Potential for the production of biogas in alcohol and sugar cane plants for use in urban buses in the Brazil

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Abstract: Brazil is one of the major alcohol and sugar producers in the world. The plants of alcohol and sugar cane have as waste the vinasse, which is used as organic fertilizer in the cane plantations and it cause contamination of the soil and water. The anaerobic digestion treatment can be used to reduce the pollution with vinasse, and at the same time increase the production of biogas. In this study, is proposed to find the potential of biogas production from anaerobic digestion of vinasse in Brazil and the availability of its use in urban buses as gas fuel. Biogas can be important to reduce the dependence of diesel, a non renewable fuel, in Brazil. Theoretical data of vinasse and biogas production, 14,6 m^3 of biogas per 1 m^3 of vinasse, were used to estimate the biogas potential. Using an estimated consumption of biogas in buses, 295,5 m^3 per bus with 400 km of autonomy per day, the total of buses supplied with biogas was estimated. The potential of biogas production estimated in Brazil by vinasse (2008/2009) is 4016892452 $m^3.crop^{-1}$ or approximately 20 million per day, which could replace 64,7% of the urban buses fleet in Brazil. A big plant of alcohol production has autonomy to supply 1018 buses per day. It has been assumed in this study the plant will produce biogas only during 200 days per year, in the others 165 days the buses could running with compressed natural gas (CNG) or the digesters can be fed on of bagasse's sugar cane as wet feedstock.

Keywords: *Bioenergy, fuel, vinasse, waste*

1. Introduction

Biomass is an important renewable source of energy in the world and its increasing has been useful to replace the fossil fuels. There are some kinds of agricultural feedstocks those can be converted in biofuels, as alcohol, biodiesel and others. The wastes of the process in food industries could be utilized for anaerobic digestion for biogas and biofertilizer production. The biofuels are expected to be one of the most important in the near future, because they will contribute to the decreasing of the global warming in the world.

The commercial sugar cane produced in Brazil is destined for alcohol and sugar production. The alcohol is utilized for domestic supply and exportation; it is available in Brazil since year 1973 as fuel in vehicles, mixed in the gasoline and in the bi-fuels vehicles. The alcohol is one renewable fuel and its combustion produces less pollution than fossil fuel. The wastes produced in the processing of alcohol and sugar is the bagasse and the vinasse.

The sugar cane industrialized in Brazil, increased 47% in five years, reaching 569063 million of tonnes in 2008/09 crop, where the central south of Brazil is responsible for 89% of the production. [1]. An increasing of the exportation of sugar and the high consumption of alcohol in Brazil have been the mainly factors of expansion the sugar cane production and its processing.

Sugar cane after the harvest gets to the mill and the juice is extracted and leavened, then the results are the alcohol and a raw material called vinasse, which is produced at high temperature and has a high chemical oxygen demand (COD), organic matter and high polluting power. In Brazil the plants of alcohol use the vinasse as a fertilizer directly applied in the soil, because it is rich in potassium. On the other hand, there is a limit of application by the environmental agencies [2,3]. The major problem of the vinasse application is the

possibility of its flowage to rivers and lakes, specially during rainy days. Moreover there is the risk of contamination the superficial water, which is response to the supply of water in some cities and rural community. In some regions of Brazil the locals environmental agencies has not powerful and the owners of sugar and alcohol plants does not respect the law.

Vinasse before disposed in the soil, should be treated in anaerobic reactors as a thermophilic UASB [2]. This kind of treatment will produce the biofertilizer and biogas. The table 1 shows the physical chemical parameters of the São Martinho Industry of Sugar and Alcohol before and after the biodigestion [4,5].

Table 1. Physical and chemical parameters – São Martinho Industry of Sugar and Alcohol.

Parameter	Vinasse before the digestion	Vinasse after the digestion
pH	4,0	4,9
Chemical oxygen demand, COD ($mg.L^{-1}$)	29.000	9.000
Nitrogen total, N ($mg.L^{-1}$)	550	600
Phosphor, P2O5 ($mg.L^{-1}$)	17	32
Sulfate, SO2 ($mg.L^{-1}$)	450	32
Potassium, K2O ($mg.L^{-1}$)	1.400	1.400

According to table 1, the anaerobic digestion of the vinasse will reduce the organic charge, but the power as fertilizer will remain the same. On the other hand the plant of sugar and alcohol will produce biogas.

