EVALUATION OF USE OF MIXTURES OF SUGAR CANE BAGASSE WITH CHARCOAL INTO THE TUYERES OF BLAST FURNACES [1]

Janaína Solvelino Brum [2]
Eric Rafael dos Reis [2]
Natália Carolina da Silveira [2]
Thiago Lucas da Silva [2]
Paulo Santos Assis [3]

Abstract

The technical contribution is going to study the alternative mixtures of sugar cane bagasse with charcoal for injection in the tuyeres of blast furnace. It was done six mixtures of the charcoal varying the percentages at 20%, 40%, 60%, 80% and, finally 100% of sugar cane bagasse. The sugar cane bagasse is already used for generation of thermal energy in boilers, as source of electric energy, and now it is being studied a possible utilization for powder mixture injection into blast furnaces. The use of renewable fuels for the output of primary iron is being discussed a lot at the last times, aiming at an environmentally sustainable steel industry. In this sense, the use of biomass as flammable agent and fuel for iron oxide reduction looks to be an efficient route for output of primary iron of environmentally sustainable and economic way. Because, from the substitution of the use of fossils fuels by biomass, produce a cycle closed of generation and the capture of CO_2.

Key words: Sugarcane bagasse; Injection; Energy; Environment

1 *Technical contribution to the 3rd International Meeting on Ironmaking, September 22 – 26, 2008, São Luís City – Maranhão State – Brazil*

2 *Member of ABM. Graduated in Metallurgical Engineering at Escola de Minas UFOP.*

3 *Member of ABM. Full Prof at Escola de Minas UFOP. Prof. at REDEMAT (CETEC-UEMG-UFOP), Researcher of the CNPq.*

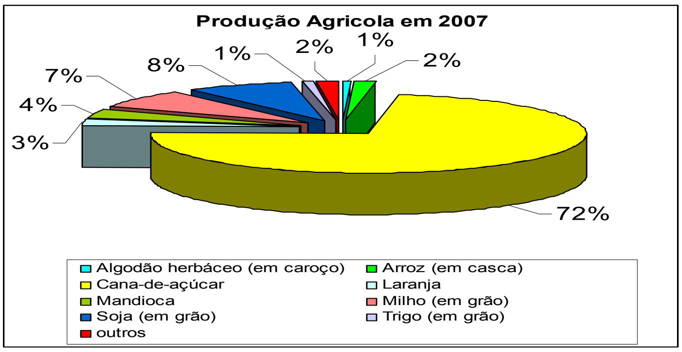
1 INTRODUCTION

Energy is an indispensable element for economic and social development of humanity. On a global scale, the energy consumed by humans comes in approximately 80% of fossil fuels (coal, oil and natural gas). It can not be forgotten that fossil fuels when burned in thermoelectricity, for transport, industries, release highly toxic gases and pollutants (carbon dioxide, nitrogen oxides, sulphur dioxide, and others), these gases are responsible for the major environmental impacts, which come to put at risk the survival of the human race. The introduction of the concept of sustainable energy points to the constant growth of use of clean and renewable sources of energy (biomass, wind, solar). Today, there is an international consensus to reduce emissions of these gases, by reducing the consumption of fossil fuels, the Kyoto Protocol, signed in 1997, is a proof. Thus, this technical contribution shows the current state of technology to generate energy from sugar cane in Brazil, as well as aspects of the generation of waste, characteristics of biomass produced and their possible application as an energy source and reduction in blast furnaces to inject into the tuyeres.

