ISSN 2359-6562 (ONLINE) 2359-6562 (CD-ROM)

POTENTIAL OF AGROENERGY RESIDUES FOR THE GENERATION OF BIOGS IN THE STATE OF TOCANTINS

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SUMMARY: Concerns over the depletion of traditional fossil energy sources and the consequent greenhouse effect generated by the use of fossil fuels have increased, creating a need to search for alternative sources of clean energy. Thus, this work had the objective of portraying the potential of residues from agroenergy in the State of Tocantins for generation of Biogas. This article was developed under the principle of the exploratory study, through data surveys from the State. The agroenergy residues researched were soybean, cassava (manioc), rice, sugarcane, maize, sorghum and beans. The energy potential of the studied residues represents 3,56% of the energy generation capacity by biomass sources. The source of highest agroenergy potential for biogas generation was maize, with an energy capacity of 498.90 MW. The use of biomass as an energy source presents itself as an interesting alternative in the survey carried throughout this work.

Keywords: bioenergy, biofuels, biomass.

POTENCIAL DOS RESÍDUOS AGROENERGÉTICOS PARA A GERAÇÃO DE BIOGÁS NO ESTADO DO TOCANTINS

RESUMO: A preocupação com o esgotamento das tradicionais fontes de energia fósseis e com o consequente efeito estufa gerado pela utilização dessas têm se tornado cada vez maior, o que torna necessária a busca de fontes alternativas de geração de energia limpa. Desse modo, este trabalho teve como objetivo retratar o potencial dos resíduos agroenergéticos do Estado do Tocantins para a geração de Biogás. Este artigo foi desenvolvido sobre os preceitos do estudo exploratório, por meio de levantamentos de dados do Estado. Os resíduos agroenergéticos pesquisados foram a soja, mandioca, arroz, cana-de-açúcar, milho, sorgo e feijão. O potencial energético dos resíduos estudados representa 3,56% da capacidade de geração de energia por fontes de biomassa. O maior potencial agroenergético para a geração de biogás foi do milho com capacidade energética de 498,90MW. A utilização da biomassa como fonte de energia torna-se uma alternativa interessante no levantamento realizado neste trabalho.

Palavras-chaves: bioenergia, biocombustíveis, biomassa.

1 INTRODUCTION

Brazil's potential in generation and use of energy sources other than oil has been known for a long time; but it was only in the 1970s that these sources began to be valued due to the global oil crisis. Hitherto this was the most widely used fuel in the world (KARLSSON et al., 2014).

Considering the search for environmentally correct waste disposal options and the need for expansion and diversification of the Brazilian energy matrix, the use of clean energy from biomass is a current and important issue (ANDREAZZI et al., 2017).

The growing increase in world energy consumption favors the search for renewable energy sources. One of the existing options for growth and sustainable development of this source is through the use of biomass as input (SANTOS et al., 2017).

The expressive supply of biomass as an energy resource in Brazil is essentially linked to integrated agricultural, agroindustrial and

Recebido em 27/07/2018 e aprovado para publicação em 15/02/2019
DOI: http://dx.doi.org/10.17224/EnergAgric.2019v34n1p67-81

silvicultural production systems. Brazil is a country that presents a biomass production with enormous energy potential (SANTOS et al., 2017).

Although traditionally agricultural residues are left on the ground to restructure the soil, recent research has focused on the potential of using these waste products to generate energy from the production of biofuels, including biogas (CAILLOT, 2017).

Considering the above and the current energy context, the continuous development of techniques aimed at obtaining new renewable energy sources and increasing energy concentration is becoming increasingly necessary.

Studies related to the production of biogas from waste are isolated, mostly carried out in a laboratory. There is a gap regarding a bibliographic study that brings together these researches and identifies the operational conditions of production that result in greater production of biogas.

This research consisted of a literary review with the purpose of portraying the potential of the main agroenergy residues from the State of Tocantins for generation of Biogas.

2 MATERIALS AND METHODS

This work analyzes and projects the potential of use of agroenergy residues from the State of Tocantins as a sustainable energy alternative for the generation of Biogas.

