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To Burn or Not to Burn. The Potential of Use and Production of Biofuels in Brazil

da Silva Ramos R[1,2], Silva GC[1,2], Martins LSS[1,3] and de Moraes Filho RM[1,2]*

[1]Department of Agronomy, Federal Rural University of Pernambuco, Brazil

[2]Department of Agronomy, UFRPE, Brazil

[3]Department of Biology, UFRPE, Brazil

***Corresponding author:** Rômulo Maciel de Moraes Filho, Department of Agronomy, Federal Rural University of Pernambuco, UFRPE, Dom Manuel de Medeiros Street, s/n, Dois Irmãos - Zip Code: 52171-900, Recife, Pernambuco, Brazil

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Abstract

Brazil is a country recognized for having a relatively clean energy matrix, made up of renewable energy sources, where the use of biomass and biofuels stands out. Biofuels are renewable energy sources derived from agricultural products, mostly from plant biomass. Brazil is also the world's largest producer of sugarcane, sugar and ethanol. Ethanol, when used as fuel in automobiles, is an alternative to petroleum gasoline. Public policies by the Brazilian government have been instituted to encourage the use of biofuels, such as The National Alcohol Program (PROALCOOL) and the National Program for the Production and Use of Biodiesel (PNPB). Recently, the National Biofuels Policy (RenovaBio), has been structured aiming to promote the appropriate expansion of production and use of all biofuels in the Brazilian energy matrix. Emissions avoided by the use of ethanol and biodiesel, compared to fossil equivalents and totaled 66.3 metric tons of CO2 in 2018. However, in Brazil, as in most countries, the participation of fossil sources in the matrix is still very large. Some economic incentives are granted by the National Electric Energy Agency (ANEEL) and the Studies and Projects Financing Agency (FINEP) for the use of biogas, biomethane and bioenergy, but new forms of incentives are needed to increase the share of bioenergy in the country. Research focusing on the use of more efficient biofuel sources is also of great importance for this purpose, as well as in order to increase the productivity and energy balance of biofuel sources.

Keywords: Biomass; Carbon emissions; Greenhouse gasses; Biodiesel; Ethanol

Introduction

Brazil is internationally recognized for its wide availability of energy resources because of the country very favorable edaphoclimatic conditions and extensive land availability, which favors the use of renewable sources. The national energy matrix is quite diverse and stands out worldwide for the high degree of use of biomass. Concerning the vehicular matrix, the participation of renewable energy sources is particularly significant, to which several public policies for the promotion of biofuels contributed, which included actions by government, sector agents and civil society [1].

Biofuels are renewable energy sources derived from agricultural products, mostly from plant biomass. From the energetic point of view, all organic matter capable of being transformed into mechanical, thermal or electrical energy is classified as biomass [2]. The use of biomass for energy production is considered an indirect way of harnessing solar energy, because solar energy is converted into chemical energy through photosynthesis [3].

Biomass has a great diversity of products and co-products and can be almost entirely used for biofuels and other energy products. Biomass waste products and co-products are excellent raw materials for energy generation, such as second-generation ethanol, biogas, biodiesel, or cogeneration of compacted products such as briquettes and pellets [4].

Biomass is classified according to its origin: forest biomass (mainly wood), agricultural biomass (soybean, rice and sugarcane, among others) and urban and industrial waste biomass (solid or liquid). This classification is important because the derivatives obtained from biomass depend both on the raw material used, which has different energy potentials, and on the processing technology used to obtain the energy sources [2,3]. The biomass used for biofuel production and thermal energy generation is predominantly from agricultural and forestry activities [5].

Several crops are used to produce biofuels, such as corn and sugar cane, for the production of ethanol; and canola, castor bean, sunflower, palm, babaçu (Attalea speciosa), peanuts, turnip and Brazilian nuts for the production of biodiesel. Sugar cane, oilseed vegetables and even wood can be used as sources of biofuels. These can be used either alone or in addition to conventional fuels. Presently, the most widely used biofuels in the world are ethanol and biodiesel [4,6].

Transformation Technology

The techniques used to transform raw material into energy source give rise to specific derivatives and are at different technological levels. In this context, the main processes for converting biomass into energy sources are direct combustion, thermochemical and biological.

The use of biomass by direct combustion is the most primitive form of power generation. The combustion of firewood generates energy that can be used for personal heating in open fields, for domestic heating and food preparation, among others. Due to technological advances, in addition to the aforementioned uses, the combustion of biomass can be done in stoves (food cooking), ovens

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(metallurgy) and boilers, for the generation of steam. It is noted that combustion can be done with or without the use of physical processes of drying, classification, compression, cutting or breaking.

Wood, in its different forms, is very important for the world energy matrix, especially in developing countries [7]. In Brazil, forest biomass accounts for 8.4% of the domestic supply of electricity, with firewood accounting for 6.6%. However, the direct combustion process of firewood presents low efficiency due to its high humidity (about 20% or more) and its low density, making storage and transportation difficult.

