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Evaluation of Potential Pseudostems *Musa* spp. for Biomass Production

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It is evident that many processes at industrial level are limited by not disposing throughout the time, in a sustainable and continuous way, sources of raw materials of high potential. It is then that the use of foliar residues of *Musa* spp. plants plays an important role, taking into account that for being a perennial tropical crop, it presents a high production of biomass per unit area annually. It is to remark that on a regular basis, biomass produced is left on plantations after every harvest, which turns to be a problem not only for crop management, but also for the environment. This research evaluated the potential of pseudostem of *Musa* spp. for biomass production in order to generate added value to its crops and decrease the productive-environmental problem that all its waste produce. Plant samples of pseudostem are taken from the villages of San Francisco de Sales, Cundinamarca - Colombia y Tibaná, Boyacá – Colombia. Pseudostem cutting was performed at a distance of 1 m from the base of the stem; the type of cut is transversal and the following 50 cm were used as raw material. With the purpose of identifying the exploitable physicochemical components of the pseudostem of *Musa* spp, one bromatological analysis was performed – Van Soest for every origin (San Francisco y Tibaná). To carry out the bromatological analysis, it was required 250g of each sample. The parameters evaluated were moisture content (H), ash content, ether extract or crude fat (GC), fiber, protein, carbohydrates, nitrogen – free extract (ELN), minerals, structural and nonstructural composites. A design with factorial arrangement with three replicates per treatment was used. A simple variance analysis (ANOVA) among the means of samples was performed by treatment with a significance level of 95% (α=0,05) in order to establish if there are meaningful differences for the variables in evaluation. In the case of not finding meaningful differences among the samples, a multiple range test was performed using the statistical package *Statgraphics Centurion.* While conducting the analysis of the study variables for raw materials in fresh, and regardless of their origin, the high potential for biomass production presented by pseudostem of *Musa* spp was detected, thus presenting a dry biomass content exceeding 70% in both stems. The elements of greater variation in the composition are lignin content, ashes, hemicellulose, nonstructural carbohydrates as well as sodium and manganese.

1. Introduction

In Colombia, plane tree cultivation has been a traditional sector of peasant economy, characterized mainly by subsistence for small producers of high geographic dispersion and of great socioeconomic importance from the point of view of food security and employment generation. According to Piedrahita Y. 2010), it is estimated that 87% of the area planted to plantain is found as a traditional crop associated with coffee, cocoa, cassava and fruit trees, and the remaining 13% is monoculture.

However, in the year 2015 the plane tree production chain started substantive transformations in terms of productivity and competitiveness, bringing its yield from 7.3 to 10.0 tons per hectare, production costs have been reduced by 5%, the area of industry reached 600,000 hectares with yield of 6,024,000 tons, and an increase of 4% to 10% of the production destined to international trade, now, to processes of research and genetic improvement as a fundamental support of these purposes.

In addition, Botero L. & Mazzeo M. (2009) indicate that a plant of *Musa* spp at the time of its harvest has an average weight of 100 kg, which are distributed in 15 kg of leaves; 50 kg of pseudostem; 33 kg of banana and

2 kg of rachis. This indicates that more than 75% of the total volume of production is the waste that man does not systematically exploit as a source of biomass. According to Oviedo (2009), the pseudostems represent more than 60% of the biomass that is produced in it plantations, however, in most cases these by-products remain in the field or are given little use as a source of food for animals.

Moreover, taken as referents the previous studies, it is evident that the environmental impact generated is high, since these residues, in most cases are incinerated or deposited outdoors in landfills with low level of technological management. Neverthese, it is important to highlight that these water source contaminated, act as host of pests that cause disease to the same plantation, generate reduction of spaces and a problem of hygiene due to the accumulation of garbage (Botero L. & Mazzeo M., 2009). What is more, the use of foliar residues of plane tree and banana as a source of biomass, is justified because they are perennial tropical crops that present a high production per unit area annually. Given the above, and making follow of new alternatives as sources to biomass that guarantee its availability in time, it's as well as its quality and quantity, was proposed in this research sought to evaluate the potential of the pseudostems of *Musa* spp. for biomass production.

2. Materials and methods

2.1 Characteristics of vegetable material

Plant samples of *Musa* spp, are taken from native plants from the municipalities of San Francisco de Sales, Cundinamarca and Tibaná, Boyacá in Colombia, with 20ºC and 16ºC average temperature and an altitude of approximately 1520 and 2115 meters respectively.

