Energetic analysis in traditional panelers burners

J G Garcia-Rincón1, G Guerrero Gómez2, and E Barrientos2

1 Grupo de investigación Gindet, Servicio Nacional de Aprendizaje (SENA), Colombia
2 Grupo de investigación Gityd, Universidad Francisco de Paula Santander, Ocaña, Colombia

E-mail: jggarcia87@misena.edu.co, gguerrerog@ufpso.edu.co

Abstract. In North of Santander, panela production is carried out in traditional burners, where bagasse is used as fuel. This rudimentary and artisanal form is inefficient in energy terms. For the present study, three burner samples were selected, determining the biomass consumption and the energy assessment of the panela production process, for developing this, a virtual instrument was designed using the Lab View software with temperature sensors and data acquisition cards, which allowed the monitoring and recording of temperatures, finally the energy efficiency of each burner was evaluated.

1. Introduction

Colombia is a major producer of panela, the Colombian panela subsector is the second most important agroindustry in the country, after coffee, due to the generation of more than 855,365 direct and indirect jobs, the occupation in planted area calculated in the year 2017 was about 241,794 hectares, with coverage in 27 departments, 511 municipalities of the country and 350,000 families that depend on this activity. By year 2014 Colombia produces more than 1,330,000 tons of panela, from which 3,441 tons were exported to different countries in the world. The country has an approximate inventory of establishments dedicated to the panela production of more than 20 thousand sugar mills, located throughout the national geography.

The traditional burners where the panela is produced are constructed of common brick, which uses bagasse of unprocessed cane as fuel, these burners reduce the cost of operation, due to their low construction, maintenance and operation costs. But the operation in these is not optimal due to factors such as: low combustion, non-uniform heat distribution and poor regulation in the bagasse feed. For this reason, it is important to conduct studies aimed at understanding the operation of the burners to determine their performance and efficiency [1].

The panela burners operate in normal conditions in average of 4 kg/min of cane bagasse (BC) [2], and the environmental air entrance temperature vary with regards to the place in ranges of 22°C to 26°C [3], and the exit temperature with mix of air plus gases of combustion are around the 600°C until 800°C.

Bagasse cane is a fibrous material with low density and a high moisture content under the conditions obtained from the cane milling process [4], and the ash obtained from sugarcane bagasse is very low, being between 2% and 5%. However, as a direct consequence of the mechanization of the harvest, and especially in the rainy season, this parameter can rise considerably, reaching extreme values % to 15% [5].
2. Methodology

In the west of the department of North of Santander there are municipalities that are more dedicated to the cultivation of sugar cane for panela processing. The municipality of Convención has been characterized for being the pioneer in the productive activity of the panela cane in the department of North of Santander. It has an average of 2,500 hectares of land dedicated to this crop [6], it is organized administratively through the Cañicultores Integral Cooperative of the Province of Ocaña Ltda. COOINCAPRO, which is dedicated to the production and distribution of panela of the three municipalities associated with it, these are: Convención, González, Teorama, in which 220 sugar mills with 20 producers are registered; from them, 110 use traditional burners [7].

To carry out the investigation, three panela burners were selected, they were situated in the San Miguel farms (panela burner N°2), Saint Antonio (panela burner N°3) and Sánchez (panela burner N°1), situated between the municipalities of Convention and Teorama, department of North of Santander, which have a production of 15, 18 and 20 sugar cane Hectares respectively. Within all these the process of production in the burners is artisan from the entrance of the prime matter until the exit of the wastes of cane bagasse in the oven camera.

2.1. Design and installation of the temperature data acquisition system

For the acquisition of temperature data, a virtual instrument was designed and programmed, using a NI cDAQ-9184 chassis, NI 9213 I/O data acquisition cards supported by National instruments and type K bulb thermocouples. The designed program shows how the temperature profiles are real-time in the positions where the thermocouples were located. When the acquisition process ends, the temperature data recorded, and the temperature profiles monitored report is generated in excel.

