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Biodiesel Blending and Price Competitiveness with Diesel on Indian Roads§

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Abstract

Much of the demand for energy has been drawn from coal; yet, India continued to rely on the import of crude oil to meet the growing domestic demand. As a result, to reduce the import dependence, biofuels have been considered as one of the ideal substitutes/additives for fuels. However, the applicability of biofuels over the conventional fuels is yet to be assessed, particularly in the context of Indian roads, in terms of pricing, availability and processing *per se*. This paper has analysed the price competitiveness of biodiesel with diesel using secondary data. Due to different densities of biofuel and diesel, the cost of biodiesel per unit has been expressed as per litre 'diesel equivalent' prices to enable their pricing competitiveness. Accordingly, biodiesel per litre diesel equivalent price (with and without taxes and other charges) for different percentages of blending has been worked out. The cost differential between ex-storage price and retail price of diesel appeared to be influenced by the sales tax and levies (tax components) in the states. A comparative study on the ex-storage price of diesel with the net cost of production of Jatropha-based biodiesel, has revealed it to be uncompetitive and uneconomical to blend with biodiesel in RSMML plant, but competitive in CBDA and Nandan Cleantec plants. However, when the energy content is taken into consideration, blending of biodiesel with High Speed Diesel (HSD) at ex-storage point and retail level does appear to be encouraging and competitive in CBDA plant on Indian roads. Inspite of biodiesel being a cheaper fuel per kilometre, the unavailability of biodiesel feedstock acts as a wet blanket in achieving its competitiveness with diesel.Therefore, adoption of better agronomic practices, suitable pricing policies, awareness generation and promotion of Jatropha crop along with proper follow-up and policies are necessary for successful implementation of the programme.

Key words: Biodiesel, biodiesel blending, heating value, by-products, Jatropha

JEL Classification: Q12, Q16

Introduction

India's energy security is predominantly influenced by fossil fuels, where coal and crude oil account for about two-thirds of India's total energy consumption. Though coal has been self-sufficient, but the country continued to rely on the import of crude oil to meet the growing domestic demand (Agarwal, 2012). In order to supplement production of energy, the National Biofuel Mission (NBM) was set up in the year 2003; with an ambitious aim of meeting 20 per cent (B20) blending mandate by the end of 11th year plan. The mission was formulated on the line of blending diesel with biodiesel primarily to concede the growing demand of diesel with biodiesel. B20 is a blending mixture of diesel and biodiesel in the ratio of 80:20. Similarly, B15 indicates a blending mixture of diesel

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and biodiesel in the ratio of 85:15. Also, B10 constitutes a mixture of 90 per cent diesel and 10 per cent biodiesel, while B5 shows a diesel and biodiesel mixture in the ratio of 95:5. The mandate of NBM is to basically decrease the dependence on crude oil, thereby strengthening the energy security in a practical and environmental friendly manner. However, in order to meet the mandate of NBM, biofuels should be economically competitive with the fossil fuels. Considering the development of biofuels in the country, it is influenced by the economic viability of biofuels which in turn depends upon a number of factors like type of feedstock and its associated impact on natural resources (water, land, etc.) and of national economy, the prevalent prices of competitor (fossil and other) fuels, and the contribution to socio-economic development of a country (Sinkala *et al*., 2013).

Among the many by-products of crude oil for use as transportation fuels, diesel constitutes about 44 per cent of the total consumption of petroleum products in the country, according to a PPAC study. According to the study conducted by Nielsen in 2013, the country's transport sector account for 70 per cent consumption (direct and retail sales) of diesel. Out of which cars/sports utility vehicles/three wheelers account for 27 per cent. Diesel is a mixture of straight run product (150 °C and 350 °C) with varying amount of selected cracked distillates. It is composed of saturated hydrocarbons (primarily paraffins, including iso, and cycloparaffins), and aromatic hydrocarbons (including napthalenes and alkyl benzenes). Biodiesel on the other hand is a methyl or ethyl ester of fatty acids produced from vegetable oils, both edible and non-edible, or animal fat of diesel quality. Unlike traditional fuel, biodiesel on the other hand is produced from the feedstock Jatropha in Indian conditions based on National Policy on Biofuels. Inspite of the availability of other tree borne oilseeds (TBO), Pongamia and Jatropha have been considered to have more benefits of growing commercially at a large scale in Indian conditions owing to their hardy nature and their ability to grow in varied climatic conditions (Dhyani *et al*., 2015). However, biofuels are disrupted by the supply and fluctuations of feedstock prices at the global level; the development of biofuel in South-East Asia still remains at an early stage (Goh and Lee, 2010; Bhullar *et al*., 2011).

