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ENVIRONMENTAL BENEFITS OF RAPESEED METHYL ESTER USE AS FUEL FOR DIESEL ENGINES

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ABSTRACT

The continuously increasing number of auto vehicles that determine a substantial growth of greenhouse gas emissions, along with the decrease of fossil fuel supply and the increase of its price, make necessary the intensification of research for less polluting, alternative fuels for car engines. Through the laws adopted by governments around the world and the huge funds allocated, biofuels receive growing attention as they are considered the number one substitute for fossil fuels. This paper focuses on some aspects concerning the use of biodiesel with regard to its environmental benefits. Even if vegetable oils as fuel for diesel engines are principally considered to be CO_2 neutral, yet there are significant carbon dioxide emissions from the cultivation and conversion processes. The Life Cycle Assessment is used to evaluate and compare the environmental effects when using rapeseed oil (RO), rapeseed oil methyl ester (RME) or diesel fuel. The results show benefits first in favor of RO then RME compared to diesel fuel; this indicates the potential to reduce greenhouse gas emissions and finite energy consumption through the substitution of conventional petro diesel with RO and RME.

KEYWORDS: diesel engine, biofuel, vegetable oil, biodiesel, emissions, life cycle assessment

1. Introduction

The European transport sector is responsible for emitting more than 17.5% of the overall greenhouse gas emissions which increased by 23% between 1990 and 2009 [1]. It is also responsible for a large share of urban air pollution as well as noise nuisance. It also accounts for around a third of all final energy consumption in the EEA member countries and increasing.

Biofuels are important because they tackle two of the most difficult challenges we face in energy policy: the security of energy supply and the climate change [2]. For all these reasons, biofuels are a key part of our energy policy.

The increasing number of automobiles is an aspect worth mentioning. Among all types of engines used in the transportation sector, the diesel one receives growing attention (Table 1) because of its superiority in fuel efficiency (30-50% economy) and low emissions of greenhouse gases (CO2, CO, CH) [4]. Today diesel-powered vehicles represent about 50% of the vehicles sold in Europe; in the United States it is predicted that diesel run automotives will rise from 4% (2004) to 11% by 2012 [4], [5].

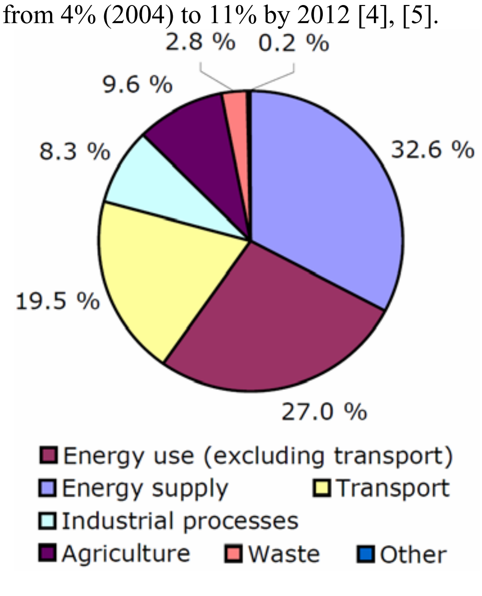

Fig. 1. *Share of GHG emissions by main source [3]*

***Table 1**. Percentage of new diesel vehicles in Europe and the United States [4]*

Year	Europe	U.S.
1997	21.7	<1
2001	35.9	<1
2004	47	4
2012	≈ 60	≈ 11

Being a substitute for fossil based diesel in the transportation sector, the use of biodiesel and vegetable oils is considered to be the easiest and most crucial solution for environmental problems as it requires no or very few engine modifications and reduces greenhouse gas (GHG) emissions substantially as well as improves lubricity. [5]. This makes rapeseed oil and rapeseed methyl ester more adaptable to the current energy scenario to ensure energy security, environmental sustainability, and boost rural development by shifting of power from petro to agro-industry, simultaneously.

In this paper we intend to compare the environmental benefits of using rapeseed methyl ester (RME) and fossil based diesel as fuel for diesel engines. One of the best methodologies to assess environmental impacts associated with all the stages of a product's life from-cradle-to-grave is the

Life Cycle Assessment, a technique regulated according to the international standard ISO 14044 [6]; moreover it also allows an identification of opportunities for environmental improvement [7] [8].

2. RME as fuels for diesel engines

The production of biodiesel from oil plants usually follows the route presented in Figure 2. The most widely used oil plant for the production of fuel based on vegetable oil is rape due to its high oil content (39–50%, varying genetic differences and climate conditions [9]).

Rape is cultivated in Europe as summer rape and winter rape. The production potential of winter rape is between 2.8 and 4.8 t/ha.

This corresponds to 1.1-2.0 t oil. For summer rape, the production potential is from 2.0 to 2.8 t/ha.