2 LITERATURE REVIEW

2.1 Sugar Cane Bagasse and Energy

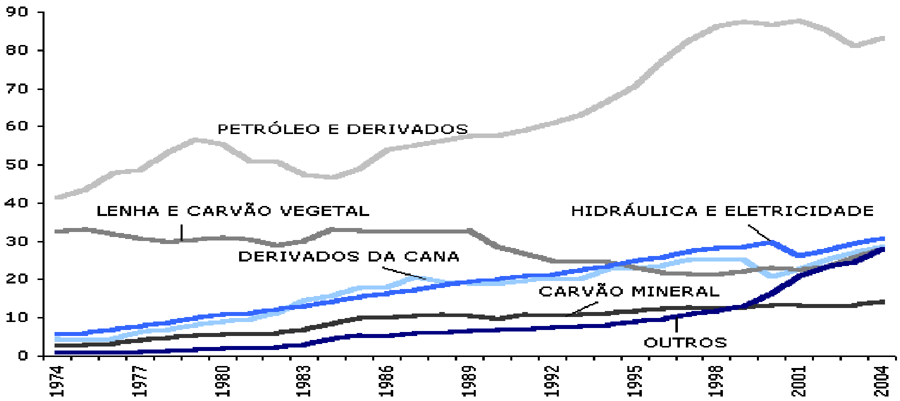
Brazil is the world's largest producer of sugar cane, which is used for sugar and alcohol industry. The last one can supply energy in manufacturing processes like as thermal source (steam process), mechanics (for the operation of mechanical devices) or electric. This gives the sugar-alcohol companies the privilege of self-sufficiency in electricity, these conditions do not exist in most industrial activities. It is estimated that the sugar cane bagasse can generate about 100 kwh per tone of sugarcane in 2012 and that the country could produce 24000 MW of electricity. This is due to the fact that sugar cane is the first agricultural product grown more in Brazil in 2007, as it can be seen in Figure 1.



Source: Group for Coordination of Agricultural Statistics - LAEC / IBGE, MEP, COAGRO - Systematical Survey of Agricultural Production, May 2008

Figure 1: Agricultural production in Brazil in 2007

One important point concerning to energy is the distribution of sources those releases all consumed energy in Brazil. Figure 2 shows the source of energy consumed in Brazil in the last 30 years. It should be pointed out how our economy is dependent on fossil fuel, like in the world.



Source: Secretaria de Energia do Ministério de Minas e Energia (MME)

Figure 2: Primary sources of energy consumed in Brazil – 1974-2004.

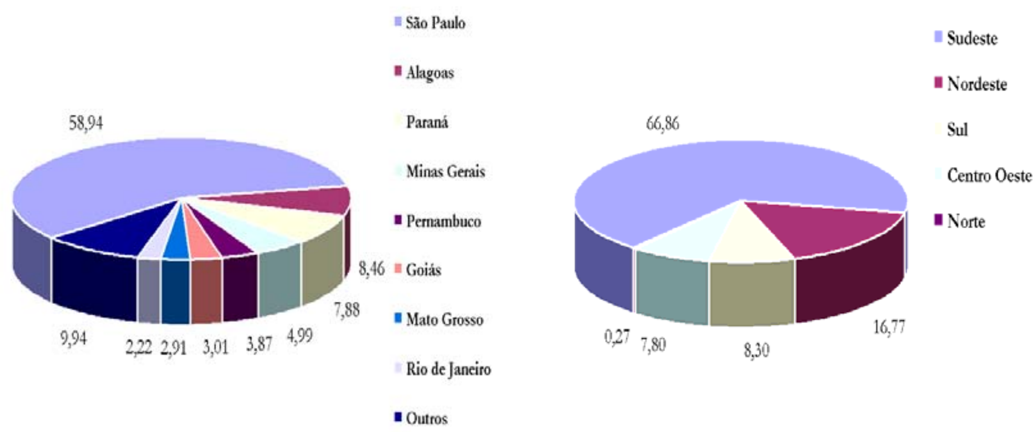
Table 1 is presented to the annual estimate of some waste plant in Brazil. It should be pointed out that the sugarcane bagasse is the main waste generated in agribusiness in the country, representing over 50% of all solid waste, not considering the firewood coming from deforestation in the north and Center wwest.