The feedstock Jatropha has a long way to go, except in countries like India where it was grown commercially (Timilsina and Shrestha, 2010). A degree of sustainability of biofuel production depends on the amount of land availability (Stoeglehner and Narodoslawsky, 2009). Meanwhile, biodiesel studies in India have been concentrated on their impact, status, market, socio-economic and environmental implications and tradeoffs (Biswas *et al*., 2010; Pere and Lele, 2010; Ravindranath *et al*., 2011; Shinoj *et al*., 2010). However, the applicability of biofuels over the conventional fuels is yet to be assessed, particularly in the context of Indian roads, in terms of pricing, availability and processing *per se*. It is on this light that this paper has analysed the viability and price competitiveness of biodiesel with the traditional fuel diesel in Indian context. Also, the study has concentrated on the use of feedstock obtained from Jatropha.

Data and Methodology

For this study, production cost of biodiesel was taken into account since the feedstock cost has also been calculated along with it. Simple tabulation, averages and percentages have been used for calculating the cost of production of biodiesel. Some limited primary information on the production cost of biodiesel per unit was obtained from the Nandan Cleantec, Hyderabad. But, the inaccessibility and limited information of primary data on cost of production of biofuels from the biofuel processing industry, entails the need to use secondary data. Thus, the secondary data on the costs of biofuels were obtained from the studies of NIAP (National Institute of Agricultural Economics and Policy Research). The data on traditional fuel, high speed diesel (HSD) was obtained from Indian Oil Corporation (IOC), Petroleum Planning and Analysis Cell (PPAC) and other reports. To analyse its price competitiveness, the cost per unit of biodiesel was compared with the ex-storage price of HSD. Again the cost of biodiesel per unit was expressed as per litre 'diesel equivalent' prices. Also, biodiesel per litre 'diesel equivalent' prices (with and without taxes and other charges) for different percentages of blending was worked out. The study has analysed the viability of B20. Also, the viability of 15 per cent (B15), 10 per cent (B10) and 5 per cent (B5) blending mandate has also been analysed.

Table 1. Breakup of total cost of production of biodiesel in India

Inputs	RSMML Plant (2010)* ₹/tonne	CBDA Plant (2010)* ₹/tonne	Nandan Cleantec (2013)** ₹/tonne
Cost of seeds	12000 (76.73)	6500 (68.21)	10000 (68.59)
Transportation and other incidentals	350 (2.24)	650 (6.82)	1000 (6.86)
Cost on chemicals	680 (4.35)	714 (7.49)	1057 (7.25)
Total variable cost, excluding chemicals and seeds	1250 (7.99)	542 (5.69)	708 (5.35)
Total fixed cost, including depreciation	1360 (8.69)	1124 (11.79)	1743 (11.95)
Total cost	15640 (100.00)	9530 (100.00)	14580 (100.00)
Revenue from by-products (₹/kg)	22.32 (35.68)	16.12 (46.19)	20.57 (38.09)
Net cost of production of biodiesel after subtracting revenue of by-products (₹/litre)	40.24 (64.32)	18.78 (53.81)	33.42 (61.89)
Total cost of biodiesel production without revenue from by-products (₹/litre)	**62.56**	**34.90**	**54.00**

Source: *Raju *et al.* (2012); **Personal communication from Nandan Cleantec, Hyderabad.
Notes: Recovery of biodiesel was assumed to be 250 kg/tonne of Jatropha seeds in RSMML Plant in Rajasthan, 273 kg/tonne in CBDA Plant located at Chhattisgarh and 270 kg/ton in Nandan Cleantec Hyderabad.
Figures within the parentheses indicate percentages to ratio.

