JLSB
Journal of Life Science and Biomedicine

J. Life Sci. Biomed. 6(3): 71-75, May 30, 2016

ISSN 2251-9939

Evaluation Energy Efficiency in Biodiesel Production from Canola; A Case Study

Reza Abshar[1] and Móslem Sami[2]

[1]*Independent researcher, Gotvand, Khuzestan, Iran.*
[2]*Department of Biosystem Engineering, Faculty of Agricultural Engineering and Technology, University of Tehran, P.O. Box 4111, Karaj*
Corresponding author's email: m.sami@ut.ac.ir; sami.moslem@gmail.com

ORIGINAL ARTICLE
PII: S225199391600012-6
Received 10 Apr. 2016
Accepted 15 Mar. 2016

ABSTRACT: Today fossil fuels are the main source of energy; however, it is becoming increasingly unlikely that fossil fuel supply will be able to meet growth in demand of energy in nearly future. The production of biofuel from farms products has been promoted as a replacement for fossil fuels. Nevertheless the debate over the energy balance of biodiesel is ongoing. In this paper, we focus on analyses of energy efficiency of rapeseed biofuel production in a case study in Khuzestan province of Iran. Our results showed that, in term of energy, canola is a reliable source of energy as biodiesel. The energy ratio in this process was rather higher than one (1.08) and net energy was obtained as 2582.37 Mj per hectare of canola farming. However this value in not high, by considering byproducts of canola farming it can be suggested as a sources of future energy.

Key words: Biodiesel, Canola, Energy analysis

INTRODUCTION

Fossil fuels are the main energy source that drives the world economy. However, for a number of reasons it is becoming increasingly unlikely that fossil fuel supply will be able to meet this growth in demand. Bioenergy is an important alternative source of energy. Energy is derived from plants and biomass can be converted into liquid fuel [1] and directly used in the existing transportation infrastructure, which is almost entirely run on fossil fuels (cars, buses, airplanes).

It is claimed that Bioenergy produced from cultivation of plants could potentially provide a sustainable alternative to fossil fuels for transport. Recent policy-driven interests in renewable energy and carbon mitigation have contributed new resources and enthusiasm for production of bioenergy, in particular the strategy of regionally produced biofuels that can help meet a low carbon fuel standard.

However, recent studies suggest that some combinations of cultivation processes and conversion technologies for bio- energy consume more energy than is produced. The production of bioenergy will have environmental impacts, including those associated with cultivation and the technologies used to process the crops into biofuel. The net benefits of biofuel production from energy, environmental, GHG, and economic perspectives is still debated. Some analyses report a negative energy balance in bioenergy production [e.g., 2]; others have reported net positive energy balances [3, 4, 5]. Most studies acknowledged that biodiesel energy balance for first-time vegetable oils depends mainly on the crop production system [6, 7].

This study evaluated energy balance of bio-fuel production to estimate the sustainability of a number of combinations of production methods and conversion technologies for producing transport energy from canola. Energy efficiency is one of the most important elements of sustainability analysis [7]. Canola refers to a cultivar of either Rapeseed *(Brassica napus* L.) or Field Mustard (*Brassica campestris* L. or *Brassica Rapa var.*). Its seeds are used to produce edible oil suitable for consumption by humans and livestock. The oil is also suitable for use as biodiesel. Canola production in Iran is 164000 tons in 2009 that 64.90% of irrigated farming and 35.10% of dry farming have been obtained.Also in this year, canola cultivation was about 86000 ha that 59.56% is irrigated farming and the rest of that was dry farming [8].

MATERIALS AND METHODS

Data used in this study were obtained from 10 large mechanized canola farms by using a face to- face questionnaire method in Gotvand County during production period of 2015-2016. The farms produce approximately more than 50 percent of canola produced in the county. Gotvand county is located in the Khuzestan province of Iran with an area 282 Km^2 within 43 º34́ and 49 º21́ North latitude and 32º04́ and 32º27 East longitude). The study region represents semiarid and subtropical climatic conditions with very hot summers and fairly cool winters. The energetic efficiency of the agricultural system was evaluated by the energy ratio between output and input.