According to [3] biogas is composed of methane (40-75%), dioxide of carbon (25-40%) and other compounds. The biogas can be used as biofuel in engines of internal combustion. In this study is proposed estimate the supply of urban buses with biogas produced in the big plants of sugar and alcohol in Brazil.

2. Methodology

The production of biogas of vinasse and the bus supply capacity were estimated using data from literature. The most of plants of cane processing are placed in central south region of Brazil, where the cities of São Paulo, Rio de Janeiro, Belo Horizonte, Brasília, Goiania, Curitiba and Porto Alegre are situated. The biggest plant of sugar and alcohol in Brazil is São Martinho, which process about 40.000 $ton.day^{-1}$ of sugar cane, during approximately 200 days per year [1] and is close to São Paulo.

According to [4,6], the production of 1 liter of alcohol discharges 10 liters of vinasse and with the digestion of 1 m^3 of vinasse approximately 14,6 m^3 of biogas are produced. These values were used to estimate the production of biogas and vinasse in the plants of sugar cane studied and the total estimation of biogas production in Brazil.By using data of alcohol production in Brazil and in the plants of production obtained of UNICA [1], was possible estimate the production of vinasse and biogas.

According to literature [7,8,9] the biogas (55% methane) has an energy value of 20,8 $MJ.m^{-3}$ and the diesel has 36,4 $MJ.L^{-1}$. In the composition of biogas, there are approximately 55% of methane (CH4), which has a specific mass of 0,714 $kg.m^{-3}$, then 1 m^3 of biogas is equivalent 0,393 kg of methane [8]. The currently specific consumption of diesel in one bus is 0,40

$L.km^{-1}$ [10,11]. Once upon time the bus autonomy assumed is 400 km per day, the diesel daily consumption of one bus is 160 liters, which has an equivalent energy of 5824 MJ.

Volvo's bus has an autonomy of 400 km running with compressed natural gas cylinders (200 bar) of 1055 m^3 and weigh 136,20 kg [10]. If compressed natural gas has an energy value of 47,5 $MJ.kg^{-1}$ [9], then a volvo's bus consumes a daily energy equivalent of 6469,5 MJ. Analysing the data above, was estimated a daily medium biogas consumption of approximately 6147 MJ per bus or 295,5 m^3 of biogas per bus. These data were utilized in the estimation of the number of bus supplied with biogas.

The data of the bus fleet in Brazil were obtained from CNT and ANTT [12,13], and the estimation of carbon emission by bus was made using the index 74.100 kg $CO_2.TJ^{-1}$ of diesel found in the guidelines of IPCC [14], this index is 2,61 kg $CO_2.L^{-1}$ or 0,71 kg $C.L^{-1}$ of diesel, and was useful to estimate the decreasing of carbon emission with the replacement of diesel for biogas.

3. Results

Table 2 below shows the production of alcohol in Brazil and the estimated production of vinasse. The alcohol production were obtained from UNICA [1]. The amount of vinasse disposal in the environment in 2008/09 crop was 275 million of m^3, certainly it caused a high environmental impact in Brazil polluting the water and soil. The production of vinasse increases a rate of 12,7% per year since 2000/01 to 2008/09 crop. Brazil has between 12 and 20% of the potable water in the world and the increasing of the sugar cane industries could be a threat because of the directly disposal of the vinasse on the soil. If the vinasse would have been treated in anaerobic reactor the impact would be less.

Table 2. Production of alcohol and estimated vinasse production in Brazil .

Crop	Alcohol production in Central South (m^3)	Alcohol production in North Northeast (m^3)	Total alcohol production in Brazil (m^3)	Total Vinasse estimated in Brazil (m^3)
00/01	9064364	1528671	10593035	105930350
01/02	10176290	1359744	11536034	115360340
02/03	11152084	1471141	12623225	126232250
03/04	13068637	1740068	14808705	148087050
04/05	13591355	1825313	15416668	154166680
05/06	14352542	1594452	15946994	159469940
06/07	16006345	1712864	17719209	177192090
07/08	20333466	2193358	22526824	225268242
08/09	25101963	2410999	27512962	275129620

With the vinasse disposed in 2008/09 crop could produce 4016892452 m^3 or 20 million m^3 per day of biogas, enough to supply 67968 buses, or better, 64,7% of the Brazilian fleet of urban bus, which have been estimated on 105000 buses in 2008 [12].

