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Scenarios and prospects of solid biofuel use in Brazil

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ABSTRACT

Sustainability is a major goal for the country development without negative effects on climate change, allied to scarcity and instability in the fossil fuels prices, makes attractive the use of several agricultural, forestry and industrial biomass which may undergo combustion processes for the production of renewable energy, either in its in natural form, pressed into dense pellets or briquettes, or after thermochemical conversion through gasification, pyrolysis, liquefaction, carbonization, and torrefaction. The aim of the current research was to identify the major environmental, economic and social impacts arising from the solid fossil fuels, as well as introduce a technical approach to address the scenario of the main energy crops produced in Brazil, wastes arising from the same, their quantification, and alternatives to using such wastes in the solid biofuels production. Moreover, it was intended to describe the current national and global market, policies, advantages, and challenges by using biofuels, in comparison with fossil fuels.

1. Introduction

For thousands of years, humanity has used solid fuels involving several types of organic materials originated from many sources, such as decomposed hydrocarbons in solid form, to produce power and heat by combustion [1].

According to the International Energy Agency (IEA) [2], 41% of the world's electricity comes from charcoal burning. A major current challenge is the search for technologies that could replace this charcoal with clean fuel sources and could possibly produce solid alternative fuels from different organic waste. Among the current types of solid biofuels, pellets, briquettes, wood chips, wood, and biochar stand out [3].

Such organic waste, known as biomass, can be converted into energy using several thermochemical processes, where the choice will depend on the type and quantity of available material, the desired form of energy, environmental regulations, and economic conditions. Such processes can be classified as direct combustion, which involves the biomass direct burning, and several processes for conversion of biomass into energy products [4].

Waste conversion processes, by means of densification, compaction, and agglomeration, according to Ferreira et al. [5], provides a number of advantages when compared to direct burning, especially regarding storage, handling, increased density, and calorific value.

Mineral coal is one of the most commonly used solid fuels in the energy chain. However, concerns regarding costs, as well as the impact on climate change resulting from the greenhouse gases generated by its combustion, have created a favorable scenario using and producing solid biofuels from residual raw materials.

Considering this context, this paper aims to approach the current scenario and the prospects of the solid biofuels in Brazil, together with the theoretical contextualization regarding the use and importance of mineral coal, charcoal and other solid biofuels in Brazil, due to the vast agricultural and forestry extension, this country annually produces significant amounts of solid biomasses.

2. Literature review

The world economy is still heavily dependent on fossil fuels; however, the unstable prices and the need to reduce pollutant gas emissions has been promoting the use of renewable energy sources. Thus, energy from wood, and waste in general, has come to play an important role in this scenario reducing thus the use of non-renewable fuels and being the same presented as a sustainable method [6].

Wood, traditionally called firewood, was one of the first energy sources used by humans, used in early times for cooking and warming. As society evolved, wood started to be used as solid fuel and to make fuel gas used in the generation of thermal, electrical, and mechanical

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energy. Today, it is still part of the world energy matrix, mainly used in domestic cooking and industry, and its use in each country varies according to the level of economic development, environmental issues, availability of forests, and competition with other energy sources [7].

Due to the increasing need for power generation and for the mitigation of global and local impacts as well as to the large volume of solid waste generated, a favorable environment has been created for application of these raw materials as energy sources. Using these materials as alternative energy sources would, at the same time, increase the supply of biofuels, enhance consumer's confidence, minimize environmental impacts, and rationalize waste management.

The advantages regarding the use of solid biofuels are environmental, social, and economic, once that the raw materials used to synthesize them are natural biomass originating from agroindustry. This means low cost, separation from the food chain, and management of the great volume of 'waste' biomass produced by agriculture. It would also provide the benefits of reducing climatic change (i.e., CH_4 and CO_2), pollutant emissions (e.g., NOx and SOx), and the use of fossil fuels. At the same time, this approach diversify the energy matrix, improve energy security, and generate jobs and income [8,9].

2.1. Feedstock

The feedstocks used for solid biofuel production are composed of lignocellulosic chemicals, classified as agricultural biomass. These are generated from oilseeds and oleaginous fruits, miscellaneous grains, medicinal plants, straw and fodder (e.g., chopped, ground, and pressed cereal chaff and straw). There are many agroindustrial types of biomass, including food and animal industry waste and by-products, including meal, ground parts from milling, pulp, bagasse and other wastes from sugar and alcohol production, oil cakes, feed pelleting waste and forestry biomasses. There is also forest biomass, such as wood and charcoal, firewood, trunks, branches and sticks, particulate coniferous and non-coniferous wood, wood sawdust, wood waste, briquettes and chipping manufacturing waste, bark from charcoal production and raw or debarked wood (e.g., oak, eucalyptus, pine) [10–13].