Table 1: Major agricultural products from Brazil

Waste type	Anual Estimating of wastes in Brazil (Million tons) in 2007
Sugar cane bagasse	84.3
Rice rind	10,0
Wood wastes from industry	60,0
Coconut husk	0,5
Caju Castanhe wastes	0.9
Wood proceeding from deforestation in Center-West and North Brazil	90.0
Total	254,7

Source: BEM/MME

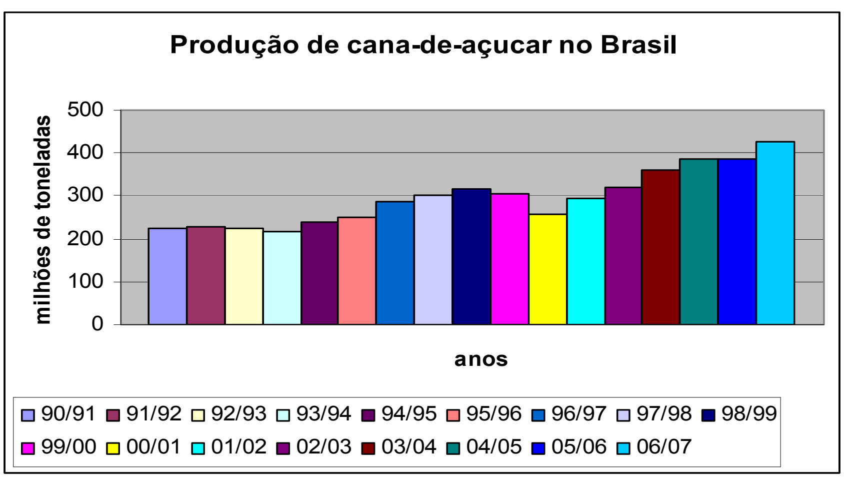
About 85% of Brazilian production of sugar cane is concentrated in the Center-West, South, Southeast, with the remaining 15% produced in the North and Northeast. Figure 3 shows the distribution of sugar cane by states and regions of Brazil respectively. Sao Paulo, Minas Gerais, Alagoas and Rio de Janeiro are responsible for the production of over 80% of all sugar cane in the country.



Source: IBGE

Figure 3: Distribution of the production of sugar cane in Brazil by States

The country has two producing regions with alternate crops, can maintain its global market presence throughout the year. In the Southeast region is planted from October to March and harvested from May to October and in the Northeast, from July to November and harvested in December to May. In this the alcohol production will be smaller, because the low participation of this region. During the last sixteen years, the production of sugar cane doubled, as it can be seen in Figure 4.



Source: UNICA 2008

Figure 4: Production of sugar cane in Brazil

The sugar cane is planted in several Brazilian states, estimated at 5.5 million hectares the area harvested in 2004 (UNICA 2004). The production of sugar cane in Brazil, during the 2007-2008 harvest, should reach a record number of 425 million tons, with growth in the sugar and alcohol production. It is planed that in 2012 the sugar cane production can reach 730 million tons. If confirmed it is estimated that in next 10 years, the area to be planted sugar cane will be more than doubled.

The crushing of 1 tonne of sugar cane, one plant produces, on average, 153 kilos of molasses (sugar and ethanol), 165 kg of straw and 276 kg of bagasse. The raw material is abundant, low-cost, and is available in large quantities in the country. For instances, in 2005 the price of sugar cane bagasse was traded at R$ 40 a tonne, price higher than the ton of sugar cane that reached R$ 30. According to the weekly magazine Veja, 2042 edition, by 2010 the only agricultural product that does not rise in price is the sugar cane, mainly because its production increasing.
The sugar cane bagasse is the industrial waste lingo-celulosis fibrous, proceeding from crushing the remainder of the stem of sugar cane in the milling device to extract the juice of sugar cane. It constitutes a conglomerate of particles very heterogeneous outcome of the process of grinding. It has been consolidated as an industrial raw material of high economic importance. According their nature, the bagasse is a fibrous biomass which contains, on a dry basis, the following substances, identified in Figure 5.

