Biomass and Bioenergy 93 (2016) 168–179

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: http://www.elsevier.com/locate/biombioe

Research paper

Small-scale production of hydrous ethanol fuel: Economic and environmental assessment

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ARTICLE INFO

Article history:
Received 10 February 2014
Received in revised form
6 July 2016
Accepted 8 July 2016
Available online 20 July 2016

Keywords:
Hydrous ethanol
Small-scale
Economic feasibility
Environmental impacts

ABSTRACT

Energy consumption in rural areas and the increasing demand for liquid fuels in Brazil has stimulated the development of alternatives for fuels production, including ethanol. The potential of small-scale ethanol production (SSEP) – up to five thousand litres daily – can help to meet this demand and contribute byproducts to animal feed. This study aims to assess the economic feasibility and environmental impacts of ethanol production at a small-scale distillery with a production capacity of 30 L h^{-1} of hydrous ethanol fuel (HEF). Regarding cost, three cases were analyzed in which the minimum, average and maximum raw material prices were assessed. The cost of HEF for these cases was US$ 0.68, 0.92 and 1.16 per litre, respectively, highlighting the cost of the raw materials, which can contribute up to 69% of the total cost. Life cycle Assessment (LCA) shows that agricultural stage is responsible for higher environmental impact in 7 of 11 categories, requiring special attention to minimize potential damage. SSEP has positive energy balance (1.97) only considering bagasse silage as byproduct or replacing firewood by bagasse to generate process heat (7.39). This study demonstrates that without the support of policies that provide economic incentives for HEF production, the small-scale production of HEF will have a secondary role in supplying HEF to meet the demand for liquid fuels in Brazil.

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1. Introduction

Ethanol fuel is in an important renewable fuel in Brazil. Hydrated ethanol is used directly in engines or anhydrous ethanol is compulsorily added to gasoline at a concentration of between 20 and 25% [1,2]. In the 1980s, ethanol was the most used fuel in passenger cars, although the level of ethanol use soon dropped below gasoline due to a shortage of ethanol in 1989 and due to a drop in international oil prices [2].

In Brazil, sugarcane is traditionally produced in the southeast region, specifically in São Paulo [3]. The business model adopted in this region is characterized by mechanized monoculture because this region has a favorable climate and topography.

The state of Rio Grande do Sul, which is located in the southern region of Brazil, contains some areas that are suitable for sugarcane cultivation. These regions are characterized by a hilly topography and a predominance of small farms, and the agricultural production is based on family labor. Thus, the large-scale production model cannot and should not be implemented in these regions. Therefore, producers in this region should seek another business model that has specific characteristics and qualities that strengthen the financial position of small-scale distilleries.

Small-scale ethanol production (SSEP) locally supplies good-quality liquid fuel that has no transportation costs from remote and traditional regions, where ethanol is actually produced. In addition, the byproducts of SSEP constitute a valuable source of raw material for other products, such as livestock, biogas, and liquid fertilizer, or as a natural source of carbon dioxide.

Despite the promising social and economical advantages of SSEP, its environmental impacts still unknown or limited to some specific case. Furthermore, the variability in the configuration of

Abbreviations: HEF, Hydrous ethanol fuel; EEA, Energy Efficiency Analysis; ICMS, Tax on circulation of goods and services; IRR, Internal rate of return; LCA, Life Cycle Assessment; MARR, Minimum acceptable rate of return; NPV, Net present value; PGE, Price of gasoline equivalent; SSEP, Small scale ethanol production.

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http://dx.doi.org/10.1016/j.biombioe.2016.07.011
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technology and processes difficult to cover SSEP environmental impacts. Environmental impact comparison among small-, medium-, and large-scale ethanol production from wheat showed to be small [4]. As opposed, environmental impacts from large scale ethanol production have been extensively studied [5–10].

The objective of this study is to present a financial analysis of the production of HEF and its byproducts on a small-scale as well as to analyze the economic feasibility of distilleries in different scenarios that produce this renewable fuel from sugarcane and sweet sorghum to replace gasoline. A Life Cycle Assessment and an Energy Efficiency Analysis were also performed to provide relevant information about impacts from small-scale fuel ethanol production.

1.1. Brazilian ethanol market

The consumption of ethanol (hydrous and anhydrous) expanded by 121% between 2003 and 2012, mainly due to the growth of the light vehicle fleet in Brazil and the commercialization of approximately 15 million vehicles with flex fuel engines [11]. Ethanol was expected to be used in 43% of the national fleet of light vehicles by 2015 [2]. Flex fuel engines have enabled consumers to choose which fuel to use, according to price. Consumers choose hydrous ethanol when it costs less than 70%[1] of the gasoline price [12,13] – the competitive price of ethanol is equivalent to 70% of the gasoline price and will be referred to as the 'price of gasoline equivalent' (PGE). The versatility of these flex fuel vehicles provides an almost instantaneous change in the consumption of these fuels in Brazil as prices change.

