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Estimation of Fixed Carbon by Ignition of Corn Fruit Residues Treated with Electromagnetic Fields

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Gasification, coming from combustion processes of lignocellulosic material, is a practical alternative to produce energy; therefore, obtaining non-forestry raw materials becomes a challenge for the energy sector. This is how the quality of the flow of input material plays a key role in the design, process and optimization of a gasifier. For the above reason, this project evaluated the potential of moisture content, ash, volatile material and fixed carbon of agricultural waste of Porva corn given the availability of these, after the harvest. The field and laboratory tests are carried out in the Fundación Universitaria Agraria de Colombia – UNIAGRARIA, carrying out the harvest until the grain maturation (168 days after sowing). For this, it was taken into account that the seeds, before sowing, had been treated with electromagnetic fields at intensities of L1-23 μT, L2-70 μT and L3-118 μT, artificially created from electronic circuits (voltage sources, capacitors, resistors, coils, switches and semiconductors, etc.) connected together. Humidity was determined with the use of Standard D3173-87, volatile material with Standard D3175-89 (02), ash with Standard D3172-89 (02) and ignition of fixed carbon with the use of Standard 3172- 89 (02); the latter, considered as the part that is not volatile and burns in the solid state of lignocellulosic material, establishing the difference between the sum of the residual moisture, ash and volatile material and 100. The data analysis was performed in the Statgraphics 5.1 Plus statistical package, performing a simple variance analysis and a multiple range test. The comparative analysis of the variables shows a statistically significant increase in the content of Fixed Carbon at the level of corn bracts (elote) higher than 11%, surpassing the control and the rest of the treatments; furthermore, the control of the tusa obtained an atypical value of 0.72% in contrast to all the combinations. The above results are in agreement with what was indicated for the % humidity (the lowest content was presented in the bracts of the cob, in the fruits of plants treated with L1 with 27%), the ash content (the most high were presented in the raw materials of plants treated with L1 and L2 in the bracts of the cob and L2 and L3 in the Tusa, not differing among them but with respect to the rest of the treatments that exceed 3%) and the content of volatile compounds (the highest content was in the Tusa of the plants treated with L1 was present, exceeding 60% and differing significantly with the rest of the treatments).

1. Introduction

The cultivation of corn is considered one of the most important food sources for humans; however, there is little information about the use of the by-products that are generated from this production chain. Likewise, information on the potential of by-products for the industrial and agro-industrial sector from an energy point of

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view is very scarce or very old in terms of technological advances. Hence, the study of the potential use of crop residues (alternative biomass) as an energy source becomes a choice that, if possible, will reduce the dependence of fossil fuels on electricity generation.
The main reasons are enough caloric power and acceptable behavior as fuel, including the non-contribution to the net production of CO_2 through the combustion of biomass. Thence, the biomass sector covers all organic matter that can be susceptible of used from an energy point of view. In other words, biomass is a complex heterogeneous mixture of organic and inorganic matter with diverse origins, which in the agricultural case will be limited by the seasonality of the crops.
It should be noted that the use of electromagnetic fields as a stimulating agent of the growth and development process of plants has become an emerging technology in recent decades, but most of the research has focused on studies focused on morphology and physiology of the plants, leaving aside the enrichment of raw materials in order of quality and use Suárez-Rivero et al.2016). This context thus becomes a relevant and prospective factor in this research.
In the earlier context, the objective of the research was to see if electromagnetic treatment could improve the energy content of corn residues.

2. Material and methods

2.1 Place of study and characteristics of vegetable material

The study was carried out in the laboratory of Phytochemistry and experimental plots of the Fundación de la Universidad Agricola de Colombia - UNIAGRARIA. This is located at 170 No 54A -10, Bogotá DC (Colombia), with coordinates 4°45´70´´N and 74°03´12´´O, an elevation 2650 m above sea level (msnm), relative humidity of 94% and an average annual temperature of 14 ° C. Certified commercial corn seeds were used to establish the harvest (Zea mays L. var Porva), given the importance that this crop has in the basic food basket of Colombia and is the variety most used in conditions of the Sabana de Bogotá. It should be noted that the plants that originated the fruits under study (the seeds sown) were subjected to stimuli with low intensity electromagnetic fields before sowing (23, 70 and 118 µT), said field was controlled and generated from electronic circuits.