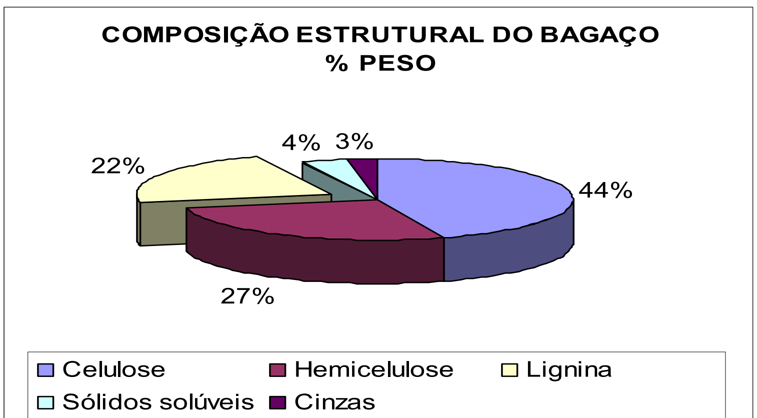


Figure 5: Structural composition of bagasse [9]

The lignin is a three-dimensional amorphous polymer found in some plants, whose function is to provide rigidity. It is said that the higher the level of lignin, the greater the chance of producing a charcoal of good quality.

The comparison of the net calorific value of bagasse and other fuels can be seen in Table 2 and its corresponding equivalence in Table 3. The calorific value of the sugar cane bagasse is a function of moisture and sugar, such as the sugar content is usually low, has been the humidity as a factor limiting the calorific value.

Of course one way to increase the calorific value of bagasse is its drying. Clearly, its use in any process will go depend on the alternative source that has for its drying. In some cases where its possible without drying additional consumption of energy, is highly advantageous because the PCI is inversely proportional with humidity content found in it. In some cases in which consumption of new energy is required for the drying of the sugar cane bagasse should be examined from the standpoint of cost-benefit.

Table 2 - Comparison between the sugar cane bagasse and other fuels.

Material	Net Calorific Power (PCI)	
BPF Oil	9.500 [1]	39.748 [2]
Bagasse 50% Moisture	1.800	7531,2
Bagasse 48% Moisture	2.250	9414

[1] kcal/kg [2] MJ/kg

Table 3 - Equivalence of bagasse [3]

Mass of Bagasse (kg)	Mass/ Material Volume
5,3	1 kg de Oil BPF
320	1 m^3 de Wood

The sugar cane bagasse, except of the biomass, is one that combines the best attributes to be economical industrialized and compete commercially with the fuel oil with the following advantages: have organized crops, whose costs are charged in prime product: sugar and / or alcohol and be produced in large quantities, concentrated in one point.

The moisture of bagasse interferes directly in the performance of combustion, which notes the ignition temperature of which is between 500 ° C and 600 ° C with 50% humidity, falling to 300 º C to 400 ° C with 35% to 40% humidity. The flame temperature also is sensitive to the level of humidity, leaving between 850 ° C and 920 ° C with 50% humidity, but getting over 1100 ° C with 35% humidity. This process of combustion that is portrayed here believes that the entry of air occurs at room temperature. It is not the case of blast furnaces

Although the sugar cane bagasse present a high humidity content, is responsible for the good ignition of the waste by having a high content of volatile, the order of 87% on a dry basis. The volatile of bagasse as 78% of the calorific value and consume 74% of combustion air.

2.2 Pulverized Coal Injection

It is known that the technology of pulverized coal injection has been practiced worldwide. Currently there are more than 400 blast furnaces that practice this technique, and in more than 70% of all blast furnaces in the world already uses some sort of injection of solid material. In the specific case of charcoal, Brazil has the technology, and initially developed by Acesita (actual ArcelorMittal Timóteo), even in the past, in the 70's decade. For integrated plants, all blast furnaces with charcoal already inject Charcoal powder injection in its tuyeres. All the blast furnaces of the world already inject pulverized coal.

