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An approach to the economics of two vegetable oil-based biofuels in Spain

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Abstract

Biodiesel is a form of renewable energy that provides a less polluting fuel for diesel engines with minimal reduced engine performance as a result of a slight power loss and specific fuel consumption increase. To extend the use of biodiesel, the main concern is the economic viability of producing biodiesel. This study identified that the price of the feedstock was one of the most significant factors. Also, glycerol was found to be a valuable by-product that could reduce the final manufacturing costs of the process up to 6.5%, depending on the raw feedstock used. Biodiesel can only compete with diesel fuel prices.

Keywords: Economics; Biodiesel; Renewable energy

1. Introduction

The European Commision's White Paper on Renewable Energy is an action plan for accelerating the use of renewable sources of energy in the EU to 12% by 2010. Among the possibilities, the use of biodiesel has been widely investigated, providing an alternative to mineral diesel for diesel engines. It is known that biodiesel increases slightly

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the volumetric brake specific fuel consumption, whereas engine power is slightly reduced or remains constant and smoke emissions are lower, compared to No. 2 diesel fuel [1–9].

An advantage of the production of vegetable oil crops for biodiesel is the employment and rent increase in agricultural areas, as well as the impact over related industries. In Europe it is important to stress that it is most economic for the farmer to produce energy crops on set-aside land in order to receive the subsidies defined within the EU Agricultural Policy.

To extend the use of biodiesel, it is important to provide a high-quality, low-cost fuel that can compete with diesel fuel. To promote biodiesel consumption, on January 1st 2003 the Spanish parliament exempted biodiesel from fuel excise tax. Until then the Spanish framework RD 1165/1995 only permitted this exemption for pilot projects over 5 years.

Undoubtedly, tax exemption will one day come to an end, so that to continue to promote the social inclusion and economic attraction of biodiesel other steps will be needed. This could be facilitated by the selection of low-cost raw materials, such as used frying oil or animal fat, and the use of a lower cost transesterification process. Zhang et al. [10] found that biodiesel from used frying oil presents a lower biodiesel break-even price. The price of feedstock oils and biodiesel was found to be one of the most significant factors affecting the economic viability of biodiesel manufacture [10]. It is reported that approximately 70–95% of the total biodiesel production cost arises from the cost of raw material [11,12]. In this sense, *Brassica carinata* (Ethiopian mustard) is an oil-bearing crop well adapted to marginal regions that does not always need irrigation, pesticides, and other culture operations which also contribute to the environmental damage [13].

In this study, economic aspects involved in the production of a low cost transesterification process to produce biodiesel from waste olive oil and Ethiopian mustard oil were studied. Final cost of both biodiesels, including seed cost, oil extraction, processing, and distribution were compared with the cost of mineral diesel fuel.

2. Methods and equipment

2.1. Fuel description

To decrease the final cost of biodiesel, two cheap raw materials were selected: used olive oil and Ethiopian mustard oil. Waste olive oil was collected from several Spanish hospital kitchens and filtered from solid impurities using a 27 μm diameter, paper no. 1305 from ALBET (Filtros Anoia SA, Barcelona, Spain). Non-erucic Ethiopian mustard oil was obtained from KOIPE S.A. (Spain).

The parameters involved in the transesterification process of both oils were optimized in a previous study in order to produce a low-cost high quality biodiesel [14,15]. The process consisted of an alkali reaction carried out in a reaction vessel that was charged with the selected oil, methanol and potassium hydroxide (KOH). The mixture was stirred and heated, then the products of the reaction were allowed to settle, providing two phases. Biodiesel was the top phase, whereas the lower phase contained a mixture of impurities