To begin the survey, agroenergy residues were selected from soybean, cassava (manioc), rice, sugarcane, corn, sorghum and beans produced in the State of Tocantins .

The collection of information for the production of this work was gathered from the databases of the Capes Periodicals Platform, among other materials related to the subject.

The main terms used for the research were: agroenergy, biomass, biogas, agroenergy crops, bioenergy, renewable energy.

3 RENEWABLE ENERGY SOURCES

Energy, in its most diverse forms, is indispensable for the survival of the human species. And, rather than surviving, man has always sought to evolve, discovering sources and alternative ways of adapting to the environment in which he lives and to attend to his needs. Thus, the exhaustion, scarcity or inconvenience of a given resource tend to be offset by the emergence of another (PIÑAS et al., 2016).

Currently, the production and consumption of energy are strongly based on highly polluting fossil fuels that generate greenhouse gases (GHG), representing risks for the planetary supply in the long-term. It is therefore necessary to stimulate the production of renewable energy sources (ALBARRACIN, 2016).

Non-renewable fuels such as oil, coal, natural gas, mainly result in serious environmental problems in their various uses. Fossil fuels are exhaustible, polluting, expensive and controlled by few countries that hold mines, wells and processing technologies (LOPES; BRITO; MOURA, 2016).

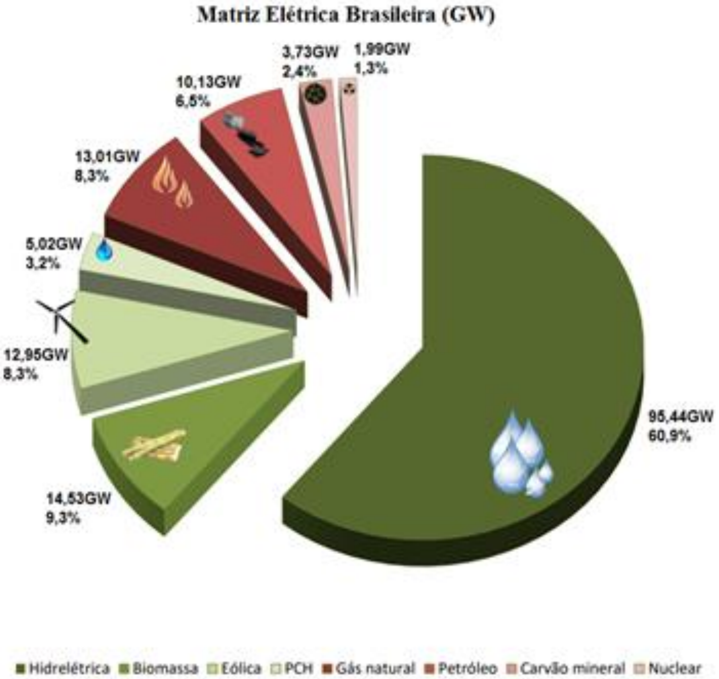
The replacement of fossil fuels by biofuels has been extremely important worldwide to stimulate the growth of economies based on sustainability through the use of renewable resources (MORAES; ZAIAT; BONOMI, 2015).

In a worldwide comparison, the Brazilian energy matrix is considered to be clean by the intensive use of renewable energy sources. In this aspect, biomass is highly representative, however, it still does not receive the deserved prominence in the national energy balance (BRAND et al., 2014).

In a national context, approximately 37% of Brazil's gross domestic energy supply came from renewable sources, of which 26%, in relation to the total energy consumed, correspond to energy from biomass (EPE, 2015b). Thus, the diversification of the energy matrix and the use of renewable sources are becoming increasingly necessary to meet this demand.

According to ABEEÓLICA (2018), the Brazilian Electrical Matrix presents a Renewable-Thermal configuration and started the month of February 2018 with the capacity of 140.95 GW of energy generation through renewable sources, the share of these sources in the matrix reached 90% (Figure 1).

Figure 1. Brazilian Electrical Matrix in GW. **Source:** ABEEólica (2018).