By carefully evaluating the ratios, it is possible to determine trends in the energy efficiency of agricultural production, and to explain these trends by attributing each change to various occurrences within the industry [9]. Chemical fertilizers (nitrogen, phosphate, potassium and sulphur), biocides (herbicides, fungicides and insecticides), diesel fuel, electricity, farmyard manure, irrigation water, human labor and machine power were the energy inputs while the outputs were the canola oilseed. For calculating the energy equivalents of inputs and output the energy conversion factors shown in Table 1 were used. The energy cost of inputs and practices were adapted from different sources of estimations that best fit Iran conditions. Based on the energy equivalents of the inputs and outputs, output-input energy ratio, energy productivity, specific energy and net energy gain were calculated.

Table 1. Energy coefficients of inputs

Input/output	Unit	Energy equivalents (Mj/unit)	References
Canola Seed	kg	25	11
N fertilizes	kg	78.1	10
P fertiliser	kg	17.4	10
K fertiliser	kg	13.7	10
Sulfur	kg	8.8	10
Micro fertilisers	Kg or lit	8.8	10
Diesel fuel	lit	46.3	10
Insecticides	Kg or lit	229	12
Herbicides	Kg or lit	430	12
Machinery	Kg h	142.7	13
Human labor	h	2.2	10
Water (transmission)	m^3	0.63	14
Canola oil Seed	lit	27.87	15
Electricity	Kw h	12	16
Natural Gas	m^3	4.20	10
Methanol	lit	30.1	17
Biodiesel (energy content)	lit	34.5	5

RESULTS AND DISCUSSION

Inputs, used in the canola production in the farms and their energy equivalents, together with the energy equivalent of the yield were illustrated in Table 2. The results revealed that, total energy consumption during the production period of canola was 21062.27 MJ/ ha, from which fertilisers had the most share with 15.75%. The second highest energy consumer in canola farming was diesel fuel that consumed 8.43 % of total input energy followed by water energy, which consumes 7.30 % of total input energy. Other inputs have a relatively small share of input energy.

Calculated energy indexes for canola farming are presented in Table 3. The average canola yield obtained was found to be 2418.84 kg/ ha. Accordingly, the total energy output from canola farming was calculated as 60471.02 MJ /ha, in the enterprises that were analyzed. The total average energy requirement for producing of this yield was 21062.27 MJ/ha, which was smaller than the total output energy (60471.02 MJ/ha). Therefore energy ratio for canola farming (2.87) was higher than one and energy balance (39408.75MJ/ha) was positive, indicating that canola production in surveyed region was efficient in terms of energy. The average energy intensity of the studied farms was 8.71 Mj/ kg. This index shows that 8.71 Mj energy was used for production of one kilogram of canola seed. Energy productivity of farms was obtained as 0.15 kg/MJ. This means that 0.15 kg of canola seed was obtained per unit of input energy.

Table 2. Input and outputs of farms and their related indexes in terms of energy

Parameter	Unit	Quantity (Unit/ ha)	Total energy equivalent (MJ /ha)	Percentage from total input
Seed	kg	9.73	243.22	0.40
Fertilisers	--	--	9527.14	15.75
N fertilizes	kg	100.04	7813.13	12.92
P fertiliser	kg	61.97	1078.30	1.78
K fertiliser	kg	35.33	483.96	0.80
Sulfur	kg	15.14	133.23	0.22
micro fertilisers	Kg or lit	2.11	18.53	0.03
Diesel fuel	lit	110.11	5098.03	8.43
Pesticides	--	--	258.69	0.43
Insecticides	Kg or lit	0.22	49.24	0.08
Herbicides	Kg or lit	0.49	209.45	0.35
Machinery	Kg h	10.40	1484.58	2.46
Human labor	h	18.46	40.61	0.07
Water (transmission)	m3	7000.00	4410.00	7.29
Total in farm energy	--	--	21062.27	100.00
Canola yield	--	2418.84	60471.02	--

Table 3. In farm energy indexes

Indexes	Unit	Quantity
Energy ratio		2.87
Net energy	Mj/ha	39408.75
Energy productivity	Kg/Mj	0.11
energy intensity	Mj/kg	8.71

