Chapter 3

Biomass and its participation in the Brazilian energy matrix

Antonio Francisco Jurado Bellote
Guilherme de Castro Andrade
Hugo Bruno Correa Molinari
José Dilcio Rocha
Márcio Luís Busi da Silva
Ricardo Luis Radiz Steinmetz
Simone Palma Favaro

Introduction

This chapter is linked to target 7.2 of SDG 7: By 2030, increase substantially the share of renewable energy in the global energy mix. This target seeks to provide cleaner energy through renewable energies and, at the same time, allow more people to have access to energy.

This chapter presents contributions from Embrapa to the research and promotion of new biomasses for use in the country's agriculture, as well as studies focused on waste produced in the various Brazilian agribusiness chains as sources of renewable energy.

Energy crops

Energy cultures, or crops, are those in which biomass can be directed toward energy production. Some examples are forests, sugarcane and forage, oilseeds (such as soybeans, African oil palm, and macaúba palm), and microalgae.

Crops with energy potential have been stimulated as more environmentally sustainable alternatives. Several of Embrapa's researches focus on understanding and minimizing the impact of agro-industrial activities on the environment and, in turn, the impact of these activities on these crops, against the possibility of climate change and related biological processes. Examples of these technologies developed by Embrapa: integrated production systems – integrated crop-livestock-forestry systems (ICLFS); eucalyptus varieties (BRS 9402, BRS 9801, BRS 8801, SCSBRS 0201), elephant grass (Cameroon, CNPGL F 06-3, BAG 02), and castor bean (BRS Energia and Gabriela).

Energy forests

In Brazil, forest biomass, represented mainly by firewood, was the main source of primary energy for over 450 years. In the 1950s, wood accounted for 75% of the total energy consumed in the country. Currently, due to the technological availability and the low cost of petroleum products, in addition to the large-scale production of electricity, forest biomass contributes only 8% to the national energy matrix.

Brazil has shown important characteristics to become a reference in energy production from forest biomass. It is located in a tropical region and has climatic and soil conditions suitable for the establishment of forest plantations, and extensive areas with potential for abundant biomass production.

There are currently 8 million hectares of planted forests in Brazil, of which 64% are eucalyptus forests present in over 500 Brazilian cities (Indústria Brasileira de Árvores, 2015). Current Brazilian demand is around 350 million cubic meters of wood, with eucalyptus forests accounting for only a third of the total annual demand. The use of planted forests in Brazil has grown significantly in recent years, mainly in the cellulose and paper segment and in the charcoal industry. Brazil has a broad technological domain on planted forest silviculture, with national and international recognition.

Embrapa develops research aimed at diversifying the potential species for biomass production, increasing productivity and reducing the impacts arising from this activity. This puts Brazil at a competitive advantage in global renewable energy production. However, it is still necessary to promote more actions to sustainably develop its production chain. This necessarily involves the prospecting, analysis and development of technologies aimed at increasing the production and quality of biomass, together with improving the processing, transformation and applications of its energy products. However, there is a lack of consolidated long-term public policies to leverage the use of bioenergy in Brazilian agribusiness. Currently, there is hope in this field with the implementation of the Política Nacional de Biocombustíveis (National Biofuels Policy – RenovaBio, Law 13,576/2017), announced as a new legal framework for biofuels in Brazil. According to the Ministry of Mines and Energy (Brasil, 2017), the RenovaBio program is a state policy aimed at drawing up a joint strategy to recognize the role of all types of biofuels in the Brazilian energy matrix, both for energy security and to mitigate and reduce greenhouse gas emissions.

In recent years, although Embrapa has participated in advances in technology development, there are still important challenges to be faced, such as: a) supply of germplasm to implement forests adapted to the different realities of the Brazilian territory; b) increased silvicultural knowledge to raise crop productivity, both in integrated and non-integrated systems; c) improvement of the technological level usually adopted in traditional forms of converting wood into energy, such as firewood and charcoal; d) advancement in the knowledge and development of technologies of high added value, such as wood alcohol, bio-oil and others. All this is aimed at the production of more elaborate energetic products destined to more specific applications from the wood.