The main resources for electricity supply are hydroelectric plants followed by biomass (mainly sugarcane), natural gas, wind energy, oil, small hydroelectric plant, coal and finally nuclear power.

The main problem for the adoption of new technologies is the lack of governmental incentive, considering that the country is one of the world´s largest food producers and has an enormous variety of available biomass. If existing subsidies are expanded, Brazil could establish itself as a power in usage of waste, consolidating the formation of a diversified green energy matrix (INÁCIO, 2016).

Anaerobic digestion of organic waste is becoming more important as an energy source and waste treatment (BACHMANN et al., 2016). Biomass is one of the most promising alternatives for renewable energy generation (LOPES; BRITO; MOURA, 2016).

Among the sources of sustainable energy, biomass, which can be characterized as any organic matter that can be transformed into thermal, mechanical or electrical energy, has been used since the beginning of human civilization (SANTOS et al., 2017).

4 BIOMASS

The amount of biomass produced in Brazil is significant, reaching 1 Gt in 2030. However, biomass residues generated from agroindustrial activities are still under-exploited, commonly left for natural decomposition, without harnessing the energy contained in them, generating important environmental liabilities (MORAES et al., 2017).

The term biomass is generically used to refer to a series of substances derived from living matter (animal or vegetable) that have the property of decomposing (by biological effect) under the action of different types of bacteria (VICTORINO, 2017).

Brazil has characteristics that are suitable for production of biomass for energy purposes since its economic base is turned to agricultural activity, besides being a worldwide precursor of this technology (TÁVORA E SILVA; SIQUEIRA; SIQUEIRA, 2018).

However, the conversion of biomass into several products with aggregated value for the use of agroindustrial residues and generation of less environmental impact still depends on the development and implementation of sustainable processes at economically viable levels (MORAES et al., 2017).

Biomass in Brazil can be classified as biomass of forest origin, of agricultural origin or of urban and industrial waste (SANTOS et al., 2017).

According to Moraes et al. (2017), biomass is the most important source of renewable energy in the world. When used for energy purposes, biomass is classified into three categories:

a) forest energy biomass, their products and by-products or waste;

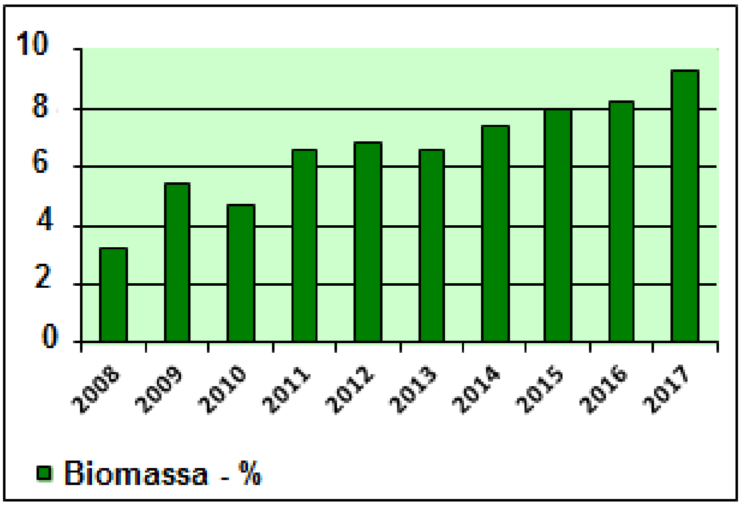
b) agricultural energy biomass, agroenergy crops and residues and by-products of agricultural, agroindustrial and animal production activities and;

c) urban waste (pruning and sweeping).

In order to promote more intense development of this energy source, information on the productive capacity of biomass for energy use and the potential risks of its use for the environment compared to other energy sources is required. It should also be verified whether there will be social and economic gains through generation of employment and income from creation and development of the waste market (BRAND et al., 2014).

Yearly the use of biomass as an energy source has been increased in Brazil as can be seen in Figure 2.

Figure 2. Increased use of biomass as an energy source in Brazil.



Source: Adapted from EPE, 2015a.

This increase is mainly due to research on the production of biofuels such as ethanol.