Table 4 shows the total inputs and their energy equivalents in industrial process of biodiesel production (conversion of canola to biodiesel). Biodiesel is produced from oil. The energy for extraction, refining and Rapeseed Methyl Ester (biodiesel) production is dependent on the many factors. Canola seed is traditionally crushed and solvent extracted in order to separate the oil from the meal. The process usually includes seed cleaning, seed pre-conditioning and flaking, seed cooking, pressing the flake to mechanically remove a portion of the oil, solvent extraction of the press-cake to remove the remainder of the oil, and desolventizing and toasting of the meal. Molecule of oils is reduced by trans esterification, resulting in a liquid fuel similar to petroleum diesel, but with some differences. Oil is reacted with methanol in the presence of a catalyst to produce esters or biodiesel. The methanol is charged in excess to assist in quick conversion and recovered for reuse. The catalyst is usually sodium or potassium hydroxide, which has already been mixed with the methanol. Energy ratio for biodiesel production (1.08) was higher than one and energy balance (2582.37 MJ/ha) was positive, indicating that biodiesel production from canola oil in surveyed region was efficient in terms of energy. Energy productivity index showed that 0.05 liter of biodiesel was obtained per unit of input energy. The positive efficiency of biodiesel production from canola was also reported in many past studies. Firrisa et al. [19] evaluated energy efficiency in different farming systems in European an resulted that production of energy from biodiesel is beneficial. Baquero et al. [20] and Smith et al. [21] also reported that biodiesel is a reliable energy sources in term of energy.

According to Table 5, 1130.55 liter of canola oil seed is obtained per hectare that present an energy of 39003.81 Mj/ha. In the process of oil extraction 1422.28 Mjand 2418.84Mj energy for electricity and heating per hectare of canola farms were consumed respectively. This means that 3.40 Mj energy consumed for production of one liter of oil seed in the extraction process. Typically, 100 kg of oil is reacted with 10 kg of methanol plus the catalyst to produce 100 kg of biodiesel and 10 kg of glycerine. In other world 100 liter of canola oil produces 104.54 liter of methyl ester [12]. In the process of transesterification 11.61 Mj per liter of output biodiesel was consumed. According to our results in the studied area 1032.96 liter (988.10 kg) biodiesel per hectare was obtained. Energy intensity index in biodiesel production shows that 32.00 Mj energy was used for production of one liter of biodiesel. Therefore according to this study, energy coefficient of biodiesel is estimated as 66.5 Mj/lit (32.0+34.5).

Table 4. Input and outputs of industrial process of biodiesel

Parameters	Quantity (Unit/ha)	Total energy equivalent (MJ/ha)	Total energy equivalent (MJ/lite oil seed output)	Total energy equivalent (MJ/lite output biodiesel)
Oil extraction				
Electricity	--	1422.28	1.26	1.38
Natural gas	--	2418.84	2.14	2.34
Oil extraction energy	--	3841.12	3.69	3.72
Output oil seed	1130.55	31508.29	--	--
Biodiesel production				
Methanol	--	3402.94	--	3.29
Natural gas	--	4748.29	--	4.60
Biodiesel production energy	--	8151.23	--	7.89
Total industrial energy	--	11992.35	--	11.61
Total energy	--	33054.62	--	32.00
Total output biodiesel	1032.96	35636.98	--	--

Table 5. Industrial energy indexes

Indexes	Unit	Quantity
Energy ratio		1.08
Net energy	Mj/ha	2582.37
Energy productivity	Kg/Mj	0.03
Energy intensity	Mj/kg	32.00

CONCLUSION

This study analyzed the energy balances in the biodiesel production from canola. Our results showed that Canola biodiesel produces 1.08 unit of energy per unit of energy spent during processing for biodiesel production. Net energy per unit of hectare canola farms was obtained as 2582.37 Mj. By increasing the energy productivity in many processes of biodiesel production spatially farming practices and also by increasing the output farm yields, this energy balances can largely increase in benefit of output energies. Therefore this study suggests the canola as a source of biodiesel from energy aspect. However more studies need to perform on the other environmental impacts of biodiesel production especially in farm effects.