The cut of the pseudostems is made a one (1) meter from the base of the stem towards the apexes of the same, realized of transverse form, taking like sample a length of approximately 50 cm. These stems are transported at room temperature wrapped in sheets of newsprint to the laboratories of the Agrarian University of Colombia (UNIAGRARIA). Before being packaged, are eliminated the traces of plant material, soil and insect's dead found superficially. Once the samples to be analyzed arrive at the destination, they are cut into slices of two (2) cm wide and stored in plastic bags with hermetic seal at a temperature of 4 °C in a refrigerator.

2.2 General pretreatment applied to the pseudostem of Musa spp.

In order to work with a homogeneous material during the experimental process a pre-treatment was developed, from the reception of the plant material to its suitability and dehydration, grinding and packing. The latter, (the packed) in bags with zipper to avoid rehydration of the plant tissue and also to own a single lot per treatment for all the tests.

2.1. Characterization by quantitative and qualitative methods of the biomass of the pseudostems of Musa spp, according to their origin

A physicochemical characterization of the raw material (pseudostem) was carried out to determine its composition. Table 1 shows the bromatological parameters evaluated in pseudostem (moisture content (H), ash content, ethereal extract or crude fat (GC), fiber, protein, carbohydrates, nitrogen-free extract (NFE), among others). For this purpose 250 g of each pseudostem was used, analyzing in duplicate.

2.3 Determination of dry mass by drying curve method and efficiency of the dehydration process.

Two samples of pseudostem were taken from two sources and two drying conditions with four replicates. The provenances are: San Francisco (a1) and Tibaná (a2), while the two drying conditions: temperatures of 45 ° C and 35 ° C in forced conversion oven. The first factor allows the characterization and physicochemical comparison of the raw material and the second factor allows to identify the percentage of dry mass of each one and the efficiency of the dehydration process with respect to the temperature.

The moisture content of the material is determined by the weight difference between the fresh material and the dry matter of the material, Equation 1.

$$\text{\% of total humidity} = \frac{\text{Damp mass - Dry mass}}{\text{Dramp mass}} \times 100 \qquad (1)$$

To obtain the dry matter content at 105 °C, the same operations are performed.

Table 1. Bromatologics parameters evaluated.

PARAMETER	METHOD
Humidity, Ash, Fiber	Gravimetric
Grease	Gravimetric
Protein	Calculation
NFE	Calculation
Total nitrogen	Kjeldahl
K, Ca, Mg, Na, Cu, Mn, Fe, Zn.	Acid digestion - quantification by atomic absorption spectrophotometry with direct flame air - acetylene
Phosporo	Colorimetry with ammonium vanadate molybdate
Boron	Colorimetry with azomethine
Sulfur	Turbidimetry
Cellulose, Hemicellulose, Lignin, Silica	
TDN, FDN, FDA, FDK	Gravimetric
Non-structural carbohydrates, Energy	
Chlorides	Volumetry

Source: Adapted from Dr. Calderón Laboratories Agricultural Technical Assistance LTDA, 2015.

3. Results and discussion

3.1 Bromatological evaluation of fresh pseudostem of *Musa* spp

Likewise, in order to characterize the biomass present in the pseudostem of *Musa* spp., a bromatological analysis was carried out - Van Soest for each source of the raw material (similar to that proposed for microalgae by Dvoretsky et al., 2015).

The results of the bromatological analysis performed are reported in table 2.

Whit this in mind, the pseudostems are composed mostly of water, since, as indicated in Table 2, the humidity is 91.48% for a1 and 92.04% for a_2. These values coincided relatively with those established by Botero and Mazzeo (2009); However, the percentages were higher in ash, ethereal extract and nitrogen, since they obtained 0.49%, 0% and 0.33%, respectively. Similarly, it should be noted that studies (Izquierdo, 2009) have reported that this raw material is a by-product low in dry matter and high in fibers.

As for, the content general of minerals of the pseudostem was not very high, however, comparing the macro and microelements of the same in the two municipalities, a higher percentage of calcium, magnesium and sodium was observed in the material coming from of San Francisco; Which does not occur with potassium, manganese and zinc. This could be influenced by the various growth factors of the plant, mainly due to the nutrient conditions of the soil of each zone, its composition and structure. Both pseudostems presented high concentrations of sodium and potassium in the sample a_1, manganese in the a_2, which could cause damages in the animal when supplying high volumes of product.

Meanwhile that in the acid detergent fiber (ADF) and neutral detergent (NDF), there are significant differences between the samples and the literature. Sample a1 presents 3.92% more of FDA than a2, but a 7.27% less than that reported by Dormond et. al. (2000); by contrast, the content of NDF in a2 was higher by 8.11%. The difference between the fiber values between a_1 and a_2 could be attributed to the specific variety of each sample. It should be noted that since the pseudostem is not true, a true stem has a low lignin content, 3.95% for a1 and 2.03% for a_2. The differences between the lignin values reported in each study may be associated with the phenological maturity of the plant, since at higher maturity higher lignin content.