5 BIOGAS AND BIOFERTILIZER

Defined by Article 3 of the ANP Resolution # 08/2015 as the raw gas obtained from biological decomposition of products or organic residues, biogas represents the end product of a chain of well established anaerobic digestion processes (ABIOGAS, 2015).

Biofuel production is strongly recognized worldwide as a source of renewable energy to reduce the unstable oil market (RABONI; VIOTTI; CAPODAGLIO, 2015).

Biogas is a source of energy that can be obtained from various industrial, agricultural and forestry activities, and also from municipal solid waste (ALBARRACIN, 2016).

Biogas (methane) is a renewable and versatile energy source since it can be used in adequate burners (biogas stoves) for heating and cooking, in biogas lamps for lighting, or in its purified form for generation of electric energy or as vehicular fuel (VICTORINO, 2017).

Biogas is a gaseous mixture with potential fuel, composed mainly of methane (CH4) and carbon dioxide (CO2), which can be used in the generation of electric energy and heating (CALZA et al., 2015).

According to Calza et al. (2015), the generation of electric energy can be done by burning biogas in properly adapted turbines, microturbines and in Otto cycle and diesel engines, being considered a clean energy source and suitable for use in rural properties .

The composition of the substrate is important for the quantification and quality of biogas, which is directly linked to the amount of nutrients and potential contaminants (metals, pathogens, organic contaminants contained in organic matter). The choice of the right material influences the process´ result, the maximization of energy production and the good quality of biogas (KARLSSON et al., 2014).

Biogas is obtained through treatment of substrates through the anaerobic digester. There are different models of anaerobic biodigesters. Normally the models differ in number of compartments and automation (CAILLOT, 2017).

Anaerobic digestion for production of biogas is recognized as a clean technology that combines the adequacy of the residues to the generation of energy, fulfilling the requirements of a sustainable alternative to provide optimization of biofuel production (MORAES; ZAIAT; BONOMI, 2015).

Biogas, produced by conversion of organic matter contained in the natural cycle of earth, must be decomposed so that it does not emit gases that contribute to increase of the greenhouse effect (KARLSSON et al., 2014).

According to Inácio (2016), in world terms, the most applied form of biogas generation from biomass is by the use of biodigesters.

Biodigesters are reactors in which the organic matter contained in effluents is metabolized by anaerobic bacteria. This process produces two elements: biogas, composed mainly of methane gas and carbon dioxide, making it an alternative energy source; and biofertilizer, which, in addition to its use as a nutrient source, is an important soil conditioning agent (GOMES et al., 2014).

The use of biodigesters for recovery of biogas is seen as one of the most appropriate treatments for the disposal of waste, both from agriculture and agroindustries (AVACI et al., 2015).

The degradation of organic matter in a biogas process also generates waste, but of good quality, which can be used as biofertilizer (KARLSSON et al., 2014).

After the process of obtaining biogas inside the biodigester, the fermented biomass leaves the interior of the biodigestor in liquid form with great fertilization power. The biomass residue used in the process becomes a biofertilizer, rich in nutrients, with significant levels of nitrogen, phosphorus and potassium (SANTOS et al., 2017).

Compared to chemical fertilizers, the use of biofertilizers is relatively new and therefore there is still a need for development of technologies and research (KARLSSON et al., 2014).

The nutritive value of biofertilizers, that is, the concentration of different final products, depends on the substrate used in the biogas process and how this will be executed (KARLSSON et al., 2014).

6 AGROENERGY RESIDUES FOR THE GENERATION OF BIOGAS AND PROJECTION OF THE STATE

Increasing public concern about preservation of the environment has stimulated a worldwide search for more sustainable agricultural practices and alternative sources of energy. However, only few countries have fullness of natural resources to produce large quantities of energy crops without compromising their food production capacity (SILVA; ABUD, 2016).

Agriculture in Brazil, historically, is one of the main basis of the country's economy, from the beginnings of Portuguese colonization up to the twenty-first century, evolving from large monocultures to diversification of production (INÁCIO, 2016).

Waste from the agricultural sector can be used for animal feeding, as well as input for other products. The generation of energy is also an important alternative for the use of some residues, and can become a renewable source option, contributing to the Brazilian energy matrix (INÁCIO, 2016).