The biogas that could be produced in Brazil, only with vinasse (4 billion m^3, 2008/09), correspond to 40% of the biogas produced in Europe, 10 billion m^3, in 2005, which is derived essencialy from landfills (64%), degradation of urbans and industrial waste (18,8%), and agriculture and energy crops (17,2%) [15]. According a study aimed in Brazil [3], the

potential of biogas from vinasse estimated was 2,74 billion m^3 (2003/04). Both studies show that Brazil has an enormous potential of biogas production by vinasse.

Table 3 presents some plants of sugar and alcohol localized in the central south region and the respective capacity of biogas and biomethane production.

Table 3. Production of alcohol and estimated vinasse in central south region of Brazil(2008/2009) .

Industry of alcohol	Alcohol m^3/crop 08/09	Vinasse m^3/crop 08/09	Biogas m^3/day	Buses (400 km of autonomy per day)
São Martinho	411991	4119910	300753	1018
Equivap	347298	3472980	253528	858
Da Barra	315804	3158040	230537	780
Santa Elisa	246591	2465910	180011	609
Colombo	200093	2000930	146068	494
Santa Candida	142436	1424360	103978	352
Santo Antônio	111615	1116150	81479	276

Figure 1 and table 3 presents the number of buses that could be supplied for the industries of alcohol above. The biggest industry (São Martinho) could supply 1018 buses per day, which represents 2,7 % of replacement the diesel fleet running in the city of São Paulo.

A big plant milling of 40.000 ton.day^{-1} could supply 1018 buses and a smaller plant milling 12.500 ton.day^{-1} 276 buses. In São Paulo state there are 145 plants with milling between 40.000 and 4.000 ton.day^{-1}, those would supply all buses of São Paulo city with biogas. The advantage is that they are not placed far from São Paulo city.

According to literature [10], in 1996 the bus fleet that could be fuelled with biogas from landfills of São Paulo city were estimated in 3005 buses which could supply 8% of the São Paulo's fleet currently. In comparison, three big plants of sugar and alcohol (milling 40.000 ton.day-1) could produce the same amount of biogas.

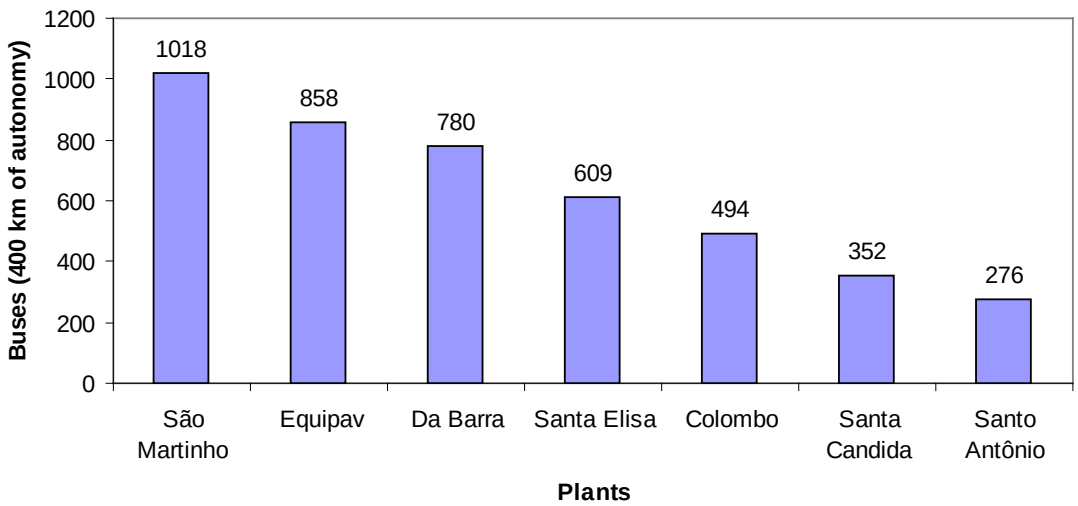

Fig. 1. Number of buses possibly supplied by industry of alcohol.