Sugarcane and fodder

Sugarcane (*Saccharum officinarum*) and some other fodder can be used as biomass to produce renewable energy, mainly ethanol. Brazil has already mastered the technology to produce the first-generation ethanol (1G ethanol) and has the industrial infrastructure and knowledge necessary to implement the production of second-generation ethanol (2G ethanol) from sugarcane biomass. The major challenge in this regard is biomass recalcitrance, that is, the rigidity provided by the chemical structure of biomass components, which prevents the release of fermentable sugars. Thus, it is necessary to investigate and develop new varieties of plants that have less recalcitrance in their biomass.

In this context, Embrapa Agroenergy has been a pioneer in the development of new biotechnological tools to develop new sugarcane varieties with greater accumulation of biomass and less recalcitrance. The use of gene-editing technology, which does not involve the creation of genetically modified organisms (GMOs), has been developed and used for the genetic engineering of sugarcane with the aforementioned characteristics (Waltz, 2016). In addition, the development of new varieties that have greater efficiency in the use of water has also been carried out at the Embrapa Unit. This is an essential factor for the cultivation of sugarcane in marginal, poorly irrigated areas that are not intended for food crops. Besides cane, other fodder species have also been studied to produce biofuels.

The genetic variability of tropical fodder found in Brazil allows the study of several genotypes that can be used to produce ethanol, together with integrated industrial processes that fit into the reality of the sugarcane industry. The integration of these processes also involves the cogeneration of energy, such as the electric energy generated in the sugarcane bagasse mills. The development of these processes at Embrapa is through public-private partnerships with the sugar-energy sector, and this will enable the viability of cellulosic ethanol on a commercial scale. In addition, events with the participation of political actors are also in the strategic plans of Embrapa, for an expansion of scientific knowledge combined with public policies that may lead to a substantial increase in Brazilian participation in the development of renewable energy in the global energy matrix.

Oilseeds

The implementation of the Programa Nacional de Produção e Uso de Biodiesel (National Program for the Production and Use of Biodiesel – PNPB) in Brazil in 2005 led to the partial and progressive replacement of fossil fuels for heavy vehicles in Brazil (Brasil, 2005). Oils and fats are the core renewable raw materials for the production of biodiesel (Othman et al., 2017). The immediate availability of renewable fatty source in Brazil relied on soya, Brazil's main agricultural crop. However, dependence on a single crop, whose oil yield per planted area is low (approximately 500 kg/ha), has led to the need for alternative sources with higher energy density. Multidisciplinary and multi-institutional projects were and are being conducted by Embrapa, in order to create technologies for other oil bearing plants with high yield potential. The researches encompass the domestication of native species such as the macaúba palm (*Acrocomia* spp.), which has an oil production potential higher than 4,000 kg/ha (Cardoso et al., 2017) and can be cultivated as a single crop as well as agroforestry and livestock integration systems in several biomes, such as the Semiarid region and *Cerrado*. The domestication of exotic species such as the physic nut (*Jatropha curcas*) and tung tree (*Vernicia fordii*) are also being studied. Projects to increase palm cultivation (*Elaeis guineensis*, of African origin; *Elaeis oleifera*, of American origin) – which, despite the traditional cultivation and high oil yield (Brazilian average of 3,500 kg/ha), is restricted to areas of high rainfall found in the Amazon and Recôncavo Baiano regions – are underway and involve from genetic improvement to the use of waste. Germplasm banks of macaúba palm, physic nut and African oil palm make up important assets of Embrapa to subsidize studies with these species.

In addition to Embrapa Agroenergy, several other Embrapa Centers are working together in these studies, in order to strengthen this line of research, development and innovation. As a result of this effort, the macaúba productive chain was promoted in the states of Mato Grosso do Sul, Minas Gerais and in the semi-arid state of Ceará (Sousa et al., 2019). Commercial scale macaúba plantations are being established in Minas Gerais (Cipriani, 2017), and public policies for extractive exploitation have been established and already benefit family farmers (Brasil, 2014). Annual crops are also under study. An example, is the work for the tropicalization of canola (*Brassica napus*), envisaging its cultivation in Central Brazil (Laviola, 2017).

Microalgae

Embrapa has also been active in algae research. For example, the Nextbio Project has as a target, in addition to oilseed plant species, the improvement and algal culture systems for the production of lipids (Laviola, 2017).