The social sustainability of biofuel production is closely linked to competition for arable land by energy crops rather than food production (RABONI; VIOTTI;

CAPODAGLIO, 2015).

The possibility of using agroenergy waste and aggregating value to their respective production chains can be a determining factor for economic viability of the activity. Therefore, aspects such as amount of residue generated, chemical-bromatological composition, storage techniques, transport and stability during storage should be studied to guide the applicability and development of technological processes for the adequate destination of the same (TÁVORA E SILVA; SIQUEIRA; SIQUEIRA, 2018).

The viability of usage of exploitable agricultural residues should be carefully evaluated, a percentage of these residues should remain in the plantation area in order to contribute to soil protection between harvesting and re-planting periods, to retain soil moisture, to protect the biota, to avoid erosion and to restore nutrients that were extracted by the plants (EPE, 2015a).

Several studies have been carried out to promote the adequate use of non-fossil fuel sources.

In this way, energetic use of waste should be considered as an option when waste is already generated and is an environmental problem. One of the consequences of this is that waste discarded in the course of production and consumption activities does not simply disappear, it becomes other substances that are harmful to the environment and human health (VICTORINO, 2017).

6.1 Agroenergy production in the state of Tocantins

In 2011, the Tocantins Government created the Agroenergy Sector, with the objective of structuring and encouraging agroenergy production in the state, based on knowledge and systematization of information, support for research, training of services and producers, dissemination of technologies, debureaucratization of environmental processes, credit support and structuring of production poles (SEAGRO, 2018).

In the Seagro website, a 2016/2017 data on the harvest of the main crops of the State of Tocantins was reported, as observed in Table 1.

Table 1. Main Cultures of the 2016/2017 Harvest in the State of Tocantins.

Main Cultures (2016/2017 harvest)	
Soybean	2,827.10 thousand tons
Cassava	49,730 ton
Rice	676 thousand tons
Sugarcane	2,348.40 thousand tons
Maize	902 thousand tons
Sorghum	55.5mil ton
Beans	71.6 thousand tons

Source: Seagro (2018).

Taking into account that these are the main crops in the State of Tocantins, it is possible to make a comparison of the potential of each of these agroenergy residues for the generation of biogas.

It is important to note that the results of quantification of energy potential generated from the residues of some of the crops considered are only illustrative and serve to demonstrate the magnitude of the energy potential that a given biomass has. That is, in order to analyze the possibility of using these potentials it would be necessary to verify several other economic, financial, regulatory, logistic and technical issues, among others that were not analyzed in this research.

6.1.1 Soy

Soybean agricultural residues remain in field and are treated as straw, consisting of stems, leaves and pods. Soybean straw contains a sufficient amount of cellulose, hemicelluloses and lignin for the production of a variety of biomaterials, biofuels and biochemicals. Soybean processing also generates a significant amount of cellulose residues such as straw, fibers, hulls and molasses, byproducts of the soybean oil and protein production process (CAILLOT, 2017).

Martins (2015) estimated that for each hectare of soybeans produced, about 3.0 to 4.0 tons correspond to plant biomass residues, in order words, remains from soybean culture.

For these values, it is estimated that there was a generation of 11,308.4 tons of residues from the soybean harvest in the 2016/2017 harvest in the state of Tocantins as observed in Table 2.

Table 2. Energy potential of soybean crop residues.

Parameter	uUnit	Value
Soybeans	Ton	2.827,10
Residues from harvest	Ton	11.308,4
Methane¹	m^3/kg	0,24
Methane	10^3m^3	2.714,02
Energetic potential²	TJ	97,41

Source: ¹ Morgado et al. (2013); ² Calorific value of methane: 35,89MJ/m^3

The energy potential of soybean waste is 97.41 TJ, equivalent to 27,058 GWh.

6.1.2 Cassava

Among the several byproducts generated in cassava processing are manueiras, a light yellow milky liquid resulting from the pressing of the grated manioc roots mass used for flour production and the process of extraction and purification of starch (DUARTE et al., 2013).