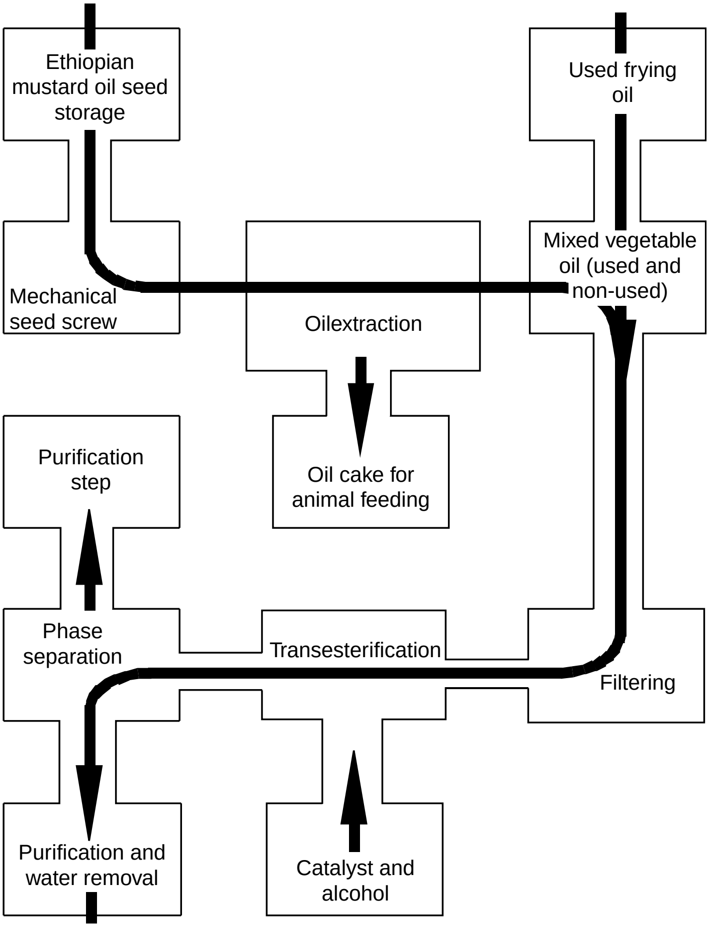

Fig. 1. The process of biodiesel production from both Ethiopian mustard seed oil and waste cooking oil.

and glycerol. Both biodiesels were separated, purified using distilled water and then any water removed by passing over Na_2SO_4 (Fig. 1).

Also, the density (EN ISO 3675), kinematic viscosity (EN ISO 3675), higher heating value (ISO 1928), and lower heating value (ISO 1928) of the glycerol were analyzed (Table 1).

Table 1
Glycerol properties obtained after transesterification according to the origin of the vegetable oils

	Glycerol from used olive oil	Glycerol from *Brassica carinata*
Density at 15 °C (kg/m^3)	1.0578	1.0560
Kinematic viscosity at 40 °C (mm^2/s)	148.90	137.26
Higher heating value (MJ/kg)	26.13	26.18
Lower heating value (MJ/kg)	24.01	24.18

2.2. Economic analysis

The main economic criteria were considered to be manufacturing cost and price of raw feedstock. Manufacturing costs included direct costs for seed, oil extraction, reagents and operating supplies, as well as indirect costs related to insurance, and storage.

The oil content of the Ethiopian mustard oilseed was 37% [16]. So that to produce 1 kg of oil 2.7 kg of Ethiopian mustard oilseed were needed. This results in a lower operation costs compared to some other oilseeds, such as soybeans, which have an oil content of only 20%, though oilseed rape can be 45%. Lower operation costs result from higher oil percentage mainly due to less capacity needed for the extruder and oilseed press [17]. To calculate the seeds and oil extraction of the Ethiopian mustard oil, the market price was considered. Glycerol selling costs were obtained and updated, considering that 0.08 kg glycerol were generated after the production of one kilogram of waste oil biodiesel, while glycerol production decreased to 0.05 kg when Ethiopian mustard oil biodiesel was produced [14,15,18]. In relation to purchasing the used olive oil, the overall costs include acquisition and transport costs.