Production Cost of Biodiesel

Studies by Wisner (2009) and Raju *et al.* (2012) have shown that larger the biodiesel plant, higher the economies of scale, than the smaller biodiesel plant. Chhattisgarh Biodiesel Development Agency (CBDA) and Nandan Cleantec plant were 10-times larger than the Rajasthan State Mines and Minerals Limited (RSMML) plant. As a result, the comparisons of the plants at Rupees per tonne have shown that the cost of production of biodiesel (without revenue from the by-product) for CDBA plant was nearly half of RSMML plant. In case of Nandan Cleantec, it was 64.63 per cent higher than CBDA plant (Table 1). Moreover, for Jatropha-based biodiesel, feedstock played an important role in the estimation of the total cost of production. A study among the three Plants has indicated that cost of feedstock was mainly determined by the total cost of production of biodiesel in India (Table 1). The cost of feedstock has contributed 76.73 per cent of the total cost in RSMML plant and 68.21 per cent in CBDA plant. Again, in Nandan Cleantec, it has accounted for 68.59 per cent of the total cost. Therefore, it can be concluded that the price of feedstock has enormous influence on the total cost of production of biodiesel.

A study on the cost of cultivation across the states of Rajasthan, Chhattisgarh and Uttarakhand has indicated that subsidy on seedlings provided by the Government has resulted in lower price of feedstock (Shinoj *et al.*, 2010). Subsidy eventually acts as a stimulus for reducing the cost of production. Also, scientific agronomic practices and better biotechnological research on the physical traits of Jatropha will help in enhancing the yield and oil content of the crop. Table 1 shows that larger returns are obtained from higher plant size. It is indicated that the co-products — glycerol and oil cake — have made a significant contribution in reducing the cost of production of biodiesel. Thus, the revenue from co-products of RSMML plant has contributed 35.68 per cent, while that of CBDA has accounted for 46.19 per cent of the total cost of biodiesel production. And for Nandan Cleantec, it has accounted for 38.09 per cent of the total cost of biodiesel production.

Taking into consideration the co-products revenue, the net per litre cost of biodiesel production was calculated to be ₹40.24, ₹18.78 and ₹33.42 for RSMML, CDBA and Nandan Cleantec Plants, respectively. Thus, the total cost of production has accounted for ₹62.56/litre, ₹34.90/litre and ₹54/litre for the same plant. Since, the revenue obtained from the co-products has offset the cost of production of biodiesel, the net cost of biodiesel production was reduced to half in CBDA plant, nearly two-third in RSMML plant and less than two-third in Nandan Cleantec biodiesel plant.

Production Cost of High Speed Diesel

In this section, the price build-up of high speed diesel from ex-storage point price to retail selling price/ retail piece (RSP/RP) has been calculated and is given in Table 2. The ex-storage point price is the basic price paid to refineries by dealers, excluding the excise duties and VAT; which is uniform in all refineries throughout the country. The RP is the final price that is made available to the consumers. It includes the ex-storage price, freight charges, surcharges and levies, cess, dealers' commission, etc. Thus, variation exists between the RP and ex-storage point price of HSD and their month-wise variations from 2010 to 2014 have been depicted in Figure 1.

The RSP/RP of HSD was calculated to be ₹ 35.87/ litre, ₹ 50.24/litre and ₹ 54.12/litre in 2010, 2013 and 2014, respectively, as given in Table 2. Also, the price build-up calculated by Petroleum and Planning Analysis Cell (PPAC) for 2010, 2013 and 2014 was ₹ 38.10/litre, ₹ 48.63/litre and ₹ 55.49/litre, respectively. Therefore, the calculated price build-ups of diesel were comparable with the estimates of PPAC study. Further, the ex-storage price contributed a large share accounting for 75.39 per cent, 73.63 per cent and 78.91 per cent of retail price of HSD in the same period. Since the ex-storage point selling price was uniform throughout the country, the variation in RSP was attributed to distances of Retail Price Outlet (RPO) from refineries, rate of sales taxes and other recoverable or recoverable local levies (Bhandyopadhyay, 2009). Among these attributes, the sales tax and levies (tax components) occupy a major stake thereby, greatly influencing the variations in retail prices of diesel in the states. Table 2 has shown that tax components contributed to 21.84 per cent of the total retail selling price in 2010. Likewise, it has contributed to 18.39 per cent and 18.32 per cent of the retail price in 2013 and 2014, respectively. However, the shares for other attributes in the total RP of diesel were barely one per cent, except for dealer commission.

