Energy Conversion and Management 75 (2013) 658–663

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Influence of economical variables on a supercritical biodiesel production process

J.M. Marchetti *

Department of Mathematical Science and Technology, Norwegian University of Life Sciences, Drøbakveien 31, 1432 Ås, Norway

ARTICLE INFO

Article history:
Received 6 June 2013
Accepted 20 July 2013

Keywords:
Biodiesel production
Supercritical technology
Economic study

ABSTRACT

Biodiesel has becoming more and more relevant in today's society and economy due to its environmental advantages such as biodegradability, lower CO and CO_2 emissions as well as less particulate pollutants.

In this work the study of market and economic variables is presented and their effects compared when biodiesel is being produced using a supercritical technology. The production process is based on a supercritical technology with no catalyst and no co-solvent. Price for the raw materials, such as price for the alcohol as well as the oil has been studied. Also, selling price for biodiesel as well as glycerin has been analyzed and compared with prices from other biodiesel production technologies. Economic decisions such as percentage of failure in the production process, investment in research and development, and advertisement have been evaluated; also it has been considered the influence of the tax incentives on the global economy of the production process.

Small variations on some of the major market variables would produce significant effects over the global economy of the plant, making it non profitable in some cases.

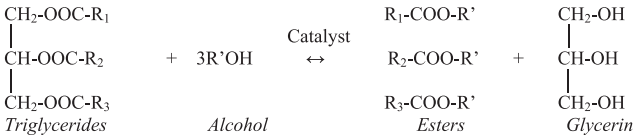
1. Introduction

Due to today's energy market is growing, and to the need of new renewable alternatives, is that several substitute for petroleum fuels are been tested and investigated. Biodiesel appears as the natural and logical alternative to substitute diesel fuels. It is defined as the mono alkyl esters of long chain fatty acids derived from a renewable lipid feedstock such as vegetable oil or animal fat. Among the mayor benefits, it can be found that is biodegradable, it has a better combustion into CO_2, producing almost none CO, it produces no sulfur contaminants and no particulate pollutants [1–3].

Biodiesel is generally produced using a base catalyst, such as sodium or potassium hydroxide in the presence of alcohol [2,4–7]. The industrial choice of alcohol is methanol due to its properties; however, in order to have a more renewable fuel, ethanol is gaining more and more relevance in biodiesel research [2,7].

Despite the fact that high conversion is achieved when using conventional technology; the raw material employed must be a refine oil, meaning that the amount of impurities must be considerable reduced before it can be used. Even more, refine oils are use for food purposes and its transformation into fuel is a debatable decision. Therefore, new technologies capable of using waste oil, has been generally studied: such as homogeneous acid catalyst [8–10], heterogeneous catalyst [11–14], enzymatic approaches [15–18], supercritical technologies [19–21], as well as membrane reactors and monolithic alternatives [22,23].

The main reaction taking place in the biodiesel process, despite the catalyst employed, is the transesterification reaction. In this reaction, a triglyceride interacts with an alcohol to produce fatty acids alkyl esters and glycerin, which is normally call fatty acid methyl ester (FAME) due to the used of methanol. The main reaction could be summarized as follows:



(1)

It is important to notice that this is a series of reactions, in which from triglycerides diglycerides are produced. Then, the diglycerides are transformed into monoglycerides and finally, the latest is modified into glycerin. In every single step biodiesel is produced. Because this is an equilibrium reaction, higher amounts of alcohol are used in order to swift the reaction towards the desire product.

Besides technical aspects and viability, economic feasibility is as relevant, making a process to be profitable or not. Different authors have also done economic analyses of several biodiesel production scenarios [24–30]. Marchetti et al. [27] studied a supercritical process where waste oil, as defined by Marchetti [31], with 5 wt% of

* Tel.: +47 64966397.
E-mail address: jorge.mario.marchetti@umb.no

0196-8904/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enconman.2013.07.039

FFA undergoes a two reactor process with intermediate separation. The authors found that the process was not profitable as it was presented due to the high cost on operation, which was more than 50% of the total cost of the process. Contrarily, Van Kasteren and Niswore [32] found that their proposed process was rentable when studied. The differences are based on the reaction system, the amount of equipment as well as the post purification. The latest have used the biodiesel selling price as comparison variable.

However, to my knowledge, there has not yet been a study where the economic variables over a supercritical biodiesel plant were analyzed and compared in order to examine the influence of the economic variables over the process.