Prices related to reagents were obtained from the chemical firm ALBUS, Hermanos Blanco Barrena S.A., Córdoba, Spain. Seed prices were obtained and updated from MONSANTO, Sevilla, Spain. Labour and distribution costs were estimated.

The delivered costs of both fuels, including seed cost, oil extraction, and biodiesel production, were compared with the cost of diesel fuel. The study did not include the evaluation of fixed capital costs involved in the construction of processing plant and auxiliary facilities. The economic assessment was completed with the inclusion of the distribution and retailer costs.

3. Results and discussion

The final cost of the biodiesel included raw materials prices, government taxes of 16% (excluding fuel taxes), transport and marketing. It is important to stress that oleaginous crops used for industry are cheaper than oleaginous crops for human consumption. The analysis included the value of the Ethiopian mustard oilcake for animal feeding and the non-purified glycerol produced during the transesterification process. The glycerol could be sold after refining, however, this would require a purification plant, thus increasing the cost. For this reason, it was recommended to use glycerol without purification, for heating purposes after removing any KOH residues. Olive residues, frequently used as biomass for heating purposes in Spain, present a lower heating value of 20.4 MJ/kg. Glycerol lower heating value was higher than 24 MJ/kg in both cases (Table 1).

The final cost of the products was 0.66 €per kg of manufactured biodiesel from Ethiopian mustard, and 0.41 €per kg of manufactured biodiesel from used olive oil (Table 2), while diesel fuel was in the range of 0.82–0.86 €/kg due to the fluctuations of the petroleum prices during 2004 in Spain.

Ethiopian mustard oil cost up to two times more per litre than waste olive oil, even though considering the market value of the oilcake (Table 2).

Table 2
Final cost of the biodiesel from used olive oil and Ethiopian mustard oil

Biodiesel from Ethiopian mustard			Biodiesel from used olive oil		
	Cost (€/kg)	Revenue (€/kg)		Cost (€/kg)	Revenue (€/kg)
Oil acquisition					
Seeds and oil extraction	0.47		Used oil	0.15	
Oilcake		0.17	Filtration	0.03	
Oil transesterification					
Reagents	0.16		Reagents	0.13	
Electricity and water	0.01		Electricity and water	0.01	
Purification					
Purification step	0.04		Purification step	0.04	
By-products					
Glycerol		0.04	Glycerol		0.07
Others					
Labour	0.01		Labour	0.01	
Subtotal (cost less revenue)	0.48		Subtotal (cost less revenue)	0.30	
Taxes (16%)	0.08		Taxes (16%)	0.05	
Distribution (20%)	0.10		Distribution (20%)	0.06	
Total	0.66		Total	0.41	

Bender [17] and Zhang et al. [10] showed the credit for the glycerol by-product has a significant impact on the net value of the total manufacturing cost. The glycerol value led to a reduction in total production costs of 6% and 6.5% in biodiesel from Ethiopian mustard oil and in biodiesel from used olive oil, respectively. Fuel tax was not considered.

Several authors found that biodiesel is currently not economically feasible unless tax credits are applied [17,19]. Peterson [19] found that diesel fuel cost less than biodiesel and an emergency or diesel shortage would be required to provide a practical reason for using vegetable oil as fuel. Bender [17] and Van Dyne et al. [20] affirmed that biodiesel could compete with diesel fuel if produced in cooperatives. According to Bender [17], biodiesel from Ethiopian mustard oil can compete with diesel fuel only if tax exemption is applied (Table 2), whereas biodiesel from used olive oil could compete.

Table 3
Delivered energy cost of the tested fuels

Fuel	Cost (€/kg)[a]	Lower heating value (MJ/kg)	Energy cost (€/MJ)
Diesel fuel (EN 590)	0.82–0.86	38.97	0.021–0.022
Used olive oil methyl ester	0.41	36.79	0.011
Brassica carinata oil methyl ester	0.66	37.25	0.018

[a] Mean of the prices achieved during 2004, in Spain.