Competing interests

The authors they have no competing interests.

REFERENCES

1. Davis SC, Anderson-Teixeira K J and DeLucia H E. 2009. Life-cycle analysis and the ecology of biofuels. Trends in Plant Science, 14(3): 140–146.
2. Patzek TW. 2004. Thermodynamics of the corn-ethanol biofuel cycle. Crit. Rev. Plant Sci. 23: 519-567.
3. Shapouri H, Duffield JA and Wang M. 2003. The energy balance of corn ethanol revisited. Trans. Am. Soc. Agric. Eng. 46: 959-968.
4. Hill J, Nelson E, Tilman D, Polasky S and Tiffany D. 2006. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. Proc. Natl. Acad. Sci. 103: 11206-11210.
5. Frondel M and J Peters. 2007. Biodiesel: A new Oildorado? Energy Policy 35: 1675–1684.
6. Hanegraaf MC, Biewinga E E and Van Der Bijl G. 1998. Assessing the ecological and economic sustainability of energy crops. Biomass Bioenergy. 15: 345-355.
7. Börjesson P. 2009. Good or bad bioethanol from a greenhouse gas perspective—what determines this? Applied Energy, 86 (5): 589–594. doi:10.1016/j.apenergy.2008.11.025.
8. Anonymous. 2010. Annual Agricultural Statistics. Ministry of Jihad-e-Agriculture of Iran. Retrieved from: http://www.maj.ir.
9. Unakitan G, Hurma H, and Yilma F. 2010. An analysis of energy use efficiency of canola production in Turkey. Energ. 35: 3623-3627.

10. Beheshti Tabar I, Keyhani A and Rafiee S. 2010. Energy balance in Iran's agronomy (1990-2006), Renewable and Sustainable Energy Reviews. 14: 849-855.
11. Kitani O. 1998. Energy and environment in agricultural engineering research. International Engineering Conference Bangkok. Bangkok: Thai Society of Agricultural Engineering.
12. Barber A. 2004. Seven Case Study Farms: Total Energy & Carbon Indicators for New Zealand Arable & Outdoor Vegetable Production. AgriLINK New Zealand Ltd.
13. Kaltsas AM, Mamolos AP, Tsatsarelis CA, Nanos GD and KL Kalburtji. 2007. Energy budget in organic and conventional olive groves, Agri. Ecosyst Environ. 122: 243-251.
14. Yaldiz O, Ozturk HH, Zeren Y and A Bascetincelik. 1993. Energy usage in production of field crops in Turkey. In: Vth international congress on mechanization and energy in agriculture. Izmir-Turkey: pp. 527–36.
15. Capareda S. 2013. Introduction to Biomass Energy Conversions. CRC Pres.
16. Sami M, Shiekhdavoodi MJ, Pazhohanniya M and F Pazhohanniya. 2014. Environmental comprehensive assessment of agricultural systems at the farm level using fuzzy logic: A case study in cane farms in Iran. Environmental Modelling and Software. 58: 95–108.
17. Worrell E, Phylipsen D, Einstein D and Ma N. 2010. Energy Use and Energy Intensity of the U.S. Chemical Industry. University of California.
18. Kleber M. 2003. The Lurgi biodiesel technology. Presentation at the Mississippi Renewable Energy Conference, 2003 Mar. 25-26. Available: http://ms-biomass.org/conference/2003/ lurgi%20psi.ppt.
19. Firrisa MT.vDIris and Alexey V. 2014. Energy efficiency for rapeseed biodiesel production in different farming systems. Energy Efficiency. 7(1): 79-95.
20. GrauB, BernatE, Rita P, Jordi-Roger R and Antoni R. 2013. Environmental life cycle assessment of rapeseed straight vegetable oil as self supply agricultural biofuel. Renewable Energy. 50: 142-149.
21. Elwin G. Smith, H. Janzen H. and Nathaniel K N.. 2007. Energy balances of biodiesel production from soybean and canola in Canada. Canadian Journal of Plant Science, 87(4): 793-801