2.2. Assembly of temperature data acquisition equipment

The instrumentation of data acquisition is located in the burner to work at a prudent distance, due to its high operating temperature. For the measurement of temperatures, eight (8) type K thermocouples were located between pans separated by 2 cm to 5 cm, see Figure 1 and at the end of the combustion gases outlet.

![Figure 1. Type K thermocouples location.](image)

The positions of the thermocouples are as follows: temperature of the burner door T1; Pan temperature N° 1 T2; Pan temperature N° 2 T3; Pan temperature N° 3 T4; Pan temperature N° 4 T5; Pan temperature N° 5 T6; T7 chimney outlet temperature and Ambient temperature T8, see Figure 2.
2.3. Energy evaluation of the oven
For the energetic evaluation in the burners, the total energy supplied by the bagasse was determined and the output heat losses are separated by chemical decomposition of bagasse [8-10], formation of water in the combustion, humidity of the bagasse, humidity of the air, pans, chimney, walls [11], unburned in the ashes and intangibles [12]. To achieve this goal, the profiles of temperatures generated in different positions in the oven were used [13], the amount of cane bagasse and its physicochemical characterization and the dimensions and volumes of the burners were used.

3. Analysis of results

3.1. Temperature profiles in the burners
After installing the temperature data acquisition equipment, the configuration for the acquisition was made. In the burners the software was programmed so that it will register temperatures in the interval of time every 3 minutes, the monitoring lasted six hours in each burner. For each position in the burner 120 data were recorded for a total of 720 records per burner. Figure 3 shows the temperature profiles obtained in burner N°1. Figure 3(a) shows the temperature in the burner entrance N°1, Figure 3(b), Figure 3(c), Figure 3(d), Figure 3(e) and Figure 3(f) show the temperature in pans 1, 2, 3, 4 and 5 respectively, Figure 3(g) shows the chimney temperature, and the Figure 3(h) shows the environment temperature.

In the No. 1 burner, approximately 3,500 kg of sugar cane are extracted from the ground, which are stored in the ground, from which 250 kg were selected as seed to be re-planted to the ground and 1750 kg of sugarcane which produced 1404.48 kg of panela and 875 kg of wet bagasse, which is stored in the “bagazera” for its subsequent drying; this can last about 2 to 3 months while its moisture content decreases to be taken to the burner [4].
Figure 3. Temperature profiles in the selected positions in the burner N° 1.
3.2. Energy balance

3.2.1. Availability and characterization of residual biomass. The physicochemical characterization of the national average of cane bagasse (BC), for the Colombian panela industry, is presented in Table 1 and Table 2.

| Table 1. Characterization of sugarcane [7]. |
|--------------------------------------------|
| Parameter | Next analysis | Bagazo |
|           | Waste | Fresh (%) | Dry (%) | Fresh (%) | Dry (%) |
| Humidity  | 65.8  | 0         | 59.2     | 0         |
| Volatility| 25.2  | 73.4      | 35.6     | 87.3      |
| Ash       | 2.6   | 75        | 0.3      | 0.8       |
| Fixation of carbon | 6.4   | 19.1      | 4.9      | 11.9      |
| Total     | 100   | 100       | 100      | 100       |
| Can calorific (kJ/kg) | 6521  | 18075     | 7925     | 19423     |

| Table 2. Calorific value of cane bagasse [7,10]. |
|-----------------------------------------------|
| Specification | (kcal/Kg) | (kJ/Kg) |
| Upper (PCS)   | 4,642.33  | 19,423.5 |
| Inferior (PCI)| 4,557.65  | 19,069.2 |

3.2.2. Energy balance in panela burners. In the selected burners, the operating conditions are the following: their feeding input is axial to the flow; the heat supply is directed in a parallel upward direction to the pans; the air inlet is lateral to the feed, in addition to its ash outlet; the combustion products gases leave the final part of the furnace in vertical draft, see Figure 4.