Additionally, the percentage of non-structural carbohydrates of pseudostem of origin a1 (San Francisco) is 45.79% and that of origin a_2 (Tibaná) of 34.31%, a significant difference of 11.48% favorable to pseudostem from San Francisco. Other results, obtained by Carneiro et al. (2015) in Acacias show a biomass with an underutilized potential in the different production chains, either to produce of biofuels, the paper industry and additionally for animal feed.

Moreover, considering the parts that compose a plant of *Musa* spp., only a small portion of fiber of the pseudostem is destined to the use of Colombian handicrafts, nevertheless, would be presenting a waste about 80% of the total biomass, provoking that in recent years there has been a strong interest in the generation of added value and efficient management of agroindustrial residues of this crop, taking advantage of them for the development of bioprocesses in which they are involved as substrates for the production of organic acids, ethanol, enzymes and other important secondary metabolites for the pharmaceutical, food and biofuel industries (Mazzeo et. al. 2010).

Other advantage, it that both the leaves and the pseudostem of this plant contain significant levels of lignocellulose, whereas the fruits present in their composition a large amount of micronutrients, characteristics that turn their residues into efficient substrates for some basidiomycete fungi that produce Ligninolytic enzymes. Given the aforementioned, it should be noted that these enzymes are capable of completely degrading lignin, a polymer formed by p-hydroxy cinnamyl alcohol and metabolizing the phenolic monomers present in aromatic compounds of interest such as vanilla, ferulic acid and eugenol; these metabolites are important as an alternative for the food, pharmaceutical and dye industry.

Table 2. Bromatological analysis -Van Soest of samples of fresh pseudostem of Musa spp.

Analysis Parameters		**a_1 SAN FRANCISCO**	**a_2 TIBANÁ**
FIBERS (%)	NDF	51,88	60,61
	ADF	20,13	16,21
	FDK	13,96	11,59
PROXIMAL ANÁLYSIS (%)	Humidity	91,48	92,04
	Ethereal Extract	0,56	0,48
	Ash	5,23	12
	Silica	0,32	0,29
	Dry Matter Digestible (TDN)	73,75	76,49
	Crude Protein	2,5	3
	Lignin	3,95	2,03
	Cellulose	12,66	8,96
	Hemicellulose	29,31	39,22
	Non-Structural Carbohydrates	45,79	34,31
MINERALS (%) Macroelements	Phosporo	0,08	0,06
	Potassium	1,72	5,27
	Calcium	0,45	0,15
	Nitrogen	0,4	0,48
	Magnesium	0,12	0,08
	Sulfur	0,02	0,02
	Chlorides	0,28	0,34
MINERALS (ppm) Microelements	Sodium (ppm)	472	71
	Iron	24	1
	Manganese	34	434
	Copper	7	6
	Zinc	28	39
	Boron	7	6
ENERGIES (Kcal/Kg)	E. Digestible	3.252	3.373
	E. Metabolizable	2.666	2.766
	E.N. of Lactation	1.691	1.758
	E.N. of Maintenance	1.850	1.930
	E.N. of Weight Gain	1.130	1.210

3.2 Establishment of Drying Curve and Process Efficiency

Drying of plant material is a complex process that simultaneously integrates heat transfer and mass; taking into account that, the amount of energy used to dry a product depends on factors such as the initial moisture content, desired final moisture content, temperature and air drying rate, according (Argyropoulos et al., 2012). It´s to say, it should be noted that the total drying time is considerably reduced with the increase in temperature and in the presence of a low moisture content of the drying air.

Therefore, Figure 1 shows how the moisture content of the raw material is high (90% for a_1 and 92% for a_2), and that the percentage of dry mass on wet basis (BH) is 10% for a1 and 8% for a2. Evidencing that the drying rate at 45 ° C is higher compared to the treatment at 35 ° C for the two samples; similarly, the decrease in humidity at 35 ° C is homogeneous for the two samples (a_1 and a_2), while at 45 ° C the sample a_2 tends to lose moisture at a higher rate than the sample of a_1.

