CHARACTERIZATION OF BANANA CROP'S BY-PRODUCTS

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ABSTRACT

Banana crops produce a great amount of wastes, due to the fact that each plant only produces fruits once in its life. In Canary Islands 400 million kilos of banana are produced each year and for each ton of fruit, around 4 tons of pseudostem are generated, as the main waste, that are frequently left at the harvest location undergoing natural degradation. Mechanical fibre extraction is one of the most relevant alternatives for pseudostem valorization but this process still produces another material, Banana's pseudostem pulp (BPP) as a byproduct.
In this work, the characterization of this material (BPP), as well as the rachis fraction has been carried out using different protocols. Both materials presented an interesting chemical composition, with a high content of polysaccharides and low content of lignin, which makes it particularly interesting for the biorefinery's biochemical platform. Some differences could be found when different protocols were used, underlining that TGA and FTIR are fast techniques but only qualitative information can be obtained from them.

Keywords: banana crops, banana by-products, residues valorization, oligosaccharides

INTRODUCTION

Due to the environmental awareness in recent years, there has been an increasing trend towards more efficient utilization of agroindustrial residues, frequently un-utilized. Lignocellulosic biomass can potentially be converted into different high value products (bio-fuels, value added chemicals, enzymes, etc.) [1] and, although significant progress has been made to use them, improvement of the quality and manufacturing efficiency has often been hampered partly due to the difficulties encountered in the characterization of the complex structures of these materials [2].
Lignocellulosic biomass is mainly composed by cellulose, hemicellulose and lignin. The proportion of each component and its composition varies for different types of biomass and also, due to location, harvesting season, weather conditions, and/or precipitation [3]. So, in order to choose the most suitable strategy for valorization of a feedstock, its adequate characterization is needed [4]. On the other hand, despite its importance, the compositional analysis of biomass remains a challenging and time-consuming task primarily due to its recalcitrant structure [5].
In the present study, a characterization of different fractions of waste generated in banana crop has been carried out. Banana plants only bears fruits once, generating great amount of residues after harvesting. A study shows that every ton of picked bananas generates around 3 t of pseudostem,150 kg of rachis and 480 kg of leaves [6], in fresh matter. Making use of this biomass could be a very attractive alternative, contributing to the preservation and adding value to the fruit production matrix, for which a correct characterization of the material is necessary.
In this work, the banana's pseudostem pulp (BPP) generated in the mechanical fiber extraction of banana pseudostem, as well as rachis fraction were characterized using different methodologies. A comparison between the results obtained with the different procedures and with other published works has been performed.

EXPERIMENTAL

Materials

Pseudostems from *Musa acuminata Dwarf Cavendish* randomly collected from an agroindustrial plantation in Arguineguín (village situated in the south of Gran Canaria, Spain) the same day that the plants were cut, were subjected to a mechanical fibre extraction using a pilot plant available in the facilities of the University of Las Palmas de Gran Canaria. In addition to the fiber, another byproduct is generated in this process, banana's pseudostem pulp (BPP), which was one of the raw material for this study. On the other hand, rachis from *Musa acuminata Dwarf Cavendish*, the other feedstock of the present study, was supplied by Cooperativa Agrícola del Norte de Gran Canaria.

Chemical characterization

For the chemical characterization, the different fractions were dried and milled to <0.5mm. Proximate analysis (moisture, crude protein, fiber and ash content) was determined according to AOAC (1995). Lipids were determined according to Folch et al. (1957).
Quantitative acid hydrolysis (QAH) was carried out according to NREL/TP-510-42618 protocol (Sluiter et al., 2008), allowing the determination of monosaccharides, acetyl groups and Klason lignin. Total extractives were determined sequentially with deionised water and ethanol (NREL/TP-510-42619, Sluiter et al., 2005).
Holocellulose content of the raw material was determined according to Browning (1967) and cellulose was determined using ANSI/ASTM (American National Standards Institute, 1977b) protocol. Hemicellulose was calculated as the difference between holocellulose and cellulose. In addition, total starch content was measured according to AOAC Method 996.11 using the Total Starch Assay Kit (AA/AMG) (Megazyme). The tests were carried out in triplicate and all determinations were carried out to the raw and extractive-free materials.