Manueira is a liquid residue from cassava pressing and presents high pollutant potential due to the amount of glucose and fructose, presenting a pollutant potential 25 times higher than that of domestic sewage (SANTOS et al., 2012).

It is considered as potentially pollutant waste and toxic to the environment due to its organic load and linamarine, which is a cyanogenic glycoside, from which originates the hydrocyanic acid (HCN), which can cause serious environmental problems, such as: reduction of dissolved oxygen, eutrophication of water bodies and death of aquatic fauna (DUARTE et al., 2013).

According to Santos et al. (2012), a ton of cassava produces about 300 L of manipueira. In the State of Tocantins, 14.919 m^3 of manipueira relative to the 2016/2017 harvest can be generated (Table 3).

Table 3. Energetic potential of *Manipueira.*

Parameter	UUnit	Value
Cassava	Ton	49.730
Manipueira	m^3	14.919
COD¹	kg/m^3	1,28
COD	Ton	19,1
Removal rate¹	%	92
COD	ton	17,57
Methane¹	m^3/kg	0,397
Methane	10^3m^3	6,98
Energetic potential²	GJ	250,324

Source: ¹ Larsen et al. (2013); ² Calorific value of methane: 35,89MJ/m^3; COD: Chemical Oxygen Demand

Thus, as observed in Table 3, the potential of the cassava residue for generation of biogas would be 250.32 GJ representing 69,534 MWh.

6.1.3 Rice

Rice straw remains in the field after harvest. Regarding residues from the processing of rice, the peel and the bran are prominent (CAILLOT, 2017).

The production of residues in the rice crop is related to the straw and, mainly, to the peel, which corresponds to approximately 20% of the rice weight (SOUZA et al., 2017).

In view of the above, the high percentage of organic residues from rice residues, as well as other lignocelluloses, make this residue a potential source for bioenergy generation.

According to Probiogás (BRASIL, 2015), there is great potential for generation of energy from vegetal residues, since they contain high contents of organic matter and the potential for methane production of some substrates can be characterized according to the content of SV / ST solids (volatile solids to total solids).

According to the 2016/2017 rice harvest, the State of Tocantins generated 135.2 thousand tons of rice residues such as peel and straw as can be seen in Table 4.

Table 4. Energy potential of the bark and rice straw.

Parameter	Unit	Value
Rice	mil Ton	676
Peel and straw	mil ton	135,2
Methane[1]	m^3/kg	0,041
Methane	$10^3\ m^3$	5543,2
Energetic potential[2]	TJ	198,95

Source: [1] Probiogás (BRASIL, 2015); [2] Calorific value of methane: 35,89MJ/m³

This rice residue has an energy potential of 198.95 TJ representing 55.27 GWh.

6.1.4 Sugar cane

Regarding the sugarcane vinasse, the use of anaerobic digestion as a treatment method has been rare due to the fact that most of the vinasse was used in an "in natura" state for the fertirrigation of sugarcane plantations. Vinasse has been directly applied to the soil due to its valuable phosphorus content, although the long-term effects of this activity are still unclear, and transportation costs are high (CHRISTOFOLETTI et al., 2013).

Application of anaerobic biodigestion technologies for the treatment of sugarcane vinasse did not prove advantageous due to the small gains involved in the use of biogas in generation of electric energy. Currently, it is receiving more attention mainly due to environmental gains, but scientific progress on this topic is still unsatisfactory, with several questionable or conflicting studies (MORAES; ZAIAT; BONOMI, 2015).

The amount of sugarcane produced in Tocantins in the 2016/2017 harvest was 2,348.40 thousand tons and a production of 260 thousand tons of ethanol can be estimated. The production of each liter of alcohol generates, on average, 13 liters of vinasse that has a high organic load reflected in the chemical oxygen demand (COD) of approximately 25 kg / m³.

There are some studies in Brazil about the energetic use of vinasse. According to the methodology proposed by Schvartz (2007), it was possible to calculate the energy potential of vinasse generated in the 2016/2017 harvest in the State of Tocantins as can be observed in Table 5.