Based on the recommendations of the Kirit Parikh Committee, the Government of India has made the price of petrol market-determined, both at the refinery gate and the retail level, with effect from 26 June 2010.

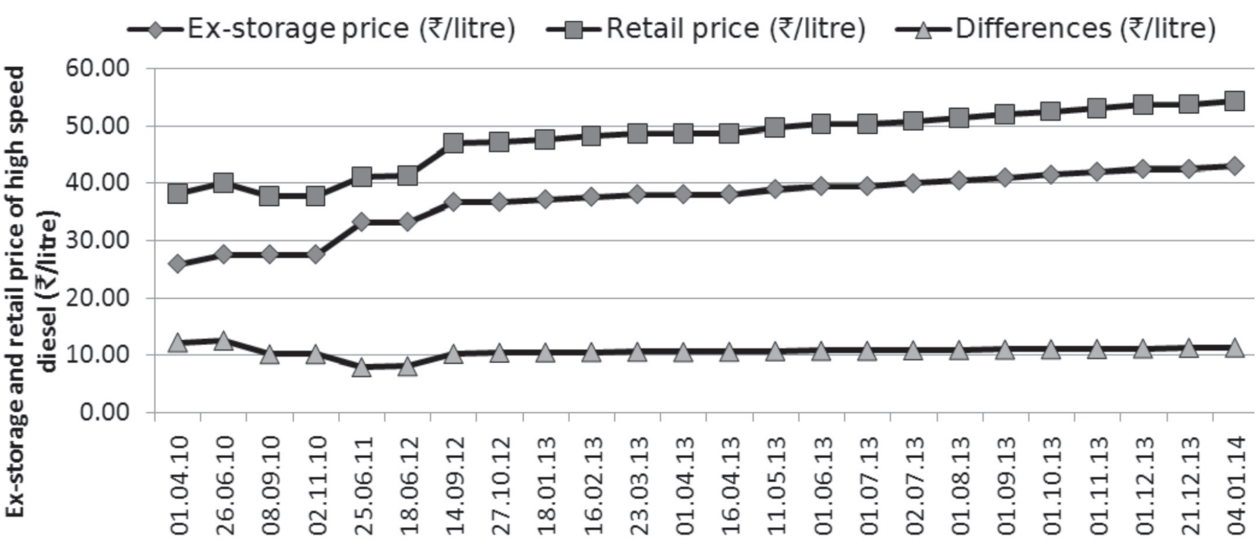

Figure 1. Variation of ex-storage price with the retail price of high speed diesel

Table 2. Price build-up of high speed diesel from ex-storage price in Delhi

(₹/kilolitre)

Particulars	2010	% to RSP	2013	% to RSP	2014	% to RSP
Ex-storage point price	27042.25	75.39	39505.79	73.63	42704.04	78.91
State specific cost	0.00	-	0.00	-	0.00	-
Siding charge	71.53	0.20	47.10	0.09	47.10	0.087
Rly/road/ocean freight	102.68	0.29	102.68	0.20	102.68	0.19
Retail Price at Outlet (RPO) factor#	21.27	0.06	21.27	0.04	21.27	0.0393
Transaction value	27237.73	-	39676.84	-	42875.09	-
Basic excise duty	1600.00	4.46	1460.00	2.91	1460.00	2.70
Additional excise duty	2000.00	5.58	2000.00	3.98	2000.00	3.70
Education cess @ 3%*	108.00	0.30	103.80	0.21	103.80	0.19
Price inclusive duty & education cess	30945.73	-	43240.64	-	46438.89	-
Local transportation	44.00[1]	0.12	145.00[2]	0.29	145.00[2]	0.27
Delivered price within FDZ	30989.73	-	43385.64	-	46583.89	-
BFDZ delivery charges	0.00	-	0.00	-		-
RPO price	30989.73	-	43385.64	-	46583.89	-
State sales tax rate	12.5 %	-	12.5%	-	13.09 %	-
Sales tax amount	3873.72	10.80	5423.21	10.79	6097.831	11.27
Billable price	34863.45	-	48808.85	-	52681.72	-
Pollution cess w.e.f. 08.02.2008	250.00	0.70	250.00	0.50	250.00	0.46
Dealer commission	757.00[a]	2.11	1186.00[b]	2.36	1186.00[b]	2.19
Retail selling price (RSP) ₹/kilolitre	**35870.45**	100.00	**50244.85**	100.00	**54117.72**	100.00
RSP (₹/litre)	**35.87**	-	**50.24**	-	**54.12**	-
Under recoveries (₹/litre)	**4.00**[x]	-	**13.64**[y]	-	**4.41**[z]	-

Source: Calculated from Petroleum Planning and Analysis Cell (PPAC) and Indian Oil Corporation (IOC).