Considering the cost versus the heating value, the delivered energy costs of the fuels were obtained (Table 3) to give a more accurate comparison between different fuels. Diesel fuel and biodiesel from Ethiopian mustard oil presented the same energy cost (0.02 €/MJ), while biodiesel from used olive oil showed a lower value (0.01 €/MJ). The lower heating value of biodiesel from both Ethiopian mustard oil and used olive oil were calculated to be 37.25 and 36.79 MJ/kg, respectively.

4. Conclusion

Raw feedstock cost is the major component of the total cost for biodiesel obtained from Ethiopian mustard oil.

Glycerol is a valuable by-product, as well as the oilcake. These reduce the final manufacturing costs of the process up to 6.5%. Glycerol presents appropriate properties for it to be used for combustion for heating purposes.

Biodiesel from Ethiopian mustard oil could become of interest if fuel tax exemption is granted. Waste olive oil biodiesel is more promising since the raw material is free in most places in Spain and hence can compete with diesel fuel even without tax exemption.

The proposed alternatives to diesel fuel significantly decrease the amount of waste oil residues as well as subsidies spent for agricultural over-production in Europe, whilst becoming less dependent on fossil oil imports.

Future research lines about this matter should include ecotoxicity studies and after effects of the inclusion of a biodiesel plant in an agricultural area including the effect of the EU subsidies.

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References

[1] Pischinger G, Siekmann RW, Falcon AM, Fernandes FR. International first symposium on alcohol fuel technology 1982;13–18:9.
[2] Kaufman KR, Ziejewski M. Transactions of the ASAE 1984;27:1626–33.
[3] Einfalt J, Goering CE. Transactions of the ASAE 1985;70–4.
[4] Peterson CL, Reece D. On-road testing of biodiesel-A report of past research activities. Moscow (USA): Department of Agricultural Engineering, University of Idaho, 1997.
[5] Dorado MP, Ballesteros E, Arnal JM, Gómez J, López FJ. Fuel 2003;82(11):1311–5.
[6] Dorado MP, Ballesteros E, Arnal JM, Gómez J, López FJ. Energy Fuels 2003;17(6):1560–5.
[7] Ali Y, Hanna MA. Bioresour Technol 1994;50(2):153–63.
[8] Chang DYZ, Van Gerpen JH, Lee I, Johnson LA, Hammond EG, Marley SJ. JAOCS 1996;73(11):1549–55.

[9] Peterson C, Reece D. Transactions of the ASAE 1996;39(3):805–16.
[10] Zhang Y, Dubé MA, McLean DD, Kates M. Bioresour Technol 2003;90(3):229–40.
[11] Krawczyk T. International news on fats, oils and related materials. Champaign: American Oil Chemists Society Press; 1996 p. 801.
[12] Connemann J, Fischer J. International liquid biofuels Congress, Brazil 1998;15.
[13] Kimber DS, McGregor DI. In: International C, editor. *Brassica* oilseeds: Production and Utilization. Wallingford (UK), 1995. p. 1–7.
[14] Dorado MP, Ballesteros E, López FJ, Mittelbach M. Energy Fuels 2004;18(1):77–83.
[15] Dorado MP, Ballesteros E, Mittelbach M, López FJ. Energy Fuels 2004;18(5):1457–62.
[16] Fernández J. Oil content of the *Brassica carinata* oilseeds. Sevilla, 2001.
[17] Bender M. Bioresour Technol 1999;70:81–7.
[18] Tinaut V, Melgar A, Castaño V, and Briceño Y. Posibilidades de utilización de los biocombustibles en motores de automoción. Valladolid: Centro de Investigación y Desarrollo en Automoción (CIDAUT), 1997.
[19] Peterson CL. Transactions of the ASAE 1986;29(5):1413–22.
[20] Van Dyne DL, Weber JA, Braschler CH. Bioresour Technol 1996;56(1):1–6.