There is some resemblance with similar results in studies on maize cultivation obtained by Suárez D. et al. (2015) and Ortiz J. et. al. (2015) when analyzing the moisture content in plant tissue. The difference in dry mass in BH for a_1 and a_2 is not more than 2%, considering that the greatest amount of water is released during the first 18 hours and that the equilibrium plateau is reached after hour 20 for both Temperatures, it is

possible to define that the best temperature to carry out the process, in terms of the efficiency of this, is at 35 ° C, due to the energy costs required to reach a temperature higher than this.
Everything indicates that cavernous structure of the tissues that make up the pseudostem, propitiates the dehydration with greater facility than the one reported for other sources of raw materials. The presence of a biomass characterized mainly by cells of the little differentiated parenchyma tissue allows its use as a source of raw material for the extraction of cellulose and hemicellulose. It is noteworthy that today, and over time, this source of raw material has been undervalued and has become a problem for banana producers not only at Colombia level, but also has impacted internationally. Generating an added value to the banana chain from the alternative use as biomass source of this waste will allow not only the increase in revenues, but its greater value will be given by the decrease in the negative impact that has been generated on the environment environment.

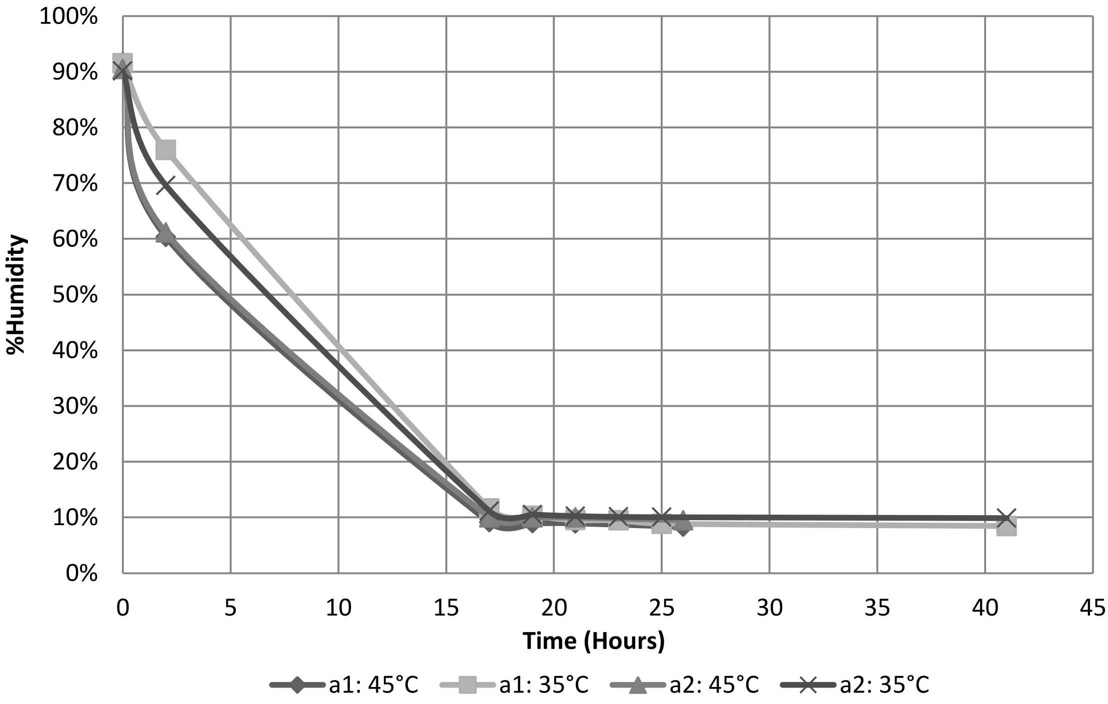

Figure 1. Percentage variation of moisture with respect to time.

In like manner, Costa et. al. (2014) evaluated the effect with microwave oven drying (50 ° C) and environment drying on the mineral content of Menta (*M. piperita* L.) plants, demonstrating that in the solar drying process did not was observed the water loss rate in the experimentation period; but, it was evidenced that the removal of moisture in said period was effected by the process of diffusion. Furthermore, the microwave technique allowed to decrease the drying time, revealing a higher value in the phenolic content; observing that the mineral values in the dry samples showed variability according to the drying method, concluding that the nutritional and commercial quality of the product could be effectively reduced using the microwave oven drying treatment.

4. Conclusions

When performing a VAN SOEST analysis on fresh raw materials, it was detected; the high nutritional potential of the pseudostem of *Musa* spp., and the difference that can exist for this raw material from its composition if one considers the provenance. During the process, too, the content of lignin, ash, hemicellulose, non-structural carbohydrates, as well as sodium and manganese were highlighted as elements of greater variation in the composition of the pseudostem.
Finally, appearde a loss of moisture at the beginning of the process with higher speed with the temperature 45 °C, regardless of the origin of the pseudostem, stabilizing after the 18 hours together with the samples that were Treated at 35 ° C.

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