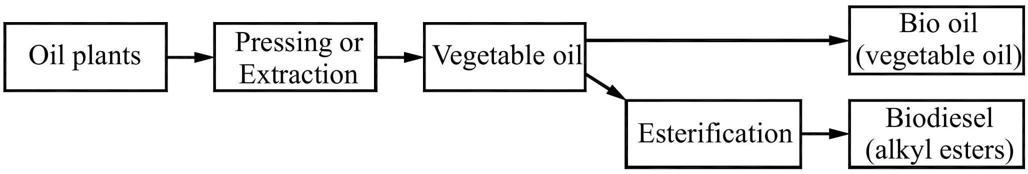

***Fig. 2.** Conversion route from oil plants to biofuels [9]*

Reports have shown that vegetable oils are possible alternative fuel for diesel engines [10]. Diesel engines with vegetable oils offer acceptable engine performance and emissions for short-term operation [11]. Long-term operation results in operational and durability problems. For these reasons it is preferable to transesterify the rapeseed oil with an alcohol to RME, reaction that takes place in the presence of an alcohol, in the presence of a catalyst, such as sodium or potassium hydroxide [12], [13].

The reaction is shown in Figure 3 [14]. Because the reaction is reversible, the excess alcohol is used to shift the equilibrium to the products side [14]. The by-products of this chemical reaction are glycerol and water [13].

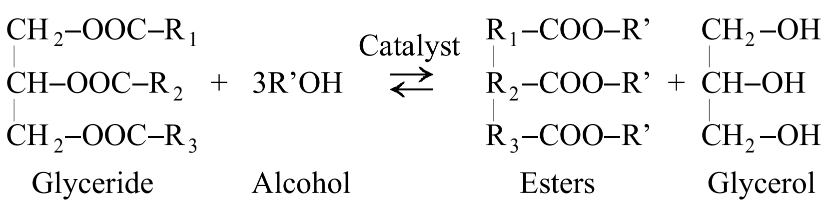

***Fig. 3.** Transesterification of triglycerides with alcohol [14]*

The specific fuel is called after the plant (or animal) source plus the alcohol [15]. Made from rapeseed oil and methanol, the biodiesel is called Rape Methyl Ester (RME), from canola oil and ethanol, Canola Ethyl Ester (CEE), and from used McDonald's cooking oil and ethanol or methanol ("McDiesel"). The base catalyzed reaction is also more economical than other production methods [16].

The reaction has a very high conversion rate (98%), generally requires only a single production step, and proceeds quickly at relatively low pressure (137.9 kPa) and temperature (65.5°C).

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3. LCA of RME and Diesel used in diesel engines

As common liquid biofuels are produ-ced from biomass, i.e. energy crops, the fuels are principally considered to be CO_2 neutral [17]. Thus it can be assumed that during the combustion about the same amount of carbon dioxide is being set free as that has been bound from the atmosphere during the growing of the crops. Having the emission balance in mind, it can be said that the carbon circle is closed. Yet there are significant carbon dioxide emissions from the cultivation and conversion processes.

All these processes are connected with environmental effects, such as air pollution and waste disposal [18]. These effects have to be taken into account for a life cycle assessment of the fuel provision. To quantify all the environmental effects of the renew-able fuel provision, the whole provision chain has to be investigated including all the efforts for transport, infrastructure and all the preliminary products. The method to rea-lize this is the life cycle assessment (LCA).

Life cycle assessment is an established technique for quantifying the total environ-mental impacts of the provision of a product or service from original resources to final disposal, or so-called "cradle-to-grave" [19].

Amongst numerous reasons for conducting LCA studies is the possibility of comparing the total environmental impacts of alterna- tive products or services.

There are four phases in an LCA-study [20], according to ISO 14040: 1. Goal and scope definition; 2. Inventory analysis; 3. Impact assessment and 4. Interpretation. In [19], there are two more stages: 5. Reporting and 6. Critical reviewing.

The central feature of a life cycle assessment is the process chain which summarizes the main activities in the provision of a product or service [19]. For a product such as a liquid transport fuel, the process chain consists of a sequence of activities, starting with the provision of the basic raw material and ending with a suitable product, distributed and available for use in suitable road transport vehicles. It should be noted that the actual use of the fuel in a vehicle could be included in the process chain and subjected to the life cycle assessment. The main stages in the life-cycle of RME for use as a transport fuel are summarized below [21]:

- agriculture - production of oilseed rape;
- transport - rapeseed to crushing plant to produce oil;
- processing - oil extraction and refining;
- transport - rapeseed oil to processing plant;
- processing - rapeseed oil to rape methyl ester;
- distribution and storage - RME to filling station;
- end-use - in a RME fuelled vehicle.