Thermo-gravimetric analysis (TGA)

In contrast with chemical characterization, which is a time-consuming process, thermo-gravimetric analysis can be used as a fast method for predicting hemicellulose, cellulose and lignin contents in a biomass. These assays were performed in a TGA device from Mettler Toledo (TGA/DSC 1 LF) 10 mg samples were heated up to 1000 ºC at a constant rate of 5 ºC/min. Purified nitrogen at a flow rate of 10 mL/min was used as the carrier gas. Each fraction was analyzed in duplicate.

Fourier Transform Infrared Spectroscopy (FTIR)

Infrared spectrometry offers an alternative approach that is robust and rapid. 5 samples of each fraction were observed in a Perkin Elmer infrared spectrophotometer (FTIR Spectrum 2). The generated spectra were analyzed to identify the major functional groups.

RESULTS

Proximate analysis reflected that rachis and BPP present a high amount of carbohydrates, upper than 50% in both cases. The content in lipids was practically zero and the protein levels were low, although slightly higher in the case of the rachis. As reported by other authors [7] for practically all parts of banana plant, ash contents were high.
High extractives content was also obtained for both materials (rachis 31.84±1.21 and BPP 21.1±0.79%), composed, in large part, of ashes, as showed in the extractive free material analysis (not shown). Holocellulose and cellulose determinations, carried out according to Browning (1967) and ANSI/ASTM respectively, reflected that the presence of extractives may interfere with the analysis and so, a previous extraction is recommended. Cellulose content obtained for rachis was 30.15±0.81% and 26.29±2.17 for BBP; hemicellulose contents were 15.36±2,06 and 19.11±2.31 for rachis and BBP respectively.

Table 1. Chemical composition of BBP and rachis

Proximate analysis			**Quantitative acid hydrolysis (NREL protocol)**		
Component	**BPP**	**Rachis**	**Component**	**BPP**	**Rachis**
Lipids (%)	1,19±0,54	1,82±0,10	Glucan	47.39 ± 0.20	27,08±0,10

Ashes (%)	17,51±2,73	34,39±0,10	Xylan	8.35 ± 0.42	12,12±0,04
Protein (%)	6,17±2,01	11,44±0,34	Arabinan	7.57 ± 0.35	-
Sum	24.87%	47,65%	Acetyl groups	0.85 ± 0.00	1,27±1,80

Especially interesting is the low content in lignin, 6.33 ± 0.23% for BPP and 10.52±0.16 for rachis. Lignin determinations were less affected by extractables presence. Quantitative acid hydrolysis showed that the main constituent of carbohydrate fractions is glucan. In the case of BPP the content of glucan was very high due to the presence of starch in this fraction (30.01±0.43%). This starch was not removed during the extraction in Soxhlet device.

Hemicellulose calculated as the sum of glucan, xylan, arabinan and acetyl groups was 16.76 ± 0.77% for BPP and 13,39±1,84% for rachis. Both values are somewhat lower than obtained with the previous procedure. Cellulose content considered as glucan content (corrected for starch presence) was 27.08% for rachis and 17.39% for BPP. Not significant differences were found for rachis analysis by both procedures, although for BPP the method greatly affects the obtained results. The results obtained in this research are similar to published in previous works [7].

Taking into consideration the decomposition ranges of the pure component, an approximate composition could be obtained from the thermogravimetric analysis. Hemicellulose contents of 38.4 and 34.1%, cellulose percentages of 27.3 and 24.8% and lignin contents of 21.5 and 24.4% were obtained for pulp and rachis respectively. As can be observed, due to the presence of other components, like starch in the pulp, only the values of percentage of cellulose approximate to the values obtained in the chemical characterization.

Concerning the FTIR spectrum the characteristics peaks of cellulose, hemicellulose and lignin could be observed, but a quantification of each component cannot be obtained from these assays, being this technique most useful for other applications like pretreatment influence evaluation.

CONCLUSIONS

The valorization of banana crop's by-products have interest for environmental reason. These by-products have an interesting composition with a high content of polysaccharides (mainly glucan) and low content of lignin

ACKNOWLEDGEMENTS

Sara Díaz is grateful to Ministry of Education, Culture and Sports of Spain, (Grant Ref. FPU15/03138). ICAAM is a research unit funded by Fundação para a Ciência e a Tecnologia (UID/AGR/00115/2019).

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