The main variables that led to the growth fast in the number of installations of injection occurred from the beginning of the 1980 are related to the reduction of cost of production of pig iron, replacement of fuel oil, recovery of waste, quality of pig iron, injection of other materials such as: fine ore, fluxes, plastics, paper and others, as described in the literature. It is clear that the injection of pulverized coal (PCI) must include significant reductions in the cost of production of iron. In this respect, it is essential that higher rates of injection are charged with significant gains in reducing consumption of charcoal in the top of the blast furnace. Normally, when inject higher rates of ICP, above 180 ~ 200 kg / t hot metal, there is no gain in the proportion of reducing consumption. Thus, efforts to increase the rate of pulverized coal combustion certainly affect the rate of injection, then, there would be financial gains in the production of hot metal.

3 MATERIALS AND METHODS

3.1 Characterization of Sugar Cane Bagasse

As reviewed above, 30 kg of bagasse from sugar cane were collected around in a production alcohol unit in Rio Casca, comprising about two bags of 80 liters each. This material was collected randomly in the field, when it was already deposited. Afterwards few visits were made to Campo Belo, MG, to see the system of provision of that waste in some plants for the production of spirits to the municipality, noting the similarity of procedures for the provision. Figure 6 illustrates a picture of where the sample was withdrawn.

Figure 6: Provision of bagasse from sugar cane in the courtyard of plant

The material was taken to the UFOP and made the comminution of the same laboratory using a typical pulverizer used in laboratories for preparation of ore-rail.
After the pulverization, was made an immediate analysis of material that identify the fixed carbon content and quantity of volatile. These data were compared with results from literature on the subject. It was also prepared a sample <150 # for determination of its PCI.

3.2 Characterization of Charcoal

The samples were taken after the system for milling, drying and mixtures of coal plants of the PCI, or did not take account of its origin. The standard NBR6923 (Charcoal - Sampling and preparation of sample in 1981) of ABNT (Brazilian Association of Technical Standards) was used to conduct the sampling. These were divided and separated in the amount of 150g per sample. Samples were identified, taking into account their immediate chemical analysis (C1, C2 and C3), size (G1, G2, G3), humidity (U1, U2 and U3) and source (AP) They were stored in glass containers properly identified and prepared to receive them. To determine the average size, the standard used is the ABNT NBR7402 (Charcoal - Analysis granules, 1982). On the other hand, used to the standard ABNT NBR8112

(Charcoal - Analysis immediate, 1986) for determining the immediate analysis on a dry basis).

The use of BET (the name derives from the initials of the names of scientists that the proposed: Brunauer, Emmet & Teller), which is a method to determine the porosity of grain, provided the determination of various physical properties. Highlight for specific surface area, total volume of pores and volume of micropores of the samples.

3.3 Ultra High Thermal Gradient Simulator [UHTS]

Initially the samples of charcoal properly identified were weighed in analytical balance to compose a sample that simulates 50, 80 and 140 kg / t hot metal in accordance with the practice of some companies. The samples are placed with the help of a spatula in a glass container properly desumidified help with acetone, then this is brought to the simulator, in Figure 7 you will see a diagram of this UHTS and their respective areas. The gas used in this experiment is pure oxygen cylinders stored in each of 13 m^3, this is attached to the simulator through hoses properly designed for this purpose. With the help of a funnel glass, charcoal is introduced in the opening called the "S" which closed after this is not to occur to the ejection of material, each oven is pre heated to a temperature of 800 ^{0}C for the pre-heating furnace and above 1200 ^{0}C for the combustion furnace.