Table 5. Energetic potential of vinasse.

Parameter	Unit	Value
Sugarcane	Thousand Ton	2.348,40
Ethanol	Thousand Ton	260
Vinasse	m³	3.380
COD[1]	kg/m³	25
COD	Ton	84,5
Removal rate[1]	%	72
COD	Ton	60,84
Methane[1]	m³/kg	0,3
Methane	m³	18,252
Energetic potential [2]	MJ	655,065

Source: [1] Solomon (2017); [2] Calorific value of methane: 35,89MJ/m³; COD: Chemical Oxygen Demand

According to the data presented in Table 2, the sugarcane residue potential for biogas generation is 655.065MJ corresponding to a potential electricity of 0.182KWh.

6.1.5 Maize

Like all agricultural production, the production of maize generates a large amount of waste, which is left in the field and not reused. It is estimated that for each ton of harvested maize, between 2.2 and 2.7 tons of stems and leaves are produced, as well as between 0.3 and 0.9 tons of corn. Considering the great variation in the production of total biomass of the plant, influenced by the cultivars used and conditions of crop management among the varieties in use, there are records of production of up to 6 tons of waste per ton of corn grains (DIONÍZIO, 2017).

The 2016/2017 corn harvest in the state of Tocantins was 902 thousand tons and the harvest residue reached 5,412 thousand tons as observed in Table 6.

Table 6. Energy potential of maize crop residues.

Parameter	Unit	Value
Maize	10³ Ton	902
Harvest residues	10³ ton	5.412
Methane[1]	m³/kg	0,081
Methane	10^6 m³	438,372
Energetic potential [2]	TJ	15.733,18

Source: [1] Probiogás (BRASIL, 2015); [2] Calorific value of methane: 35,89MJ/m³

The methane production potential generated by the maize crop residues is 81m³ / ton, that is, a production of 438,372 m³ / year of methane with an energy potential of 15,733.18 TJ or 4,370,33 GWh.

6.1.6 Sorghum

The cereal has been gaining relevance in the national market due to the expansion of its production process and its strengthening as an alternative culture to corn in the production of silages and grains (GALVÃO et al., 2015).

After the usage of its sugars for bioethanol production, biogas can be produced from sorghum silages, for a better valorization of this energy culture, using the anaerobic digestion process (BARBOSA, 2015).

Currently sorghums used for silage production are selected according to their production of green mass per hectare and, mainly, the proportion of grains present in their constitution, since these account for the largest available energy fractions of the plant.

The energy potential of biomass (broth, bagasse, straw and grains) is high, and all sorghum energy can be transformed with current technology (DURES et al., 2012).

For this study, sorghum grain quantity was used to evaluate the potential energetic potential of sorghum in the biogas generation, since it was not possible to obtain sorghum harvest data for silage, which includes leaves, stems and grains. Table 7 shows the energy potential of sorghum for the generation of biogas.

Table 7. Energetic potential of sorghum.

Parameter	Unit	Value
Sorghum	10^3 Ton	55,5
Methane[1]	m^3/kg	0,15
Methane	$10^3 m^3$	8.325
Energetic potential [2]	TJ	298,784

Source: [1] Barbosa (2015); [2] Calorific value of methane: 35,89MJ/m³

Thus, a production of 55,500 tons of sorghum would yield a production of 8,325,000 m² of methane with an energy potential of 298,784TJ, or 82,995GWh.

6.1.7 Beans

No studies were found on bean harvest residues for bioenergy generation, in particular, biogas. However, in 2012 the Institute of Applied Economic Research (IPEA) prepared a diagnosis of organic residues in the agrosilvopastoral sector and associated agroindustries in which it describes a calculation methodology for energetic conversion to estimate the potential of some dry base residues from agriculture, among them, beans. This potential is presented by equation (1).

$$potential = \frac{Residues \times PCI \times \eta}{860 \times func.} \quad (1)$$

Where:

Potential – energetic potential generated from the annual residues (MW);

Residues – amount of waste generated (tonnes);

PCI – lower calorific value (kcal/kg);

ŋ – conversion efficiency (%);

860 – conversion factor (kcal/kg para kWh/kg); and

Func. – system operating time (hours of operation / year).

