BIOMASS AND BIOENERGY 61 (2014) 276–297

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Review

A review of current technology for biodiesel production: State of the art

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ARTICLE INFO

Article history:
Received 2 July 2012
Received in revised form
7 October 2013
Accepted 23 November 2013

Keywords:
Biodiesel
Homogeneous catalyst
Heterogeneous catalyst
Reactive distillation
Biomass source

ABSTRACT

This article reviews various technologies that have been used for biodiesel production till date, with a view to comparing commercial suitability of these methods on the basis of available feedstocks and associated challenges. This review shows that while emphasis is on the use of micro alga oil sources, the viability of the economics of the process is still in doubt. Homogenously catalyzed processes are the conventional technologies. However, their large-scale applicability is compromised due to their characteristic challenges. Batch processes and continuous processes are used for industrial purposes with typical capacity of 7.26–7.5 $\mathrm{Gg\,y^{-1}}$ and 8–125 $\mathrm{Gg\,y^{-1}}$ respectively, and heterogeneous catalysis may be sustainable for the continuous processes. Heterogeneous catalysts from renewable sources may be both environmentally and economically viable. Reactive distillation has the major advantage of combining the reaction and separation stages in a single unit, thereby significantly reducing capital costs and increasing opportunities for heat integration. This paper is a comprehensive overview of current technologies and appropriate options for scale-up development, providing the basis for a proposal for the exploitation of heterogeneous catalysts from natural sources to optimize biodiesel production.

1. Introduction

The consciousness of cleaner production technology is increasing globally. The need for an alternative to fossil fuels has engendered extensive research in recent years. Fossil fuels are non-renewable sources of energy which generate pollutants and are linked to global warming, climate change and even some incurable diseases. The impending challenges and the environmental implications of fossil fuels have been reviewed widely in the literature [1–3]. Biodiesel has been identified as one of the notable options for at least complementing conventional fuels. Its production from renewable biological sources such as vegetable oils and fats has been reviewed widely [4–7]. Its advantages over petroleum diesel cannot be overemphasized: it is safe, renewable, non-toxic, and biodegradable; it contains no sulphur; and it is a better lubricant. In addition, its use engenders numerous societal benefits: rural revitalization, creation of new jobs, and reduced global warming [8]. Its physical properties have been reviewed

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http://dx.doi.org/10.1016/j.biombioe.2013.11.014

widely as well [4–6], some of which are dependent on the feedstock employed for its production. The flash point of biodiesel is significantly higher than that of petroleum diesel or gasoline, thus making it one of the safest fuels available. However, the calorific value of biodiesel (~37.27 MJ L^{-1}) is about ~9% lower than that of the regular petroleum diesel. The variations in the biodiesel energy density are more dependent on the fatty raw materials used than the production process [9].

There are several reports on biodiesel production from edible oils [5,10–12]; thus, its competition with food consumption has been a global concern. About 6.6 Tg (34%) of edible oil was estimated for worldwide biodiesel production from 2004 to 2007 [13], and biodiesel is projected to account for more than a third of the expected growth in edible oil use from 2005 to 2017 [13]. Consequently, employing waste and non-edible oils in biodiesel production would eliminate the competition with food consumption [9]; it will also allow for compliance with ecological and ethical requirements for biofuel. Algae are currently considered to be one of the most promising alternative sources of non-edible oils for biodiesel. Although full-scale commercialization of biodiesel from algae oil has not been launched, current research efforts have shown that algae are exceedingly fast growing and richer in oil (oil content in microalgae can exceed 80% by weight of dry biomass) [14] than the best oil crop. Biodiesel production from algae has been reviewed in detail elsewhere [14,15]. The fatty acids composition of some feedstocks used for biodiesel production has been reviewed by certain authors [4,7,16–19]. Comprehensive lists of the composition of various oils and fats have been compiled in this review (Tables 1a–f) to allow for comparison and easy choice of material. A high percentage of mono-unsaturation in fatty acid composition is a requirement for the choice of best oil for biodiesel production [4,20]. Tables 1a–f further reveal the percentage of saturated, monounsaturated, polyunsaturated and free fatty acid of each of the oil respectively. The acid values reported in g kg^{-1} of KOH are twice the free fatty acid values in percentage [21,22].

Various methods have been employed in the production of biodiesel from oils and fats feedstock [6,7,23]. A number of published articles investigated a simulated approach to evaluate some of these methods with a view to proposing cost-effective alternatives [24–26]. However, available simulated reports considered only pure materials as feedstocks. Pure feedstocks may not be realistic on a commercial scale. Preliminary review has shown that the '*one size fit all*' approach proposed by various authors may in fact not be achievable due to problems associated with the downstream processing. The use of a homogeneous catalyst also poses an environmental concern as the disposal of the resulting quantities of glycerol may be challenging [27,28] and not economically viable. Hence, the quest for more innovative and efficient processes is reflected in the number of publications on biodiesel production till date. Some advances in heterogeneous catalysis have also been reported [29,30]. Heterogeneous catalysts from natural resources or biomaterials may be useful alternatives to conventional catalysts in view of the economics of production on commercial scale.

This paper reviews various technologies that have been used for biodiesel production till date with a view to comparing commercial suitability of these methods on the

Table 1a – Edible oils with high mono-unsaturation values.

Fatty acid	Oil types						
	Groundnut oil (*Arachis hypogaea*)[a]	Sesame seed oil (*Sesamum indicum*)[b]	Hazelnut kernel oil (*Corylus avellana*)[b]	Almond kernel oil (*Prunus dulcis*)[b]	Olive kernel oil (*Olea europaea*)[b]	Moringa oil (*Moringa oleifera*)[c]	Canola oil (*Brassica campestris*)[d]
Caprylic 8:0	0.01	–	–	–	–	–	–
Capric 10:0	0.01	–	–	–	–	–	–
Lauric 12:0	0.28	–	–	–	–	–	–
Myristic 14:0	0.12	–	–	–	–	–	–
Palmitic 16:0	8.23	13.10	4.90	6.50	5.00	6.80	4.00
Palmitoleic 16:1	0.11	–	0.20	0.50	0.30	1.00	<1
Stearic 18:0	2.46	3.90	2.60	1.40	1.60	4.60	2.00
Oleic 18:1	58.69	52.80	83.60	70.70	74.70	77.50	62.00
Linoleic 18:2	21.77	30.20	8.50	20.00	17.60	0.30	20.00
Linolenic 18:3	0.34	–	0.20	–	–	–	9.00
Arachidic 20:0	1.83	–	–	–	–	–	–
Eicosenoic 20:1	–	–	–	–	–	–	2.00
Behenic 22:0	3.89	–	–	–	–	5.20	–
Erucic 22:1	–	–	–	–	–	–	<1
Lignoceric 24:0	–	–	–	–	–	0.30	
Saturated	16.82	17.00	7.50	7.90	6.60	16.90	6.00
Monounsaturated	58.79	52.80	83.80	71.20	75.00	78.50	65.00
Polyunsaturated	22.11	30.20	8.70	20.00	17.60	0.30	29.00
Acid values (g kg^{-1} KOH)	5.64	2.40–10.20	4.20	–	0.40–12.28	2.90	0.50

[a] Ref. [193].
[b] Ref. [10].
[c] Ref. [194].
[d] Ref. [195].