Another important source of agricultural biomass is sugarcane bagasse, which is used by direct combustion with physical processes to produce bioenergy. In a broader view, biomass occupies the 4th position in the energy matrix, representing 9% (14889 MW) of the authorized capacity of bioelectricity generation in Brazil, which totals 169664 MW. Among the biomass sources, sugarcane represents 77% (11424 MW) of the total [8].

Brazilian in 2018, bioenergy produced from sugarcane biomass was able to: supply 11.4 million households throughout the year; avoid the emission of 6.4 million tons of carbon dioxide (CO_2), equivalent to the cultivation of 45 million native trees over 20 years; save 15% of the total energy stored in the reservoirs of the Southeast/Midwest (SE/CO) submarkets, due to the greater predictability and availability of bioelectricity in the dry period, with 83% of the bioelectricity produced by the sugar-energy sector offered to the grid in dry period [8].

Regarding technical and economic feasibility, evaluated projects for the generation of electricity from sugarcane bagasse, straw and pointers, and pointed to sugarcane biomass as an option complementary to the expansion of the Brazilian electric system [9]. The increase in demand for sugarcane biomass for electricity production is associated with high economic viability, mainly due to its high yield and low production cost, being considered one of the most sustainable and economically competitive alternatives. Compared to other crops such as napier grass, elephant grass, eucalyptus, among others [10,11].

It is important to note that sugarcane cultivation techniques are already well-known, industrial parks are already set up they produce electricity from their industrial waste (bagasse and crop residues) [11].

In 2016, there were 417 thermoelectric plants from sugarcane biomass in operation. However, due to lack of incentive and public investment, only 90 units sold the surplus to the national system, which represented 5% of the total consumed in the country [12]. Even in the face of the Brazilian economic crisis, which led to the closure of the activities of several producing units, incentive actions allowed 369 sugarcane biomass plants to remain operational in 2018. Of these, 200 have already traded electricity (54%), while 169 plants only produce for self-consumption (46%) [8]. This increased the energy representation of sugarcane bagasse to 10.8% of final energy consumption in Brazil [2].

The yields in the conversion of sugarcane bagasse into energy indicate great economic viability, since, on average, 240kg to 250kg of bagasse per ton of crushed sugarcane and 200kg of straw and tips are produced [8,13]. It is possible to produce about 120 kilowatt hours (KWh) per ton of ground sugarcane [14]. The instantaneous power generation capacity of all sugarcane plants in Brazil is approximately 15000 MW, equivalent to slightly more than the Itaipu Hydroelectric Power Plant, which has the installed capacity to produce 14000 MW and provides approximately 15% of all energy consumed in Brazil [12]. Currently, the total sugarcane bagasse bioenergy produced is already higher than the installed capacity at the Belo Monte Hydroelectric Power Plant (11,233.1 MW) [8].

Thus, the burning of sugarcane bagasse and straw (lignocellulosic materials), which for a long time was considered a problem for the environment, becomes one of the most important alternatives for solving the energy matrix problems.

The thermochemical processes used are gasification, pyrolysis, liquefaction and transesterification.

Pyrolysis or carbonization is the oldest and simplest process of converting one solid fuel (usually firewood) into one of better quality and energy content (coal). This process consists of heating the original material between 300°C and 500°C, in the almost absence of air, until the volatile material is extracted.

The main product of pyrolysis is charcoal, in addition to tar and pyroligneous acid. Charcoal is twice as dense and has a higher calorific value than the source material. Thus, charcoal is responsible for 1.8% of final energy consumption [2].

Gasification is a thermochemical process that makes it possible to turn solid fuel into gas. The gas produced has medium calorific value, is composed of carbon monoxide, hydrogen, methane, carbon dioxide and nitrogen, and can supply internal combustion engines and turbines for electricity generation [2,3].

Gasification is considered a clean process of biofuel generation, as the production of gases removes chemicals harmful to the environment and human health [2,3].

Transesterification is characterized by the reaction of vegetable oils with the intermediate active product obtained by the reaction between methanol or ethanol and a base (sodium or potassium hydroxide), resulting in glycerine and biodiesel [2].

Biodiesel is an alternative biodegradable fuel to petroleum diesel, created from renewable energy sources, free of sulfur in its composition. Due to its origin from renewable raw materials (basically alcohol and vegetable oil or animal fat), biodiesel has a clean burning, generating less pollutants than the combustion of petroleum diesel.

In Brazil, biodiesel is produced predominantly from palm and babassu in the northern region, soybean, sunflower and peanut in the southern, southeastern and central-western regions and castor bean in the northeastern semiarid, among other raw materials of plant origin [3]. In 2018, approximately 5,383,000 m^3 of biodiesel was consumed in the country. Of all the biodiesel consumed in 2018, 3.7 billion liters were produced from soybean oil [1].

The most common biological processes are anaerobic digestion and fermentation [3]. Anaerobic digestion consists of the decomposition of the material by the action of bacteria and occurs in the absence of air, producing biogas, which is basically composed of methane (CH_4) and carbon dioxide (CO_2).

Fermentation consists of the conversion of sugars to alcohol by the action, usually of yeast. Sugars for alcohol production may come from the following agricultural crops: potatoes, maize, sugar beet and sugarcane.

