apricot (Prunus sibirica L.) seed kernel oil. Bioresour. Technol. 112 (Supplement C), 355–358.
Wong, C.S., Othman, R., 2014. Biodiesel production by enzymatic transesterification of papaya seed oil and rambutan seed oil. Int. J. Eng. Technol. (IJET) 6 (6), 2773–2777.
Xie, B., Gong, W., Tian, Y., Qu, F., Luo, Y., Du, X., Tang, X., Xu, D., Lin, D., Li, G., Liang, H., 2018. Biodiesel production with the simultaneous removal of nitrogen, phosphorus and COD in microalgal–bacterial communities for the treatment of anaerobic digestion effluent in photobioreactors. Chem. Eng. J. 350, 1092–1102.
Yaakob, Z., Mohammad, M., Alherbawi, M., Alam, Z., Sopian, K., 2013. Overview of the production of biodiesel from waste cooking oil. Renew. Sustainable Energy Rev. 18 (Supplement C), 184–193.
Yadav, A.K., Pal, A., Dubey, A.M., 2017. Experimental studies on utilization of Prunus armeniaca L. (wild apricot) biodiesel as an alternative fuel for CI engine. Waste Biomass Valorization.
Yang, J.C.K., He, QS., Caldwell, C., 2015. The optimization of alkali-catalyzed biodiesel production from camelina sativa oil using a response surface methodology. Bioprocess Biotech 5 (235).
Yusaf, T.F., Yousif, B.F., Elawad, M.M., 2011. Crude palm oil fuel for diesel-engines: Experimental and ANN simulation approaches. Energy 36 (8), 4871–4878.
Zare, A., Bodisco, T.A., Nabi, M.N., Hossain, F.M., Ristovski, Z.D., Brown, R.J., 2018. A comparative investigation into cold-start and hot-start operation of diesel engine performance with oxygenated fuels during transient and steady-state operation. Fuel 228, 390–404.
Zare, A., Nabi, M.N., Bodisco, T.A., Hossain, F.M., Rahman, M.M., Chu Van, T., Ristovski, Z.D., Brown, R.J., 2017. Diesel engine emissions with oxygenated fuels: A comparative study into cold-start and hot-start operation. J. Cleaner Prod. 162, 997–1008.
Zhu, L., Ketola, T., 2012. Microalgae production as a biofuel feedstock: risks and challenges. Int. J. Sustainable Dev. World Ecol. 19 (3), 268–274.