To compare the environmental impacts of RME and diesel oil, the complete life cycles of both fuels are compared against each other (Fig. 4) [23].

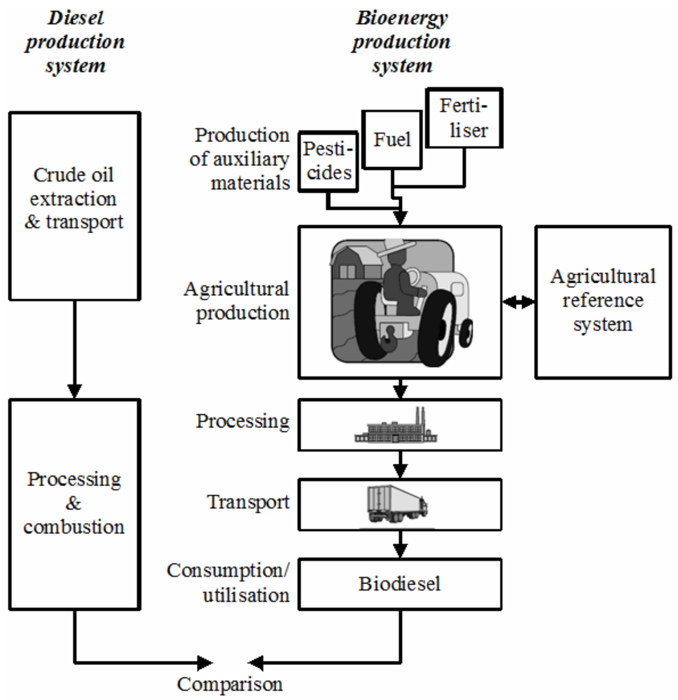

Fig. 4. *Comparative assessment of liquid biofuels versus fossil fuels [22]*

The detailed inven-tory of the life cycle assessment of RME and diesel oil for finite energy, CO_2 equivalents, NO_x emissions and SO_2 equivalents is pre-sented in [23]. Since the cycle for rapeseed oil (RO) is included in the RME cycle, the inventory was detailed in Table 2. Additionally, the credits for RME and RO (which account for the energy for producing cattle cake and/or using rape straw as fuel etc.).

Table 2. *Energetic expenditures and selected emissions for RME and diesel oil [22]*

Life cycle step	**Finite energy**	**CO_2 equiv.**	**NO_x**	**SO_2 equiv.**
	[MJ/kg]		[g/kg]	
Plant production	11.36	2319	4.474	17.441
Provision				
Oil	*5.56*	*347*	*0.800*	*1.005*
Esterification	*7.61*	*517*	*0.355*	*0.704*
Total Provision	13.17	864	1.155	1.709
Energetic use	0.22	233	10.348	7.437
Total RME	24.75	3415	15.977	26.587
Total RO	17.14	2898	15.622	25.883
Diesel oil	47.78	3766	10.839	9.925
RME minus Diesel oil	**-23.03**	**-351**	**5.138**	**16.662**

4. Conclusions

Biofuels have received a growing atten-tion as an alternative to fossil based fuels to reduce greenhouse gases, to create of new markets for agricultural products and to reduce dependence of imported oil.

Vegetable oils are attractive by their high biodegradability, high calorific value and reduced emission, particularly carbon dioxide, sulphur oxides, soot and aromatic compounds. The disadvantages of vegetable oils (high viscosity, lower volatility, a mediocre ignition quality, reactivity of unsa-turated hydrocarbon chains and the tendency of large molecules to crack) make them unu-sable as fuel for the modern diesel engines.

To reduce the high viscosity of vegetable oils and to improve their combustion quality, there are three possible solutions:

1) to modify the oil to methyl ester, i.e. to use biodiesel;

2) to blend the raw oil with diesel fuel;

3) To use conversion kits to adapt the fuel system or to modify the engine concept to run directly on vegetable oil.

The use of esters of vegetable oil as fuels for stationary and on vehicle diesel engines brings one to the conclusion that the emissions of HC are reduced in some studies as much as 50 percent; CO is reduced by as much as 10 percent; NO_x and PM are related and tend to change inversely with each other, differing from diesel by at most 10-15 percent. Generally, NO_x was found to be slightly higher than diesel and PM slightly lower than diesel, although this differs with particular conditions.

Even if vegetable oils as fuels are mainly considered to be CO_2 neutral, there are significant carbon dioxide emissions from the cultivation and conversion processes. To evaluate the environmental effects of all these processes and to compare biofuels with diesel fuel, the life cycle assessment is used. Individual results for rapeseed oil, RME and diesel oil signal benefits first in favor of RO and then of RME. The balance shows the potential to reduce finite energy consumption by the substitution of diesel oil with RO and RME and to reduce the greenhouse gas emissions.

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