The final product of fermentation is ethanol in the form of hydrated alcohol, with an approximately 95% concentration. Another fermentation product, however, produced on a smaller scale, is anhydrous alcohol, that is, a product with less than 1% water. While the former is widely used as a pure fuel in internal combustion engines, the latter is blended with 27.5% gasoline in Brazil. It should be noted that fermentation residues are of great importance to the sugar-energy sector. Vinasse, which is produced in the proportion of approximately 14 liters per liter of ethanol produced, is considered strategic for sugarcane fertigation. Solid waste from the fermentation process can be used in thermoelectric plants for the production of electricity.

Another great potential for the use of lignocellulosic residues of sugarcane, sorghum, corn, beet, among others is the production of second generation ethanol. Second generation ethanol is produced after the following steps: pretreatment, hydrolysis, fermentation and purification. Despite the abundance of raw materials, the accomplishment of such steps, associated with the low efficiency of the production process and the high cost of production, when compared with the costs related to conventional ethanol production, makes this great innovation not yet economically attractive for the investor. By 2025, second generation ethanol is believed to be economically viable and can strategically compose Brazil's energy matrix.

National Production and Consumption of Biofuels

Brazil is the world's largest producer of sugarcane, sugar and ethanol. Ethanol, when used as fuel in automobiles, is an alternative to petroleum gasoline, which is a multi-billion dollar industry per year. The Brazilian production of ethanol in the 2018/2019 crop was 33.14 billion liters, which represents an increase of 21.7% or 6.3 billion liters compared to the previous crop. Anhydrous ethanol production decreased by 13.1%, totaling 9.56 billion liters. Hydrous ethanol reached 23.58 billion liters, representing an increase of 45.2% or 6.7 billion liters compared to the previous crop [15].

As defined by legislation, all automotive gasoline currently sold at gas stations contains 27.5% of anhydrous ethanol. In the same manner all diesel sold, contains at least 10% of biodiesel [2]. Public policies to encourage biofuels usage were developed by the Brazilian government over the years. The National Alcohol Program (PROALCOOL), in the 1970s, the insertion of flex fuel technology in 2003, and the National Program for the Production and Use of Biodiesel (PNPB), in 2005, are examples of success in this area. Since the enactment of Law No. 13.576 of December 26, 2017, the National Biofuels Policy (RenovaBio), has been structured aiming to promote the appropriate expansion of production and use of all biofuels in the Brazilian energy matrix, with emphasis on the regularity of supply in the national fuel market. RenovaBio also aims to cooperate in meeting Brazil's commitments under the Paris Agreement under the United Nations Framework Convention on Climate Change [1].

A priority point for biofuel production is the energy balance, which is by definition the relationship between the total energy contained in the biofuel and the total fossil energy invested in its entire production process, including the agricultural and industrial process [16]. In this regard, sugarcane ethanol has been the best option so far, as it consumes 1 unit of fossil energy for between 8 or 9 units of renewable energy produced [6,17,18]. For corn or wheat ethanol this ratio is 1.1 to 1.5 (depending on how the energy value of by-products is taken into account). For biodiesel, this balance indicates that the relationship between renewable energy from biofuel and fossil energy spent on its production only exceeds 3 for palm oil [6,18].

Conclusion

Brazilian energy matrix has a large share of renewable energy sources. The country plays a prominent international role in climate change discussions and negotiations, and a whole legal framework has been built, with the objective of promoting the use of renewable sources, especially biofuels. The high share of renewables in the national energy matrix provides a significant reduction in greenhouse gases emissions. As for liquid biofuels, emissions avoided by the use of ethanol (anhydrous and hydrated) and biodiesel, compared to fossil equivalents (gasoline and diesel), totaled 66.3 metric tons of CO_2 in 2018 alone [1,19].

However, in Brazil, as in most countries, the participation of fossil sources in the matrix is still very large. Some economic incentives are granted by the National Electric Energy Agency (ANEEL) and the Studies and Projects Financing Agency (FINEP) for the use of biogas, biomethane and bioenergy, but new forms of incentives are needed to increase the share of bioenergy in Brazil. Thus, more research is needed in order to increase the productivity and energy balance of biofuel sources, to allow an increase in production without necessarily increasing the planted area and the replacement of food crops with crops for biofuel production. Research focusing on the use of more efficient biofuel sources is also of great importance for this purpose. RenovaBIO's proposal is an opportunity to achieve sustainable public policy objectives of energy supply, environmental preservation, industrial and economic strengthening, taking advantage of the potential of the agro-industrial sector.

It should be noted that the use of biomass especially that from sugarcane, as an energy source, is already a well stablished reality in the country. Just considering the area already planted with sugarcane today, it is estimated that Brazil has the potential to generate 20GW of energy through the burning of sugarcane bagasse, while the use of this raw material for the production of second generation ethanol is still a possibility for the near future. There are several challenges and technical difficulties still to be overcome for the production of second generation ethanol to be economically viable in Brazil. Thus the direct burning of biomass for energy production is a simpler and more efficient alternative for sugarcane producers and it has been a way to reduce the dependence on fossil fuels in the country's energy matrix.

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