For the estimation of the energy generation potential of beans, data on the generation of residues according to Dionízio (2017) were used, the main residues of beans were composed of straw and pod, totaling a residual factor of 53% over the total produced. With this technical coefficient, it is estimated that the amount of waste generated was 37,948 tons in the 2016/2017 harvest in the state of Tocantins (Table 8).

Table 8. Energy potential of bean harvest residues.

Parameter	Unit	Value
Beans	10^3 Ton	71,6
Residues from harvest	Ton	37.948
PCI[1]	Kcal/kg	3.700
η[2]	%	72
Energetic potential	MW	13,61

Source: [1] ABIB (2011); [2] Solomon (2017)

According to Table 8, it can be observed that the energy potential of the bean residues is 13.61MWh.

6.2 Comparison of the Energy Potential of the main wastes for generation of Biogas in the State of Tocantins

As shown in Table 9, the potential contained in residues of the main crops produced in the State of Tocantins can be harnessed. The residues with the lowest energy potential are beans, manioc and sugarcane.

Table 9. Energy potential of the main crop residues in the state of Tocantins.

Residue	Energetic potential	Energetic capacity(MW)
Soybeans	27,058 GWh	3,09
Cassava	69,534 MWh	0,008
Rice	55,264 GWh	6,30
Sugarcane	0,182 KWh	-
Maize	4.370,327GWh	498,90
Sorghum	82,995 GWh	9,47
Beans	13,61 MWh	0,002

Regarding beans, there are no studies using it as an energy source and, despite having a low energy potential, there is still viability of biogas generation in small farms for their own consumption.

Cassava residues are usually co-purified with swine residues in order to leverage methane production and increase the economic viability of bioenergy generation.

Regarding sugarcane, although widely used for the production of biofuels, it did not present economic viability for the generation of biogas. For these residues, as well as cassava, some studies have shown that they should be codigested with livestock residues to increase their energy potential and to enable their use to generate biogas.

As for the other residues surveyed, there was a high energy potential with economic viability for generation of biogas. These residues can also be co-purified with livestock residues for higher yields in biogas generation, better digested product quality and reduced costs.

Residues of soybeans and rice have potential for biogas generation and sorghum has already been widely used for this purpose. The agroenergetic potential of sorghum can be even greater, because everything harvested from it, grains, leaves and stems is used, and in this study only grains were considered.

Maize crop residues present the highest energy potential with an energy capacity of 498.90 MW representing 3.43% of the electricity generated in Brazil and the sum of the energy potential of the residues studied represents 3.56% of the generation capacity of energy by biomass sources in February 2018 (ABEEÓLICA, 2018).

7 FINAL CONSIDERATIONS

Biogas as a source of renewable energy could contribute much to environmental preservation. It is necessary to link mankind to the environment through rational use of technologies that ensure environmental respect and provide less impact in the present, providing for more sustainable conditions in the future.

From the brief review aimed to portray the potential of the main agroenergy residues of the State of Tocantins for generation of Biogas, it was possible to verify that Tocantins has a great unused potential of biomass with aptitude to be converted.

The generation of energy from biodigestion offers numerous socioeconomic and environmental benefits by providing alternatives for energy generation by supplying local needs with the possibility of aggregating revenues to the rural producer, correct destination of generated waste contributing to reduction of environmental impacts caused by activities of the agricultural and agro-industrial sectors, reducing the emission of greenhouse gases and also generating carbon credits by replacing fossil fuels.

There are still many difficulties for the use of biomass as an energy source, since it requires high investment, but as we overcome the information deficit and knowledge becomes diffused, we will face a new reality.

The moment requires formulation of solid strategies with participation of the different agents involved, in order to take advantage of the economic and environmental potentials of the agroenergy industry, and considering an effective policy of land use, the definition of production areas and agricultural and environmental policies protecting family farming.

In other words, encouragement of the entry of new agents, especially those with knowledge in the energy business, can also be an alternative to turn feasible the biogas exploitation projects.

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