There is great global interest in exploiting the biotechnological potential of microalgae. However, one of the major limitations in the production of this type of biomass on a large scale is the high cost of the nutrients needed to formulate the culture medium.

The use of livestock effluents as an alternative source of the culture medium is adequate for the growth of microalgae and can be promisingly applied for large-scale biomass production. Concurrently with the microalgae production process, the nutrients present that may potentially cause eutrophication of the water bodies are partially removed, reducing or eliminating the environmental impacts from livestock activities.

The microalgae produced during the treatment of effluents are collected and can serve as feedstock for the production of ethanol (at 0.5 g/g of sugar per microalgae), animal feed (contains 56% proteins), and/or methane when algae are used as substrate for anaerobic digestion generating 0.6 L/g of methane per microalgae.

Therefore, effluent treatment systems based on the production of microalgae can become a sustainable and economically attractive option, presenting itself as an interesting opportunity in the agribusiness business portfolio.

Waste

Waste from agribusiness production chains, including industrialization and even the end consumer, poses a major threat to the environment, and the health and quality of life of people. However, with the use of appropriate technologies, they can be harnessed in distributed energy production, thus generating clean, renewable and quality energy in places normally far away from the large production centers.

Use of agricultural, forestry and agro-industrial waste

Wastes are raw materials that do not have viable uses yet, both from a technical and an economic point of view. The challenge is to transform the byproduct of one process into another, providing the full use of resources, generating income and jobs, reducing pressure on the environment, and increasing the profitability of the enterprise. Embrapa's Research and Development (R&D) and Technology Transfer professionals have always been involved in the search for technological solutions applied to the conversion of waste into products with higher added value.

The generation of energy with organic waste can take place via thermal or biological processes, universally known as bioenergy and biofuel. Agricultural wastes are related to crops for the production of food, fiber or biofuels, such as sugarcane straw, rice straw, ratoon cotton, etc. Livestock wastes are mainly animal manure, chicken litter, etc. Forest wastes are the remains of forestry, such as thin branches, leaves, bark, etc. The industrial residues are sugarcane bagasse, vinasse, rice husk, tallow, sawdust, shavings, black liquor (cellulose industry), the result of oil extraction by pressing, coconut husk, corn husk and cob, peanut shell, etc. Municipal solid wastes (MSW) are the organic fraction, sludge from sewage treatment plants, used frying oil, pruning of urban trees, etc.

To quantify agricultural waste, there are indexes that relate the agricultural production of each product to the amount of waste generated. For example, for rice it is 30% of husk, considering rice production in the shell (IBGE, 2015). According to Balanço... (2016) the following information is given: for coconut, an average weight of 500 g per unit is considered, with 60% waste; for livestock waste, there are also amounts of manure per animal head; for MSW there are several studies, and the average value in Brazil is about 1 kg/inhabitant/day. In the case of sugarcane bagasse, which is widely used in cogeneration (heat and electricity), the country produced 121 million tons in 2016 and consumed all of this to generate energy; another waste is the black liquor, with 16 million tons produced that year and consumed for energy generation (Balanço..., 2016). Figure 1 presents several agricultural products characteristic of Brazil with their respective production and generated residues.

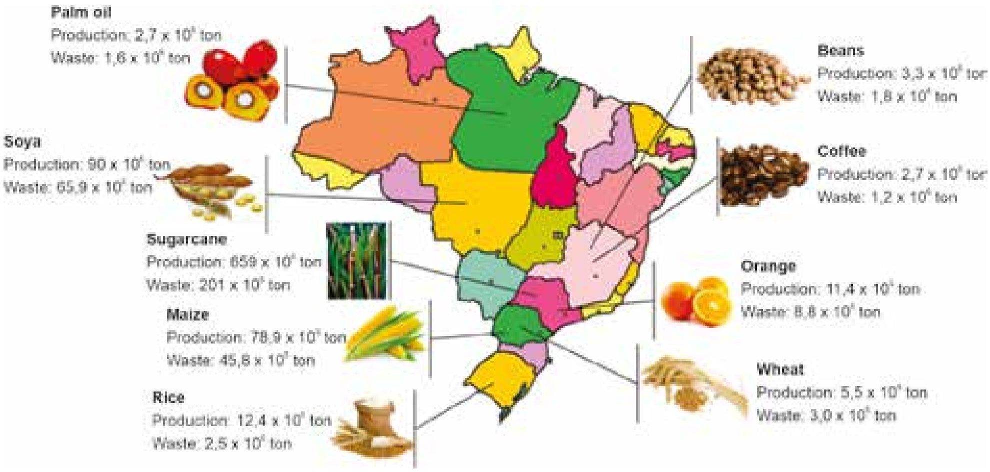

Figure 1. Estimate of agricultural production in Brazil and its respective waste production.

