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Why small-scale fuel ethanol production in Brazil does not take off?

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ABSTRACT

Ethanol production on small scale (on-farm) substantially contributes to the effort to replace fossil fuels. However, the share of small scale production remains incipient, either due to inefficiency in the process or legal restrictions on the commercialization of hydrous ethanol fuel. The aim of this paper is to justify this incipient industry by detailing the small-scale ethanol production process and presenting operational data collected in the literature from the last three decades. The reviewed data showed that the inefficiency of the process affects the economic feasibility by product losses in bagasse and vinasse or through excessive energy consumption. The feasibility of ethanol production on small scale requires addressing these technological obstacles through the integral use of co-products.

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1. Introduction

Fuel ethanol produced from biomass presents an excellent substitute for gasoline because it is renewable, uses the same logistic infrastructure as fossil fuels, can be produced locally

Abbreviations: HCCI, homogeneous charge compression ignition; HEF, hydrous ethanol fuel; SSEP, small-scale ethanol production; TRS, total reducing sugars

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(unlike gasoline), and in some cases, can be obtained more inexpensively.

In Brazil and in many other countries, programs to encourage the development of alternative energy sources appeared following the oil crisis in the 1970s. In 1975, the Brazilian government created the National Alcohol Program (PROALCOOL), which had the goal of reducing heavy oil imports [1–3]. PROALCOOL incentivized ethanol production through price setting, mandatory blending, tax exemption, stock policy and funding [3] but did not address the scale of production. Considering the advantages of ethanol production on a small scale, it was expected that small-scale ethanol production (SSEP) would have a significant role in ethanol production; however, small scale production was never considered as an alternative. Technical-economic studies had indicated regions appropriate to feedstock cultivation and also confirmed the economic feasibility of SSEP for the scale up to 1200 liters/day. [4,5]. However, these studies were mostly demonstrative [6].

There are two periods during which there was significant interest in SSEP. The first period, from 1975 to 1985, was characterized by the production of ethanol as an alternative to oil (gasoline and diesel) driven by the shortage and high cost of the fossil fuels. The second period, from 2005 to the present day was characterized by environmental concerns, including the reduction of greenhouse gas emissions, in addition to the previous driving factors. During the 20-year gap between the periods, the concept of small-scale distillery lay dormant. Several SSEP methods were established during this time, using different raw materials (sugarcane, sweet sorghum and cassava) and applying different technologies for juice extraction, fermentation and distillation; in some cases operating data from industrial plants were published.

The objectives of this study are to present the results obtained by SSEP assessments conducted during the past 30 years, to discuss the difficulties of ethanol production on a small scale, and to disseminate the technical information of this activity.

1.1. Fuel ethanol production in Brazil

Many countries have improved the production of ethanol used for fuel, notably the United States and Brazil, which accounted for over 86% of the world production in 2010 [7]. Other regions also plan to expand the production or share of biofuels in their energy matrix, including Latin America, Europe and Asia [8–12].

Brazil produced 27.7 billion liters of ethanol in 2010 [13], mainly from sugarcane, with a centralized production system with large-scale plants concomitantly producing sugar, ethanol and electricity. This system is readily adjusted so that the production rates of sugar and ethanol can be tailored to meet international demand for these products. Thus, although ethanol is not a “commodity” in Brazil, it behaves as such, because ethanol production is greatly influenced by sugar prices.

The top 50 sugarcane processors in the state of São Paulo (the largest producer in the country) account for 33% of the total national production [14], with some distilleries producing over 1 million liters of ethanol per day. Walter et al. [15] reported that the average grinding capacity of the 343 mills in Brazil is approximately 1419 thousand tons per year.

The importance of ethanol production to Brazil in terms of economics and energy is clear, as it accounts for 2.35% of the GDP; 3.6 million direct and indirect jobs, including 72,000 farmers [16]; and 19.3% of the domestic supply of Brazilian primary energy [17]. There are economic and social impacts of ethanol production, such as underemployment and increased competition with food production [18]. The environmental gains of the sugarcane and sweet sorghum bioenergetics crop should be noted because the use of ethanol instead of gasoline reduces the emissions of greenhouse gases by over 70% [15]. This value can reach over 100% if the emission credits for co-products (including electricity) are included in the sugarcane industry [19].

However, similar to any monoculture, sugarcane cultivation has disadvantages, including the concentration of land and income, a rural exodus due to farming mechanization, the risks of single crop dependence and the environmental pressures on ecosystems. Corsini [20] cites the seasonality of production (approximately 6 months) and transportation costs for the raw materials and product, as a large crop area is needed to supply a distillery. Because of these factors, large-scale ethanol production is only feasible in regions with favorable climate and topography, which are present in the southeast and central-west regions of the country in the states of São Paulo, Mato Grosso, Mato Grosso do Sul and Goiás.

In regions with high topography or where there is a predominance of small farms and agricultural production based on family labor, the model of large-scale production cannot and should not be applied. In these regions, another model must be sought that has specific characteristics to leverage the advantages of small-scale production, including those of small-scale fuel ethanol production.

1.2. Small scale fuel ethanol production

Ethanol production on small scale plays an important economic and social role in the region in which it operates because the activity can become a source of income and also guarantee self-sufficiency to the producer and region. These two characteristics promote the development and adaptation of small-scale distillation technology.

The interest in SSEP was intensified in times of petroleum product shortages (mainly gasoline) or increase in their market prices. During these times, significant development and deployment of SSEP have been observed, although not to the extent of large scale alternatives. Noteworthy growth occurred between the world wars, such as when the Brazilian government created the Institute of Sugar and Alcohol in 1933 (IAA *in Portuguese*). During World War II (1939–1945), there was a shortage of gasoline. During the first oil crisis (1975–1989), PROALCOOL was created, and this was followed by ethanol shortages (1989) and the extinction of the IAA. In the current period (2002–present), an increase of approximately 55% in ethanol production [17] occurred as a result of 3.3 times increase in international oil prices between 2002 and 2013 [21].

In Brazil, the movement towards ethanol production on a small scale gained momentum with the advent of PROALCOOL in 1975, launched after the first oil crisis in 1973, although this program aimed large scale ethanol production [6]. In this context, two goals for SSEP were developed: (1) to ensure energy self-sufficiency for the farmer, under the slogan, “manufacture your own fuel” [22–27] and (2) to include small-scale ethanol producers in the effort to meet the national demand for liquid fuels [6].

The first line of action has always been the most promising. The higher cost of fuel ethanol produced on a small scale (due to lower efficiencies) would be offset by the absence of taxes on self-consumption. As another competitive advantage, ethanol self-producers do not pay freight costs. In Brazil, ethanol production is concentrated in the southeastern region, and the transportation and distribution costs increase the final price of ethanol fuel by approximately 5% [28].

The ability to produce liquid fuel on a farm to meet the demand of the agricultural machinery used in the production of other crops, such as soybeans, could encourage ethanol self-production, as reported by Dias et al. [24]. The industrial efforts in this direction resulted in the improvement of agricultural machinery with ethanol–diesel hybrid engines [29–32].