2.2 Determination of moisture content

To demonstrate this indicator, the protocol established in D3173-87 was followed, evidencing the loss of moisture from a known sample mass, which is heated in a stream of nitrogen in an oven maintained at a temperature between 105 ^oC y 110 ^oC, where the sample was equilibrated for the first time in atmospheric laboratory conditions, the result is the percentage of humidity calculated by the loss of mass.

2.3 Ash Content Establishment

The ashes were determined under Standard D3172-89 (02). Thus, a sample of known mass was taken, which was subjected to heating in air up to 500 °C for 30 minutes and subsequently going from 500 °C to 815 °C for 60 to 90 minutes until a constant mass was obtained. The amount of ash in the dough is a measure to determine the portion of minerals it contains and was established by weight difference.

2.4 Determination of volatile content

For this process, Standard D3175-89 (02) was used, which established the content of volatile materials, considered as gaseous detachments of organic and inorganic matter during heating. In a sample of estimated mass, the portion was heated to 900 ° C without friction with the air for a certain time (7 minutes), as it was heated, the gaseous and liquid elements that contained it emanated (mainly water, hydrogen, carbon dioxide, carbon, carbon monoxide, methane, among others).

2.5 Determination of fixed ignition carbon content

The fixed ignition carbon was established following Standard 3172-89 (02). This is the part that is not volatile and burns in a solid state. It is the difference between the sum of residual moisture, ash + volatile material and 100, as it appears in equation 1:

$$Fixed\ carbon\ (FC) = 100 - (Rh + A + Vm) \tag{1}$$

Where:

Rh= relative humidity

A= ashes

Vm=Volatile Material

2.6 Treatments and statistical analysis

The evaluations were carried out in triplicate for each of the treatments, as evidenced in studies carried out by Suárez-Rivero et al. (2018). The treatments correspond to:

L1_ cultivated straws treated to 23 µT
L2_ cultivated straws treated to 70 µT
L3_ cultivated straws treated to 118 µT
CP_ control growing straws
L4_ culture tuza treated to 23 µT
L5_ culture tuza treated to 70 µT
L6_ culture tuza treated to 118 µT
CT_ Tuza cultivation Control

An analysis of variance (ANOVA) was performed between the averages of the samples per treatment at a significance level of 95% ($\alpha = 0.05$) to establish whether there are differences, as well as a multiple range test to establish the level of significance (Suarez, 2011). Both tests are used using the Statgraphics 5.1 PLUS statistical software.

3. Results and discussion

3.1 Moisture and ash content

The highest reported percentage of humidity was for the straw-based treatment (L2) as well as the L3 treatments and controls, not significantly differing between them. alike, it is reported for this variable that the lowest moisture contents are presented in L4, differing significantly from the rest of treatments, as shown in Figure 1 (right).

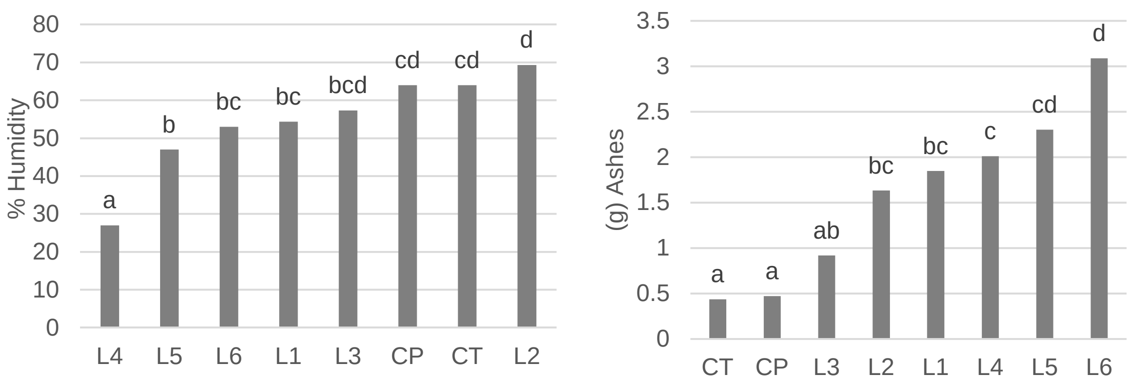

Figure 1. Right: Moisture percentage of the raw material. Left: Ash content of the samples (Equal letters show no significant differences between treatments and different letters show significant differences between treatments).