Notes: #Retail Price at Outlet (RPO) factor = RPO Surcharge + RPO Charge.

*Education Cess @ 3% = (Basic Excise duty + Additional Excise duty) * 3 %.

[1]Local transportation charges of High Speed Diesel w.e.f. 01.12.2001.

[2]Local transportation charges of High Speed Diesel w.e.f. 01.07.2013.

FDZ = Free Delivery Zone; BFDZ = Beyond Free Delivery Zone.

[a]Dealer Commission w.e.f. 07.09.2010.

[b]Dealer Commission w.e.f. 21.12.2013.

[x]Under-recovery (Financial Express 04.02.2010)

[y]Under-recovery w.e.f. 16.05.2013.

[z]Under-recovery w.e.f. 16.05.2014.

However, high speed diesel (HSD) continues with Trade Parity Pricing (TPP), where the government takes an in-principle decision to move to market-determined pricing at both refinery gate and retail level for HSD at an appropriate time (GoI, 2010). The diesel constitutes the major proportion of under recoveries, particularly from 2010 onwards and by 2012; it made up to 60 per cent of the fuel subsidy bill. The under-recoveries refer to the difference between Refinery Transfer Price (RTP) and the depot price. The former is the shadow price faced by the refineries, while the latter is the price charged by them (Anand, 2012).

As a result, the retail price of diesel was increased by roughly 20 per cent from June 2010 to January 2013. Therefore, in September 2012, the Government of India announced 14 per cent increase in the retail price of diesel. Again, from January 2013, the partial deregulation of the retail price of diesel follows, whereby, the Oil and Marketing Companies (OMCs)

Table 3. Comparison of Jatropha based biodiesel, ex-storage price of diesel in India

(₹/litre)

Particulars	RSMML plant (₹/litre) (2010)	CBDA plant (₹/litre) (2010)	Nandan Cleantec plant (₹/litre) 2013
Net cost of production of Jatropha based biodiesel (B)	40.24	18.78	33.42
Glycerol	5.52	3.76	-
Oil cake	16.80	12.36	-
Cost of co-products	22.32	16.12	20.57
Net B-100 breakeven price	62.56	34.90	54.00
Ex-storage price of branded grades of diesel in 2010			
a) HSD – BSIII	a) 26.85		a) 39.49
b) HSD BS – IV	b) 27.24		b) 39.53
c) Total average (A)	27.04		39.51
Difference (A-B)	-13.2	8.26	6.09

Note: Net breakeven price = Total fixed cost/volume of production + variable cost per unit.

would gradually raise the price every month to a maximum permissible limit of ₹ 0.50/litre until it counterbalances the subsidy of diesel in India (Fattouh *et al.,* 2013). Hence, from Table 2, the under recoveries/ subsidies ranges from ₹ 13.64/litre to ₹ 4.41/litre in May 2013 to May 2014, respectively.

Price Competitiveness of Biodiesel with Diesel

Biodiesel has gained interest as a substitute/ alternative to fuel on account of environmental, social and economic advantages offered by it. Therefore, the government has introduced several programmes and policies to spur the production and demand for biodiesel. But, the production of biodiesel has not been very encouraging. Also, biodiesel cannot compete with the petroleum based diesel on fuel price alone. Table 3 shows that the net cost of biodiesel in RSMML, CBDA and Nandan Cleantec was ₹ 40.24/litre, ₹ 18.78/litre and ₹ 54.00/litre, respectively.