In Table 3, all energy flows are appreciated during the panela production process, in which the efficiency of each heat flow was also determined whether lost or used.
Figure 4. Panela burners N°1.

Table 3. Thermodynamic balance of the panela burners.

| Description of the type of heat inside the burner | Burner N° 1 | Burner N° 2 | Burner N° 3 |
|--------------------------------------------------|-------------|-------------|-------------|
| Supplied of bagazo                              | 31,395.202 kJ | 43,271.375 kJ | 30,241.908 kJ |
| \( Q_{s1} \)                                    | 100.00%      | 100%        | 100%        |
| Chemical decomposition of bagazo                | 8,523.475 kJ | 11,331.138 kJ | 6,147.010 kJ |
| \( Q_{s1} \)                                    | 27.15%       | 26.19%      | 20.33%      |
| By water formation in the combustion             | 3,091.821 kJ | 4,160.733 kJ | 2,794.464 kJ |
| \( Q_{s2} \)                                    | 9.85%        | 9.62%       | 9.24%       |
| Extract the humidity of the bagazo              | 1,133.436 kJ | 1,204.176 kJ | 593,089 kJ  |
| \( Q_{s3} \)                                    | 3.61%        | 2.78%       | 1.96%       |
| Air Humidity.                                   | 183,352 kJ   | 184,182 kJ  | 136,235 kJ  |
| \( Q_{s4} \)                                    | 0.58%        | 0.43%       | 0.45%       |
| Transferred to the pans                         | 12,295.954 kJ | 14,813.094 kJ | 12,323.180 kJ |
| \( Q_{s5} \)                                    | 39.17%       | 34.23%      | 40.75%      |
| Lost in the chimney                             | 2,809.543 kJ | 3,962.894 kJ | 1,792.175 kJ |
| \( Q_{s6} \)                                    | 8.95%        | 8.95%       | 5.93%       |
| unburned in the ashes                           | 941,856 kJ   | 1,256,266 kJ | 665,322 kJ  |
| \( Q_{s7} \)                                    | 3.00%        | 2.90%       | 2.20%       |
| Lost by walls                                   | 2,152.116 kJ | 3,898.475 kJ | 1,772.281 kJ |
| \( Q_{s8} \)                                    | 6.85%        | 9.01%       | 5.86%       |
| Lost intangible                                 | 251,471 kJ   | 2,460.419 kJ | 4,018.153 kJ |
| \( Q_{s9} \)                                    | 0.80%        | 5.69%       | 13.29%      |

4. Conclusions
The analysis of the results in the samples shown in the traditional burners determine the biomass in the combustion chamber, as a main factor in the use and final disposal throughout the process in the production of panela with the following values in the San Miguel burners, San Antonio and Sanchez farms were 3.1 kg/min, 2.36 kg/min and 2.8 kg/min respectively.
The system of acquisition of data using the Lab View software showed to be a reliable tool in the analysis of the thermal behavior of the panela burners. In the thermodynamic balance in the panela burners of the Sanchez, San Miguel and San Antonio farms; the amount of energy used in the pots for the transformation of cane juice in the production of panela was 12,295.954 kJ, 14,813.094 kJ and 12,323.180 kJ, which represent 39.17%, 34.23% and 40.75% of the energy supplied respectively, while the amount of energy due to decomposition of the bagasse, elimination of water formed in the combustion and humidity of the bagasse and air add up to 12,932.084 kJ, 16,880.229 kJ and 9,670.798 kJ they mean 41.19%, 39.02% and 31.98% of the energy supplied respectively; the heat loss in the walls was 2,152.116 kJ, 3,898.475 kJ and 1,772.281 kJ, which means 6.85%, 9.01% and 5.86% of the energy supplied respectively and the chimney was expelled 2,809.543 kJ, 3,962.894 kJ and 1,792.175 kJ, which represents 8.95%, 8.95% and 5.93% of the energy supplied. The energy efficiency of the traditional burners analyzed reaches on average 40% to 46% of the energy supplied by the bagasse.

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