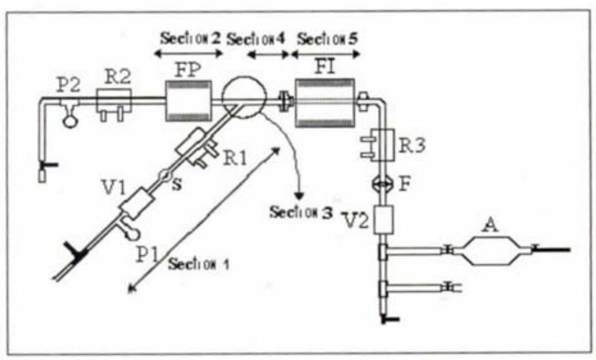


Figure 7: Schedule of the regions of the simulator [1]

After opening the valve of the cylinder, the gas is intended for a branch of hose that leads to the pre-heating furnace and another that leads to the boom of the pre injection in the furnace - heating where it is heated to the temperature reached a similar blast in a blast furnace. In launching the injection of gas drag particulate matter under the command of the electromagnetic valve (V1), which is driven simultaneously with the valve (V2) by only 2 seconds repeating this drive by 4 or more times. The pressure in the gas regulators (P1) and (P2) are respectively 5 kgf/cm^2 and 2 kgf/cm^2.

The gas dragging the particles of the material injected enter into contact with the gas from the furnace to pre-heating and come together in the furnace of burning case where the burning and then separated the particulate and gas collected in collector ampoules.

The gas dragging the particles of the material injected enter into contact with the gas from the furnace to pre-heating and come together in the furnace of burning case where the burning and then separated the particulate and gas collected in ampoules. The ampoules are of a glass with two openings at each end and an internal volume ranging from 200 to 500 ml, filled with distilled water and a dye as the gas enters the ampoule he expelled the water by other end, soon after gas is collected it is sent to the gas analyzer ORSAT.

3.3.1 ORSAT

The gas collected in **UHTS** is connected by a rubber hose to ORSAT, after open the valve of the gas ampoule is driven by hose to the valve of entry where the ORSAT may be directed to each line, for gas analysis. Chosen the vial of solution being used, the gas is forced to go through this by a difference in level between the Saline and ampoule that force the separation of gases, this difference is established until the saline solution into balance with solution in solving the ORSAT ampoule of not allowing more gas is absorbed thereby separating the fraction of gas that specified that the solution to separate, after this procedure is banned ampoule of the gas and closes the valve that provides the way for this, repeating the procedure for other ampoules. Then from the test results, it is estimated the rate of combustion using the equation 1 shown [2].

$$TC = \{(\%CO + \%CO_2)*n / [(m_a*\%C_f / 1200000) - (k_1*n_g / 100)]\}*100 \quad (1)$$

where:
TC = combustion rate (%);
% CO, CO_2= Percentages (in volume) of gases produced;
C_f =% fixed carbon contained in the sample;
n_g = Number of moles of gas after the experience;
m_a = Mass of the sample of carbon injected into milligrams.
k_1 = determined constant for each material.

4 RESULTS AND DISCUSSIONS

4.1 Characterizations of Materials

The sugar cane bagasse was characterized with regard to its bulk density, moisture, immediate analysis and PCI. Table 4 shows the results

Table 4 - Preliminary results of the characterization of powder sugar cane bagasse.

Parâmetro	Granulometria	Densidade	C	Voláteis	PCI
Unidade	% < 200 #	kg/dm^3	%	%	$kcal/m^3$
Valor	80	195	16,46	78,28	2095

Some results have been obtained of analyzed elementary of the powder originating from milling of the cane bagasse, as was C =46,1, H=6,5 and O = 43,0. Comparing these results with results showed on literature, [3] can be observed only one good agreement from the states. The chemical and physical characterization for charcoal was represented in Table 5. The results of the testing of BET are represented on Table 6. Must be emphasize what the sample what generated the mixture of the charcoal with the sugar cane bagasse powder was that one corresponding the sample C2.

From the results obtained on the burnt from the patterns can summarized on Table 7 where if they have the averages from the values obtained on the tests and the tax of combustion. Each testing was composed from she burns of 25 patterns variant the percentage from she stirs and the weight of each pattern. Figure 8 related the combustion rate with the percentage of charcoal. Into the mixture. Then figure 8 illustrates the effect of injection rate on the combustion rate by two limits situations, in other words, 100 % of charcoal and 100 % of sugar cane bagasse as agent of injection.