However, Đurišić-Mladenović et al. [14], categorize the biomass used to obtain wood solid fuel, which include materials from conventional forests and plantations, and non-wood ones as well (e.g., by-products of agricultural and agroindustrial processes).

Forests with eucalyptus and pine plantations stand out in Brazil because they represent a major source of energy in the industrial production chains and productivity varies according to crop management methods and various factors (e.g., vegetation type, plant density, altitude and latitude of the location, land relief, precipitation, humidity, wind, water and nutrients availability). In Brazil, considerable portions of commercial eucalyptus and pine plantations are located in regions subject to longer or shorter drought periods, and usually in regions with low-fertility soils [15–18].

According to Mood et al. [19], lignocellulosic materials have in their structure mainly cellulose, hemicellulose, and lignin, with lower amounts of ash and other compounds, as illustrated in Fig. 1.

According to Embrapa [22], Brazil has the potential to process more than 500 million metric tons of lignocellulosic waste originating from the agrosilvopastoral sector, as well as of raw materials that originate from other activities. The viability of the use of this waste as an energy source in the production of solid biofuels relates to equipment, transport, and places where the biomass is generated. Therefore, it is necessary to analyze the costs involved in its use, to make the process feasible, and to increase the participation of biomass in the Brazilian energy matrix [23].

Brazil is one of the main producers and exporters of agricultural products in the world, which is possible due to its rich tropical heritage. Biologically diverse land contributes to the production and the climate of certain regions. These are factors that, together with agricultural modernization, directly influence the intensity of agricultural practices and the increase in grain and food production in general. Since then, agroindustry has become responsible for the primary food processing, reporting increasingly numbers not only concerning the productive process but also on the waste generation [24].

2.2. Main Brazilian agricultural crops and their waste

The current debate over "fuel vs. food" intensifies the national and global interest in the use of agricultural waste in the biofuels production. This has led to a scenario in which agriculture provides both, without causing scarcity and competitiveness between fuel and food [25].

Based on data published by the Ministry of Agriculture, Livestock, and Food Supply [26], and by the Food and Agriculture Organization of the United Nations [27], among the main crops grown in Brazil, the following stand out: rice, beans, soybeans, corn, wheat, and sugar cane. Table 1 shows the data concerning the cultivated and the harvested area per Brazilian region in hectares, and the total harvested production (tons) based on the information published by IBGE [28], regarding the State Agricultural Production. The amount of waste generated for each of the crops was estimated taking into account the percentage of by-products created during processing for each culture type [29].

The diversity of crops and the quantities produced in each region, varies depending on the climate, soil, planting time, planting density, and seasonality [30]. In Southern Brazil, soy is the most cultivated crop, invariably generating more waste. Northeastern soils are used mainly for corn crops, and according to Costa et al. [31], corn culture has one of the highest percentages of waste production: approximately 620,000 tons in 2012 (Table 1).

According to Espíndola and Cunha [32], soy prevails as an agricultural product in terms of Brazilian exports and is also responsible for increasing the national grain harvest. This indicates that this crop is the leader in large-scale agriculture in Brazil, which is the second largest producer and first exporter of soybeans in the world. Soy corresponds to 49% of the area planted in grain in the country [26], and provides a high volume of hulls, straws, meal, and cake from oil extraction [33].

The Midwest is the dominant soybean producing region in Brazil, with (in 2012) an area under cultivation of 9,014,957 ha, and generating 19,126,996 tons of waste. The literature mentions, among the applications of such waste, its use as a fertilizer, soil conditioner, animal feed, feedstock for ethanol production [33], adsorbent for water purification [34]. enzymes synthesis [35,36], raw material for composting [37], and brick production [38].

In the field of dendroenergy and solid biofuels, these wastes are used as feedstock for pyrolysis to obtain syngas and bio-oil [39,40]; for gasification [41,42]; and to obtain biochar [43–45].

According to Embrapa [46], in addition to soybeans, maize (corn) is a major contributor, accounting for about 80% of the grain production in Brazil. The definitive difference between these two crops is the fact that much of the soy produced is exported, while the corn production is aimed at domestic supply. Corn production has grown at 3% per year, and accounted for 0.4% per year increase in the area of corn plantation. In the country, corn is grown in two different seasons, the first cultivated in summer and the second during the winter, adopting no-tillage techniques and with or without crop rotation [47].

Among the corn producing regions in Brazil, the South stands out as the largest producer, with 4,850,976 ha cultivated in 2012, production of 24,020,568 tons of corn, and generation of 13,931,929 tons of waste (Table 1). According to Owamah and Izinyon [48], this waste includes straw, hulls, cobs, meal, leaves, and grain.

According to the literature, corn lignocellulosic waste can be used as feedstock in anaerobic co-digestion for biogas production [48]; for direct combustion for heat generation, using the ash in construction due to its high silicon dioxide concentration [49]; for benzyl alcohol