Regarding moisture content, these results are consistent with those shown by Suárez-Rivero et al. (2016) and Romo et al. (2011), who point out that for the woody type biomass a lower percentage of humidity must be presented than in other types of waste such as sugarcane bagasse, which has a humidity close to 50%. The fact of having low humidity gives it an advantage in combustion, since its high content reduces the efficiency of this process, because the water must evaporate wasting part of the energy of the material (Suárez-Rivero, 2017; García, 2012). Similarly, other authors (Atuesta and Sierra, 2015) report that the humidity ranges for woody biomass should range between 4.7% in pine bark and 62.9% in sawmill residues; so, Data obtained in these tests are within intervals sayings or very close to them, as is the case with the L2 treatment and the controls that presented the highest humidity percentages. The results presented are satisfactory since coffee wood when exposed to sunlight tends to lose moisture quickly and has a lower water content to other materials, such as wood or forest residues (Correa-Méndez et al., 2015).

As for the ash content, a lower mineral accumulation established through the ashes in the raw material from the control plants is reported (figure 1 left), as well as those included in the L3 treatment. On the other hand, the highest ash accumulations are reported according to Figure 1 for the L6 treatment, who does not differ significantly from the L5. In all cases, low ash contents were observed, but they are within the limits reported by the literature for wood that is used as fuel. In this sense, the determination of the ash content indicates whether the biomass can reach almost total combustion. According to Telmo et al. (2010) and Cigasova et al. (2016) usually tropical varieties have high ash content compared to temperate forest species.

3.2 Volatile content

On the other hand, the volatile content present in the samples showed, according to figure 2, its highest expression, exceeding 60% in the L4 treatment, which differs significantly from the rest of treatments and controls.

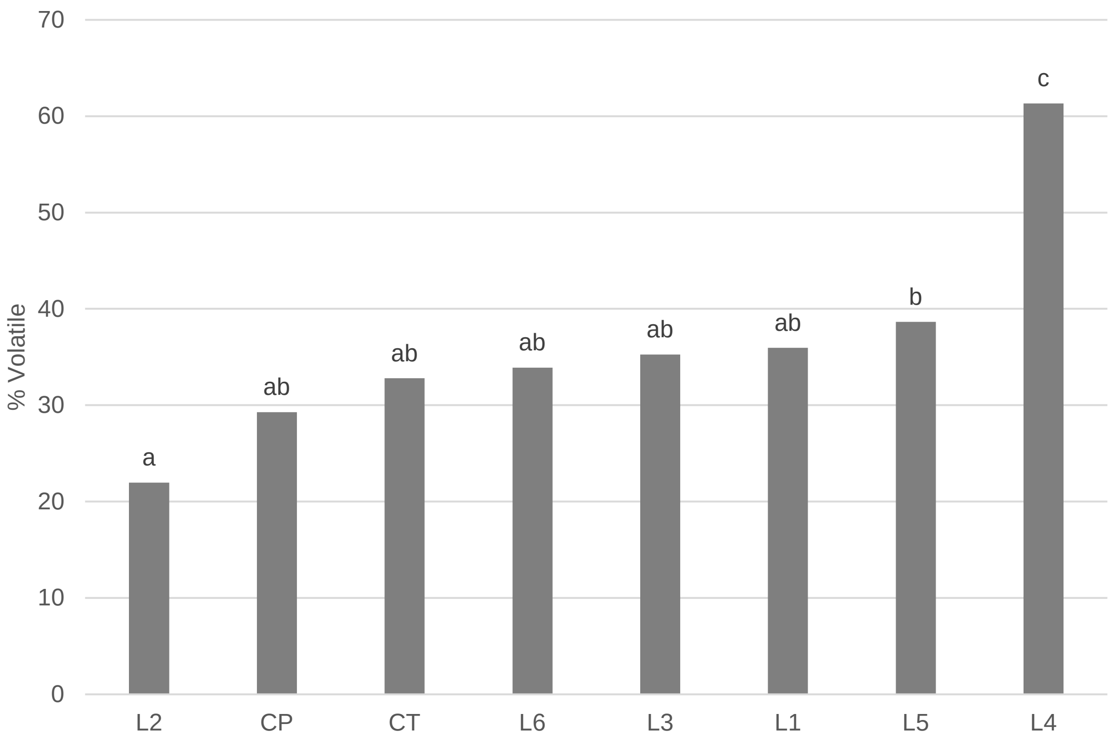

Figure 2. Expression of the % of volatiles present in the samples studied (Equal letters show no significant differences between treatments and different letters show significant differences between treatments).