Table 5: Representation from analysis chemistry and granulometry of the charcoal featured.

Sample	Immediate analysis; dry basis				Elementar Analysis				Médium Grain size (mm)
	Cf (%)	TU (%)	MV (%)	CZ (%)	C (%)	H (%)	N (%)	O (%)	
C1	54,8	1,4	24,2	21,0					0,070
C2	59.6	1,4	24,6	15.8					0,072
C3	65.3	1,4	24,1	10.6					0,068
U1	59.6	1,1	24,6	15.8					0,070
U2	59.6	2,9	24,6	15.8					0,072
U3	59.6	4,8	24,6	15.8					0,070
G1	60,1	1,5	24,4	15,5					0,070
G2	59,8	1,5	24,3	15,9					0,119
G3	60,9	1,5	24,4	14,7					0,162
AP	60,1	1,6	24,2	15,7	66,67	2,54	0,81	29,98	0,073

Table 6: Results of parameters of porous and specific weight of charcoal.

Sample	Specific Surface	Total Volume of pores	Volume of microporo* (θ_m<2ηm)	Surface of microporo*	Médium diameter of pores	Maximum Grain of pores	Specific weight
Unity	**m^2/g**	**$10^{-2}cm^3$/g**	**$x10^{-3}cm^3$/g**	**m^2/g**	**Å**	**Å**	**g/cm^3**
C1	1,861	0,5804	0,7991	2,262	120,48	2918,6	1,512
C2	1,729	0,6945	0,7995	2,264	160,07	1342,8	1,504
G1	1,367	0,1143	0,7453	2,110	330,44	1795,4	1,597
G3	2,171	1,086	1,0119	2,885	200,00	1466,8	1,539
AP	2,442	1,102	1,057	2,993	180,05	2278,1	1,555

**Classification of microporo for diameter (8m < 2nm) of pore and macroporo (8m > 50nm) according IUPAC (International Union of Pure and Applied Chemistry)*

It can be observed what the combustion rate of mixtures of charcoal undergoes a maximum, what normally varies is in the region of 20%. By increasing the injection rate, there is a small variation with addition of 50 till 80 kg/t hot metal. The variation of the combustion rate is practically insensitive to this variation. By increasing the injection rate to 140 kg/tgusa there is a cutback sensible on rate of combustion. This may be explained for a mechanism already proposed by Assis et al.[3]

Table 7: Combustion rates as function of the % of charcoal on mixture and the rate of injection of mixtures (kg/t hot metal).

Charcoal + Sugar Cane bagasse				
Charcoal (%)	**Bagasse (%)**	**50 kg/t hot metal**	**80 kg/t hot metal**	**140 kg/t hot metal**
0	100	86	85,1	78.0
20	80	87,2	87.5	81.3
40	60	90.2	88.6	83.5
60	40	93.3	92.7	88.7
80	20	95.1	94.8	88.7
100	0	94.8	93.2	87

The combination of factors linked together the pirolysis and the burn of volatiles explains why the amplification of the rate of combustion occurs when two fuels are scrambled. Regarding effect showed on Figure 9, is possible to note what bespoke when the injection rate increases, there is a smaller rate of combustion. This effect is practically the same one observed for charcoal and sugar cane bagasse as well. This can explained due to the high value of volatiles both fuels. It explains why the decreasing of combustion rate for the sugar cane bagasse (as green fuel) is smaller than charcoal, when the combustion rate increases. Based on this results it can be expected that when mixtures of both fuels will be practiced then it is expected higher combustion rate.