Given such versatility of use and the fact that the price of gasoline in Brazil has remained at a stable level since 2005 because the government, through the state company Petrobras, avoids transfer fluctuations in international oil prices to the consumer market and acts as a "buffer", the price of ethanol becomes the primary factor with regard to it's level of consumption. Interactions arise from the international sugar trade with ethanol production in Brazil because ethanol is produced from sugarcane at autonomous distilleries or at distilleries adjacent to sugar production. This makes the HEF price susceptible to the sugar prices of the international market, as seen in Fig. 1.

There is a trend between increases in the price or quantity of exported sugar and the price of HEF. In Brazil, the relationship between the production yield of sugar and ethanol is more than 2.0, that is, from the same amount of sugarcane that is processed it is possible to produce two sugar units or one HEF unit. Thus, ignoring production costs, it can be inferred that the selling price of ethanol must be at least double to that of sugar. However, in recent years, this relationship has remained at an average value of 1.47 [14]. Thus, it has been and is currently more profitable to allocate sugarcane feedstock to sugar production than to HEF production, enhancing its price, decreasing its competitiveness with gasoline and, consequently, reducing its consumption. In recent years, ethanol has not been competitive with gasoline because its selling price to the consumer has systematically exceeded the PGE.

The commercialization of ethanol fuel in Brazil is regulated by the National Agency of Petroleum, Natural Gas and Biofuels (ANP) by resolutions No. 07/2011 [15] and No. 43/2009 [16]. Resolution No. 07/2011 established the quality standards for HEF, while resolution No. 43/2009 regulated the supply chain agents acting to commercialize ethanol: the ethanol producer sells its product to a distribution company that transfers the fuel to gas stations, which

[1] 70% is a parity number that indicates the performance ratio of ethanol to gasoline in flex fuel engines. Thus, the choice for ethanol occurs when its price is less than 70% of gasoline price [13].

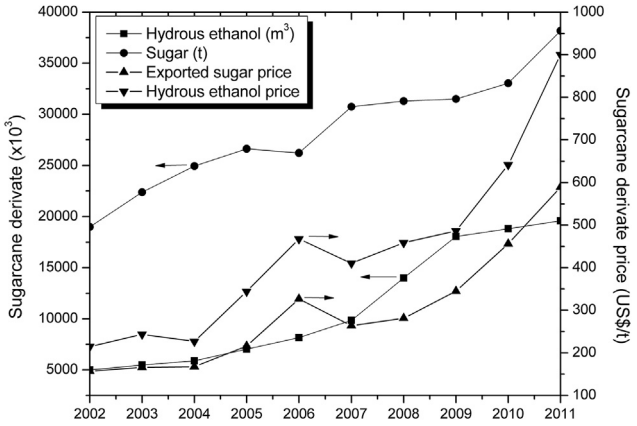

Fig. 1. Sugar and hydrous ethanol production and prices in Brazil (Data sources: [38] [39], and [40]).

in turn sell fuel to the end consumer. The sale of ethanol by the producer directly to consumers is not allowed, increasing the final product cost due to freight costs, as the distributor is often located at a distance from the producer, forcing the fuel to be transported to an ethanol fuel distributor and then returned to be sold in the region in which it was produced, as well as the remuneration of agents involved in this distribution chain.

Table 1 shows the composition of the HEF price in Brazil in 2011 considering the average final price is US$ 1.11 per litre. For fuel ethanol, the tax burden on the supply chain is higher than 30%, highlighting the ICMS (Tax on Circulation of Goods and Services), which reaches 18.2%. In the state of Rio Grande do Sul, the ICMS rate reaches 25%.

From Table 1, it can be observed that the competitiveness of HEF compared to gasoline depends largely on the cost and the profit margin for the producer because the state and federal taxes applied to HEF and gasoline are similar.

1.2. Small-scale fuel ethanol production

Ethanol production in Brazil uses mainly sugarcane as feedstock in large scale distilleries. Sugarcane harvest season lasts for 180 days [17] resulting in a high period of industrial inactivity, unless the distillery utilizes stored sugarcane molasses from sugar production. In this context, sweet sorghum could be used as a complementary raw material in ethanol production [18], even on a small scale [19].

SSEP process can be considered to be a simplification of the

Table 1
Composition of HEF price in Brazil in 2011.

Item	%
Final price (gas station)	100.0
Cost and producer profit	55.7
ICMS[a] – tax substitution[b] (gas station)	3.5
ICMS[a] – distributor	2.0
PIS/COFINS[c] – distributor	5.4
ICMS[a] – producer	18.2
PIS/COFINS[c] – producer	2.2
Profit margin – distributor and gas station	13.0

[a] Tax on the Circulation of Goods and Services;
[b] Third party designated to pay taxes through a system of withholding at source;
[c] Social Integration Program (PIS)/Contribution to Social Security Financing (COFINS);
Source: [41].

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