The ex-storage price of HSD–BSIII, HSD BS–IV and its total average of diesel in the year 2010 in Delhi was ₹ 26.85/litre, ₹ 27.24/litre and ₹ 27.04/litre, respectively. Likewise, the ex-storage price and its average in Delhi in the year 2013 was ₹ 39.49/litre, ₹ 39.53/litre and ₹ 39.51/litre, respectively. Also, their net breakeven price was calculated to be ₹ 62.56/litre for RSSML, ₹ 54.00/litre for Nandan Cleantec and ₹ 34.90/litre for CBDA plant. Moreover, the traditional fuel cost in case of diesel was lower than the net cost of Jatropha-based biodiesel production in RSMML plant, while it was competitive in CBDA plant and Nandan Cleantec plant.

Energy Content of Biodiesel and its Price Competitiveness with Diesel

There are two values of specific heat of energy for the same batch of fuel. One is Higher (or gross) Heating Value (HHV) and the other is Lower (or net) Heating Value (LHV). The HHV of a fuel is the amount of heat released by a specified quantity (initially at 25 °C) once it is combusted and the products have returned to a temperature of 25° C, which takes into account the latent heat of vaporization of water in the combustion products. The LHV of a fuel is the amount of heat released by combusting a specified quantity (initially at 25 °C) and returning the temperature of the combustion products to 150 °C, which assumes the latent heat of vaporization of water in the reaction, and products are not recovered (Boundy *et al.*, 2011).

Though biodiesel could be used as additive/ substitute for diesel, it has different densities and energy values as compared to diesel. Thus, to work out the price competitiveness of biodiesel with diesel, the energy content of diesel should be similar with diesel fuel. As a result, biodiesel was expressed as biodiesel per litre ‘diesel equivalent’ prices. Table 4 shows the

Table 4. Energy value and density of traditional fuel and biofuel

Particulars	Diesel	Biodiesel
Energy value		
Lower heating value (KJ/kg)	38462.43	35797.46
Energy value		
Higher heating value (KJ/kg)	41136.38	38315.71
Density (kg/litre)	0.836	0.887

Source: www.afdc.energy.gov, Accessed on 08.06.2014.

LHV and HHV for diesel to be 38462.43 KJ/kg and 41136.38 KJ/kg, while for biodiesel these values were 35797.46 KJ/kg and 38315.71 KJ/kg, respectively. Also, the densities for diesel and biodiesel were 0.836 kg/litre and 0.887 kg/litre, respectively.

Using the energy value and densities given in Table 4, the energy supplied by diesel per litre was worked out as 32154.59 kilojoules and 34390.02 kilojoules for LHV and HHV of a fuel respectively (Table 5). Also, it was estimated that energy required at LHV to produce 1 litre of diesel was equivalent to 0.797 litres of biodiesel. Similarly, for HHV, the biodiesel in per litre 'diesel equivalent' accounts for 0.796 litres. Thus, biodiesel has 25.51 per cent higher energy content as compared to diesel at LHV. Therefore, the biodiesel prices were multiplied by 1.255 or divided by 0.797 to calculate 'diesel equivalent' prices. Likewise, the biodiesel prices at HHV were multiplied by 1.256 or divided by 0.796, since biodiesel has 25.61 per cent higher energy content as compared to diesel at HHV.

The blending of biodiesel with diesel was assumed to be carried out at the ex-storage point. In Table 6, the net cost of Jatropha based biodiesel production has been expressed as biodiesel per litre 'diesel equivalent' (BDE) prices at their LHV and HHV. The BDE prices in 2010 at LHV were ₹ 50.50/litre for RSSML, ₹ 23.57/litre in CBDA and ₹ 41.94/litre for Nandan Cleantec plant. Likewise, the BDE prices were valued as ₹ 50.54/litre, ₹ 23.59/litre and ₹ 41.98/litre at HHV for the same plants, respectively. Also, the ex-storage price of diesel was estimated to be ₹ 27.04/litre and ₹ 39.51/litre in 2010 and 2013, respectively. Even though, biodiesel has higher energy content than diesel, but their net cost of production was higher than the ex-storage price of diesel, except in CBDA plant.