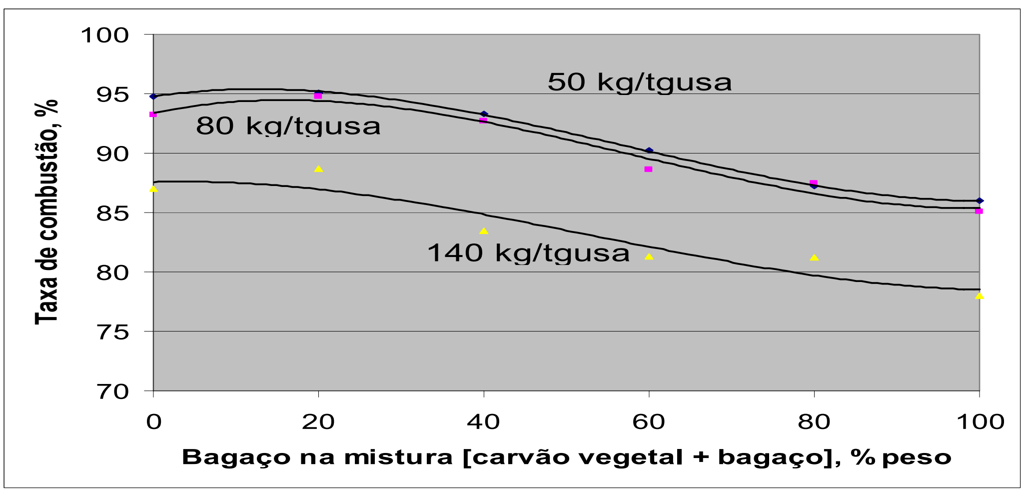


Figure 8: Effect of the sugar cane bagasse on the combustion rate by mixture of charcoal + sugarcane bagasse.

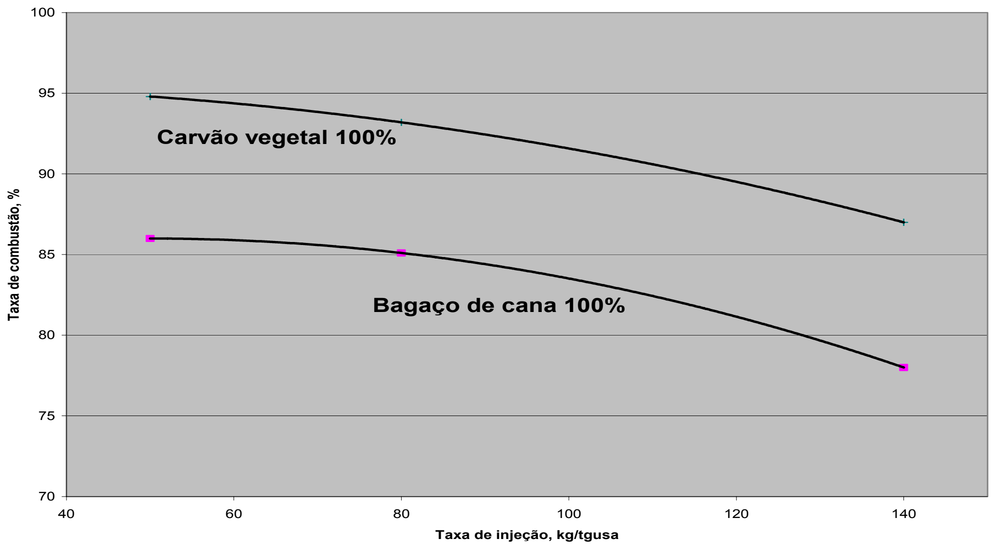


Figure 9: Effect of the rate of injection of charcoal on the combustion rate in two limit situations: 100 % charcoal and 100 % of sugar cane bagasse.

5 CONCLUSIONS

From this technical contribution, it follows that:

- There is a amplification on rate of combustion when sugar cane bagasse is mixed with charcoal.
- The increase up to 20% of sugarcane bagasse in the mixture, for the all injection rates implies an increase on the combustion rate.
- An increase of injection rate implies a reduction of combustion rate for both fuels. But for an increase from 50 to 80 kg/t hot metal, practically there no exists modification on the combustion rate.
- The increase of the combustion rate implicates on reduction on the rate of combustion of the sugar cane bagasse less than occur with charcoal.

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