The total replacement of the bus fleet of São Paulo city for biogas could avoid the emission of 4,3 ton.day^{-1} of carbon from fossil fuel (diesel) into atmosphere.

One limitation in this study is that the plant will produce biogas only during 200 days per year, in the others 165 days the buses could running with compressed natural gas (CNG) or the digesters can be use the bagasse's sugar cane as wet feedstock.

Figure 2 presents the bus fleet running in the big cities in Brazil in the year 2007 [13].

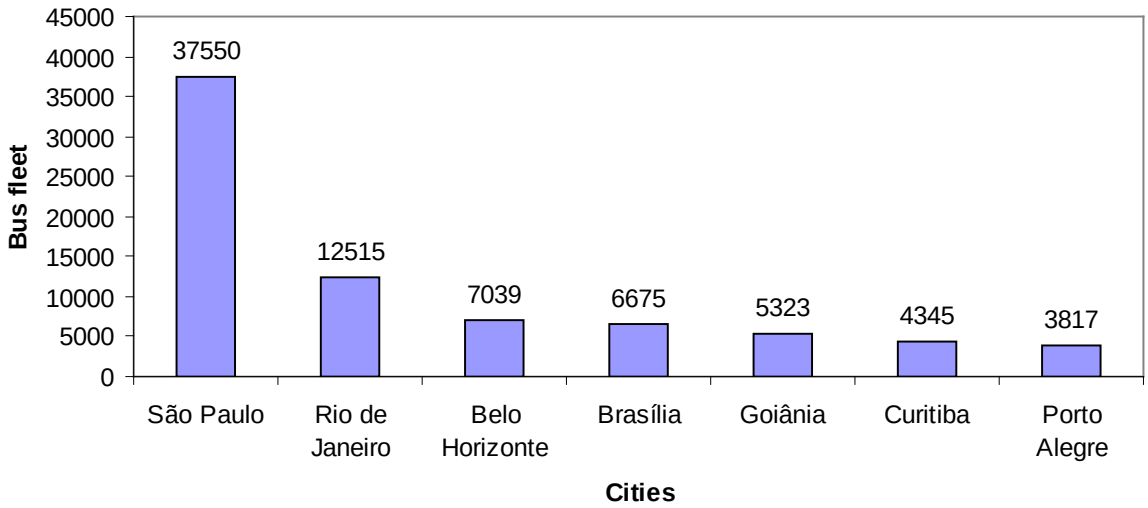

Fig. 2. Bus fleet in the mainly cities of central south region from Brazil (2007).

The possibility of replacement the buses to run with biogas could became the big cities in Brazil more sustainable, by other hand there are technical and market limitations. The gaseous form of biogas at normal temperature and pressure require its compression in cilynders to be used and, the cost will increase.

There is a lack in technology innovation to convert the vinasse to biogas in Brazil. Surely , the use of diesel is aconomically better than biogas to the owner's buses and the utilization of biogas feasibility depends of financial and policy incentives by the government.

In Brazil there is other forms of feedstocks to biogas production which could be explored togheter with vinasse and, the biogas in set with liquid biofuels (alcohol and biodiesel) could help the big cities of the country became more sustainable. By other hand the urban transport system need to be organized before this. The major of the big cities in Brazil need create BRT's as Curitiba city, an international reference.

The economy of Brazil is growing quickly and there is yet a lack of development in technological innovation in diverse sectors of economy, specilly in the development of the new forms of renewable energy, wich could help it increase with an economy sustainable.

4. Conclusions

With the increase rate (12,7% per year) of the vinasse disposal in Brazil, the better option is to promote the anaerobic digestion of the vinasse and produce biofertilizer and biogas. Brazil has a great number of buses, running mainly in the central south region cities, that could use the biogas as fuel replacing the diesel.

The biogas that could be produced with digestion of vinasse in Brazil had been estimated in 20 million m^3 per day, enough to supply 67968 buses, or better, 64,7% the Brazilian fleet. The use of the biogas to supply this fleet could reduce the emission of carbon from fossil fuel diesel in 21 $ton.day^{-1}$.

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