Table 6 also shows that BDE prices at LHV and HHV were higher than the ex-storage prices of diesel, except in CBDA plant. Further, 5 per cent blending and the subsequent increase in blending mandate from 10 to 20 per cent follow a similar approach. However, CBDA appears to be competitive at all blending rates. It was interesting to note that blending at higher rates with diesel has resulted in an increase of BDE price, but lower than unblended/BDE (B100) price as biodiesel appears to be cheaper per kilometre than diesel. Even though BDE price increases with increase in blending mandate, it appears to be nearly competitive for Nandan Cleantec, where the blending from 5 to 10 per cent ranges between ₹ 0.12/litre and ₹ 0.49/litre, respectively. Therefore, Nandan Cleantec could be made competitive by reducing the cost of feedstock.

At 5 per cent blending mandate, the RSMML plant with a cost differential of ₹ 1.17/litre was nearly competitive. Though, B5 has the highest spike, the higher mandate showed a decline in BDE price at LHV and HHV in CBDA plant. Thus, biodiesel plant with higher economies of scale is preferable to make biodiesel competitive with diesel. Since feedstock has contributed a major share in the cost of biodiesel production, greater production and continuous availability of the Jatropha feedstock is necessary. In accordance with the National Biofuel Mission, Jatropha was considered as the most suitable feed stock for biodiesel production in India. The crop has been

Table 5. Biodiesel in per litre diesel equivalent

Particulars	LHV	HHV
Energy supplied by diesel per litre (KJ)	32154.59	34390.02
Mass of biodiesel in per litre 'diesel equivalent' (kg)	0.8982	0.8975
Amount of litre of biodiesel in per litre 'diesel equivalent' (litre)	0.797	0.796
Litre of diesel per litre of biodiesel (litre)	1.255	1.256

LHV= Lower heating value, HHV = Higher heating value

Table 6. A comparison of diesel prices with biodiesel per litre diesel equivalent prices

(₹/litre)

Particulars	RSMML plant (2010)	CBDA plant (2010)	Nandan Cleantec plant (2013)
Net cost of production of Jatropha-based biodiesel	40.24	18.78	33.42
Ex-storage price of diesel in 2010	27.04	27.04	39.51
Biodiesel per litre diesel equivalent price (B100)			
Lower heating value (LHV)	50.50	23.57	41.94
Higher heating value (HHV)	50.54	23.59	41.98
B5 (without taxes and other charges)			
Lower heating value (LHV)	28.21	26.87	39.63
Higher heating value (HHV)	28.22	26.88	39.63
B10 (without taxes and other charges)			
Lower heating value (LHV)	29.39	26.69	39.75
Higher heating value (HHV)	29.39	26.70	39.76
B15 (without taxes and other charges)			
Lower heating value (LHV)	30.55	26.52	39.87
Higher heating value (HHV)	30.57	26.52	39.88
B20 (without taxes and other charges)			
Lower heating value (LHV)	31.73	26.34	40.00
Higher heating value (HHV)	31.74	26.35	40.00

Note: B100 = unblended biodiesel price; B5 Price = 95 % Diesel price + 5 % Biodiesel Price; B10 Price = 90 % Diesel price + 10 % Biodiesel Price; B15 Price = 85 % Diesel + 15 % Biodiesel Price; B20 Price = 80 % Diesel price + 20 % Biodiesel Price.

considered as the rational choice for non-food feedstock because of its ability to grow in diverse agro-climatic conditions, withstand droughts and pests attacks. Since India has a large wasteland area suitable for Jatropha cultivation, it is believed that a large volume of biodiesel could be supplied. In addition, it would generate environment and employment opportunities to ensure socio-economic development of the rural poor.

It is also believed that biofuels would help in mitigating climate change and reducing Green House Gas (GHG) emissions. However, biofuels could not be considered as a complete solution against conventional fuels. For achieving that outcome, biofuels need to undergo several transformations and developments for many decades in the long-run. Also, without proper irrigation and agronomic practices, there is bound to be accompanying variation in important parameters like seed yield, oil content, and nutrient requirements, etc. that would be critical to economic viability of biodiesel plant. Again, areas regarded as marginal and degraded wastelands may not be available for growing Jatropha as the land might be occupied in some way or the other way by the villagers (TERI, 2005). Uncertainty exists in the potential to meet the required availability of Jatropha feedstock. Thus, even a decade after its implementation, the biodiesel industry has been insipid and struggling to make a niche of its own. As a result, the present yield of biodiesel is insignificant and even the use of multiple feedstock along with Jatropha could meet only 0.1 per cent of the total blend rate (USDA, 2013). Hence, even the 5 per cent blending target has become a distant reality.