The volatile percentage represents the amount of gas that is removed when performing a heating process (Oliveros et al., 2017). For Guo et al. (2014), a greater number of volatiles indicates that the nonvolatile matter will be smaller, thus improving the combustion process.

Evenly, authors such as Basu (2011) and Ruiz et al. (2013) express in their studies that during the processes of drying gasification, pyrolysis, oxidation and reduction occur, indicating that during the drying process the water is removed from the biomass, in the pyrolysis, thermal degradation or volatilization of matter occurs in the absence of oxygen, starting at temperatures close to 200 °C, obtaining a solid material (coal or biochar) and condensable fluids that give rise to fuels; concluding that cellulose and hemicellulose are the main sources of volatiles in plant material.

3.3 Fixed carbon content of ignition

Figure 3 shows the behavior according to the established treatments of the content (percentage) of the fixed carbon determined by ignition. In this sense, with values ranging between 11.44 and 11.04%, it was obtained that treatments L4 to L6 showed the highest fixed carbon content, but these do not differ significantly between them; however, if differences are found with the rest of the trials. The treatment with CT showed the lowest values (0.72%), which differ significantly from the rest of the treatments and the CP.

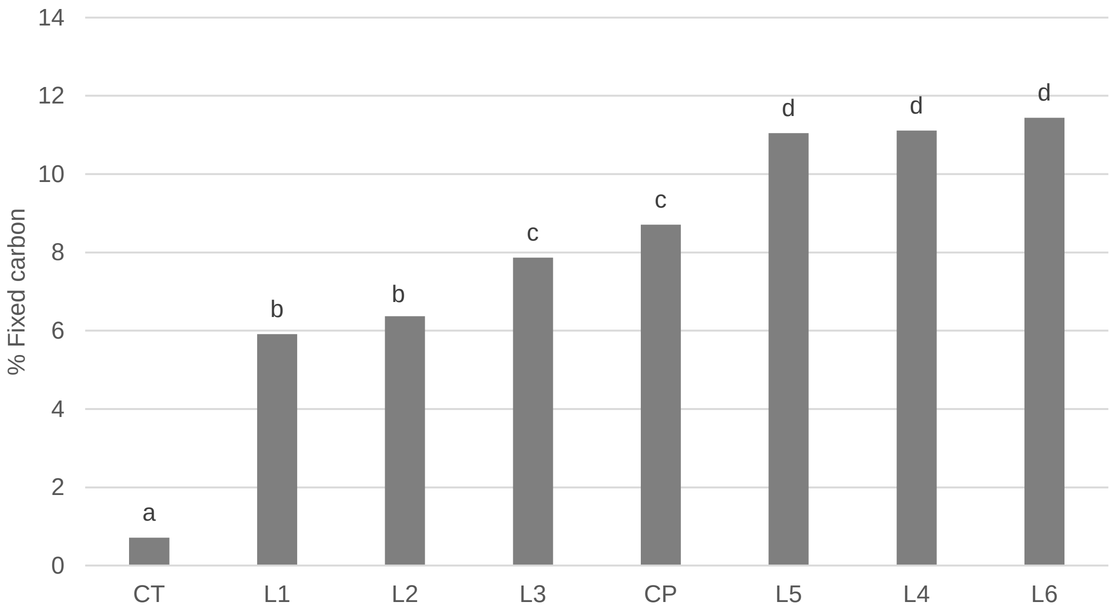

Figure 3. Expression of the% of fixed carbon by ignition in the studied samples (Equal letters show no significant differences between treatments and different letters show significant differences between treatments).

These results indicate that the waste studied in general is suitable for use in a boiler, in such a way that energy is produced; this is since the amount of solid waste can be the minimum possible, thus avoiding pretreatment of the raw material. According to Nova (2013) contrary to the volatile material content, fixed carbon is a crucial characteristic in the composition of a fuel as it represents the greatest source of heat during the combustion of the fuel.

4. Conclusions

The corn residues studied can be used in the manufacture of pellets for energy purposes; thus, the results show that the biomass studied have adequate energy and moisture characteristics, which are favored by the application prior to the sowing of electromagnetic fields.
The results of proximal analyzes with higher fixed carbon content, related to the energy properties of biomass, in treatments L4 to L6, also presenting the highest ash content. The highest values of ashes are 3.09, amounts that are lower than some reported in the literature for ashes such as coconut (3.69) and cotton (5.92), which cause a higher content of waste after a combustion process, revealing thus, from this parameter, the suitability of the waste for this purpose.

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