Source: Conab (2017).

Cogeneration technologies are well known and use steam cycle boilers, steam and gas turbines. Compaction by baling, briquetting or pelletizing can be used as a logistics solution. Waste with high moisture content, such as manure, vinasse, and municipal solid waste, can be used as a substrate for anaerobic fermentation in a biodigestor to produce biogas with a high methane content, to converse into energy (electric or thermal), as well as producing biofertilizers.

Livestock waste

Animal production in Brazil has undergone several changes in the last 3 decades, migrating from subsistence systems to industrial systems based on animal confinement (Kunz et al., 2009). This trend has placed the country as the second largest producer and world leader as an exporter of chicken meat, with 13 million tons produced and 4.3 million exported in 2016 (Associação Brasileira de Proteína Animal, 2017). Regarding egg production, it has surpassed 39 billion units, and, for turkey meat, there were over 367 thousand tons in 2016, of which 38% were exported (Associação Brasileira de Proteína Animal, 2017). According to the Central de Inteligência em Aves e Suínos (Poultry and Swine Intelligence Center), Brazil stands out as the fourth largest producer and exporter of pork in the world, surpassing 3.7 thousand tons of protein produced annually (Embrapa Suínos e Aves, 2017). In addition, the intensive raising of dairy cattle is in full development (Mao et al., 2015). Between 1996 and 2013, there was approximately 40% increase in milk production in Brazil (Cavicchioli et al., 2015). The Brazilian production of this product in 2014 was 35.2 billion liters (IBGE, 2015).

Thus, based on its large production volumes as an important economic source, intensive livestock production is highly representative of waste generation. Animal waste and other waste related to the production of these animals need alternatives for treatment and disposal to mitigate the environmental impacts. As a comparison, by rule, a pig has a polluting potential equal to ten people (considering nitrogen). Among the treatment routes, we note its potential as a source of energy in a consortium with the use of nutrients in soil fertilization (Kunz et al., 2009).

The biological route is a highlight in this context, especially due to the opportunity to convert organic matter from cattle and pig waste into biogas, but there is also an opportunity for thermal energy use (e.g., poultry and/or turkey litter, litter bed overlapping of pigs or even byproducts of cattle *compost barn* systems). Although it currently accounts for only 0.9% of the Brazilian renewable electricity matrix, it is estimated that the biogas generation potential from animal waste is higher than the generation capacity of the Itaipu hydroelectric plant. The challenge consists of logistics for the use of this raw material, which has been instigated through public policies such as the Plano de Agricultura de Baixo Carbono (Low Carbon Agriculture Plan – ABC) (Brasil, 2016) and the RenovaBio Program (Brasil, 2017), with direct contributions from Embrapa through technical-scientific information.

Embrapa has developed research to improve the energy use of these wastes through laboratory structuring and networks coordination, such as the Rede BiogásFert. This network, for example, has been studying and organizing information regarding technologies to produce and use biogas and fertilizers from the treatment of animal waste under the Agricultura de Baixa Emissão de Carbono (Low Carbon Emission Plan – ABC) and is, therefore, directly linked to SDG 7.

Final considerations

Embrapa has been active on several fronts, seeking to obtain and optimize energy sources from plant biomass, which can be called energy crops. New varieties developed and adapted to the different Brazilian biomes have been studied with very promising results.

From the perspective of agricultural waste, due to its tropical condition, our country is immensely competitive when compared to other nations (e.g., the European community), and this potential has been addressed by adapting and developing alternatives to Brazilian conditions.

Therefore, the increase in the share of renewable energies in the energy matrix has a direct impact by reducing emissions and, because of their distributed nature, by bringing energy to more needy regions.

Embrapa's future challenge is to continue current research and offer other types of crops with which farmers can generate more income in the field, making it possible to use this biomass as an energy source.

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