Table 7 shows a comparison of the retail price of diesel per litre and the subsequent blending of biodiesel at BDE prices with taxes and other charges. Though, the blending of biodiesel was assumed to be executed at the ex-storage point, several taxes and transportation charges need to be implemented, in order to make the blended fuel accessible at the retail level. As a result, the blended biodiesel at BDE prices have employed the taxes and charges akin to diesel owing to larger

Table 7. A comparison of diesel prices with biodiesel per litre diesel equivalent prices

(₹/litre)

Particulars	RSMML plant (2010)	CBDA plant (2010)	Nandan Cleantec plant (2013)
Retail price of biodiesel at Delhi in 2010 (RP)	35.87	35.87	50.24
Ex-storage price of diesel in 2010 (EP)	27.04	27.04	39.51
Difference (RP-EP)	8.83	8.83	10.73
B5 (with taxes and other charges)			
Lower Heating Value (LHV)	37.04	35.70	50.36
Higher Heating Value (HHV)	37.05	35.71	50.36
B10 (with taxes and other charges)			
Lower Heating Value (LHV)	38.22	35.52	50.48
Higher Heating Value (HHV)	38.22	35.53	50.49
B15 (with taxes and other charges)			
Lower Heating Value (LHV)	39.38	35.35	50.60
Higher Heating Value (HHV)	39.40	35.35	50.61
B20 (without taxes and other charges)			
Lower Heating Value (LHV)	40.56	35.17	50.73
Higher Heating Value (HHV)	40.57	35.18	50.73

percentage of diesel content in the blended biodiesel. However, with the implementation of taxes and other charges, the successive blending of biodiesel from 5 to 20 per cent at BDE prices becomes dearer as compared to retail price of HSD, except in CBDA plant. Therefore, blending of biodiesel with HSD at ex-storage point and retail level does not appears to be encouraging and competitive when the energy content is taken into consideration.

Conclusions and Policy Implications

Biodiesel is considered as an ideal additive / substitute for traditional fuels. But, the degree of success in its use depends on many factors, such as price competitiveness and its associated impact such as land, water and other resources. Since India has favourable conditions for growing Jatropha as a feedstock for biodiesel, the feedstock and price competitiveness of Jatropha biodiesel with diesel has been studied. The study has indicated that feedstock occupies a major share in the cost of biodiesel production, but the by-products make a significant contribution to reducing the cost of biodiesel production. The RSP/RP of high speed diesel (HSD) has been found to be ₹ 35.87/litre, ₹ 50.24/litre and ₹ 54.12/litre in 2010, 2013 and 2014, respectively. The ex-storage price has contributed a large share of 75.39 per cent, 78.63 per cent and 78.91 per cent in the retail price of HSD during these years. Though the ex-storage point price occupies a large share, the sales tax and levies (tax components) occupy a major stake and largely influence the variations in retail prices in the states. When the ex-storage price of diesel was compared with the net cost of production of Jatropha-based biodiesel, it was not found competitive and economical to blend with biodiesel in RSMML plant. However, it appears to be competitive in CBDA and Nandan Cleantec plants.

At lower heating value (LHV), biodiesel has 25.51 per cent higher energy content as compared to diesel. Also, it has 25.61 per cent higher energy content as compared to diesel at higher heating value (HHV). Thus, biodiesel appears to be a cheaper fuel per kilometre than diesel. However, blending of biodiesel with HSD at ex-storage point and retail level does not appear to be encouraging and competitive even when the energy content was taken into consideration, except in the CBDA plant. Since, feedstock has contributed a major share to the cost of biodiesel production, greater production and continuous availability of the Jatropha feedstock is necessary. Also, biodiesel plant with higher economies of scale has been found to be more successful in making biodiesel competitive with diesel. However, the present yield of biodiesel is insignificant and even the use of multiple feedstocks along with Jatropha could meet only 0.1 per cent of the total blend rate. Therefore, adoption of better agronomic practices, suitable pricing policies, awareness generation and promotion of Jatropha crop along with proper follow-up and policies are necessary for successful implementation of the programme.

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