In this work, the influence of several market dependant variables (price of raw material, selling price of biodiesel, etc.), over the economy of a biodiesel plant, has been studied. This analysis was done over a biodiesel production plants that employees a supercritical technology with no catalyst neither co-solvent. This technology has been selected due to its versatility for raw materials with high amount of impurities.

2. Study case

For this study, a supercritical biodiesel was design as follow: methanol and the impure oil are fed into the first supercritical reactor. After the reaction, a distillation column is used to separate the methanol phase from the oil and glycerin phase. The methanol is then recycled and the oil phase is separated into glycerin and biodiesel/unreactant components. The latest is fed into a second supercritical reactor with methanol in order to achieve a higher conversion, yield and selectivity. After the second supercritical reactor, the methanol is separated and recycled by a distillation column and the oil/glycerin phase is passed through a decanter to produce high pure biodiesel and glycerin of high concentration. Fig. 1 shows the flow sheet of the process.

For this purpose, it was used a commercial software, Super Pro Design [33]. Data from the literature was employed as a source for the cost and prices of equipment and materials. The technical aspects (operational conditions for the process), cost of equipment as well as other assumptions used in this work, plus the mayor economic variables were set as previously done in Marchetti et al. [27].

Table 1 show the major economic parameters used in this work such as investment, total capital cost and plant capacity. The major economic assumptions have been done according to information from the literature [27]. In this work it has been compared the internal return rate (IRR) and the payback time. Net present value (NPV) has not been used since the tendencies obtained for IRR and NPV will not suffer major modifications if one or the other are presented. This work is to show tendencies and comparison more than absolute numbers.

As mentioned, the production biodiesel has several physical–chemical variables involved, such as: reaction temperature, molar ratio between reactants, types of catalyst, amount of catalyst, and many others. It also has economic parameters which require specification. Some of these economic variables have been studied to evaluate their influence on the global process. Their effect over the internal return rate, which is a key variable in order to see if a process is profitable or not, and over the payback time, which gives idea of the time needed to recover the investment, were analyzed.

Table 1
Technical and economical aspects.

Technical aspects	
Plant capacity (kg/year)	39,910,500
Project life time (year)	15
Feed streams (kg/h)	
Oil	4550
Methanol	8700
Out coming streams (kg/h)	
Biodiesel (purity over 98%)	4556
Glycerin	424
Economic aspects	
Total capital investment ($)	$ 12,464,138
Equipment purchase cost ($)	$ 2,613,366
Direct fixed capital (DFC) ($)	$ 8,744,177
Working capital ($)	$ 3,132,752
Start up and validation cost ($)	$ 437,209
Total operating cost ($/yr)	$ 42,086,302
Labor dependant ($/yr)	$ 273,240
Utilities ($/yr)	$ 1,556,634
Laboratory ($/yr)	$ 40,986
Biodiesel unitary cost (US$/kg)	$ 1.1789

It was carried on a research to identify how each of the following variables separately affects the global economic of a biodiesel process.

1. Oil price (associated to its purity).
2. Biodiesel selling price.
3. Glycerol selling price.
4. Alcohol price.
5. Advertisement and selling expenses.
6. Tax incentives.
7. Investment in research and development.
8. Product failure.

These variables are market related and their values are ruled by the market as well as other companies and political decisions.

Each of these variables has a study range in order to evaluate the influence over the IRR and the payback time. Table 2 shows these ranges for all the studied variables. In the same table it is also included the standard value for each of them.

3. Results and discussion

3.1. Changes on the selling price of biodiesel

Biodiesel selling price is a key variable of the process, it is a fundamental variable that will allow the process to be economically

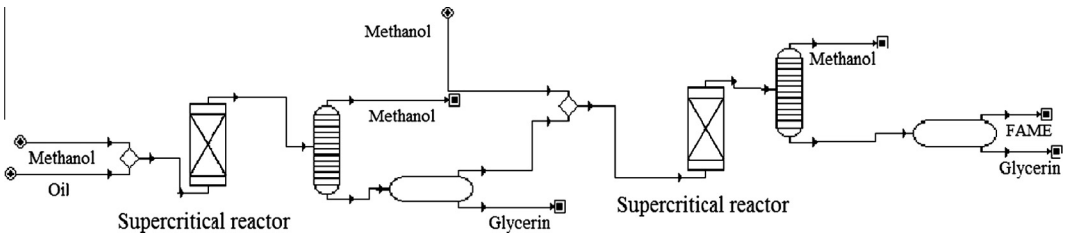


Fig. 1. Flow diagram of the process under studied.