STUDY OF THE CHEMICAL CHARACTERIZATION AND STARCH EXTRACTION YIELD FROM *Bambusa vulgaris* FOR BIOREFINERY

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Abstract

Bamboo is a biomass with great potential for biorefinery, since it can be entirely used in industrial processes. Starch extracted from parenchymal cells can be saccharified for the production of bioethanol, while stalks can be applied for the production of paper and charcoal. Therefore, this paper aims to study the applicability of the *Bambusa vulgaris* species for the alternative production of cellulosic kraft pulp by analyzing its chemical characterization, in addition to obtaining starch for the production of bioethanol. The bamboo samples were manually transformed into chips, classified and dried. A fraction of the chips was directed to the extraction of starch, while the other was separated for chemical analysis. The chemical characterization of *B. vulgaris* was carried out using standardized methods. The starch was extracted using the mechanical chip defibration method with a hammer mill, followed by a leaching in water. In the chemical characterization, 23.2% of total lignin and 63.4% of holocellulose were obtained, which is favorable for the production of cellulosic kraft pulp. It was observed that *B. vulgaris* has a lower lignin content than wood, representing an advantage for the delignification process. A low ash content was obtained, which is close to that usually noted for pine and eucalyptus. There is an average of 8.9% of total extractives in this sample, a very high content compared to wood, which, in this case, is unfavorable for this technological purpose. The starch yield obtained after extraction was 3.59%. It is concluded that bamboo has a great potential as an alternative source for the production of cellulosic kraft pulp, since it has competitive chemical characteristics with the conventional raw materials used in this industry. Finally, it is observed that it is possible to extract starch from bamboo using the mechanical chip defibration methodology followed by leaching in water, for its later conversion into bioethanol.

Keywords. Bamboo. Chemical Characterization. Starch. Biorefinery. Cellulosic pulp

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Introduction

The increase in the application of natural resources and the development of new processes that make their use feasible is an increasingly evident reality, directing efforts from the academic and industrial sectors towards new sustainable technologies. It is in this context that the concept of biorefinery arises, which consists in the conversion of biomass into bioproducts, such as biofuels, and bioenergy in the form of heat (BASTOS, 2012 and BATALHA *et al.*, 2016). Among the biomasses usually applied for biorefinery, wood and agricultural residues, such as sugarcane bagasse, wheat, corn straw and rice straw can be mentioned (ALVIM et al., 2014).

Bamboo is one of the alternative feedstocks that has been mostly studied recently. It is a grass that has tropical and subtropical origin, but can be found on all the continents of the planet (XUHE, 2003). The most abundant genera in Brazil are Asians: *Dendrocalamus* and *Bambusa*, which were brought by Portuguese settlers, while Asian immigrants were responsible for the most recent establishment of the *Phyllostachys* genus on Brazilian soil (BERALDO and AZZINI, 2004).

Especially in the Brazilian territory, the use of bamboo as an alternative raw material becomes even more relevant, since Brazil is the country with the largest area of bamboo plantation in the American continent (FILGUEIRAS and GONÇALVES, 2004; JUDZIEWICZ et al., 1999). There are more than 130 different species throughout this country (LONDOÑO, 2001). Another important factor of this crop is the good capacity of development in poor soils and its fast harvest cycle (REUBENS, 2010).

Bamboo is a biomass that may have great manufacturing potential, since it can be entirely used in industrial processes. Starch extracted from parenchymal cells can be saccharified for the production of bioethanol, while stalks can be applied for the production of paper and charcoal. The extraction of starch for the use in biofuel production, in addition to adding value to the process, is also very interesting for the optimization of cellulose pulp production, since starch increases the consumption of reagents in the pulping step and reduces the conversion of the chips into cellulosic pulp (AZZINI et al., 1987).

This paper aims to study the applicability of the *Bambusa vulgaris* species for the production of cellulosic kraft pulp by analyzing its chemical characterization and comparing it to the conventional raw materials, in addition to obtaining starch for the production of bioethanol. Therefore, this paper is an initial study for a complete application of this species in a biorefinery plant.

Methodology

The *Bambusa vulgaris* samples were manually transformed into chips, classified and dried. A fraction of the accepted chips was directed to the extraction of starch, while the other was separated for chemical analysis. The fraction of not accepted chips may be reserved for the further production of charcoal.

The chemical characterization of *B. vulgaris* was carried out using standardized procedures to determine the levels of total extractives, soluble and insoluble lignin, and the content of carbohydrates, uronic acids, acetyl groups and ashes, as summarized in the Table 1.

Table 1. Methodologies for the chemical characterization of bamboo samples

Parameters	Procedures
Classification of wood chips	SCAN 40:94
Total extractives	TAPPI T 264 cm-97
Acid-insoluble lignin	TAPPI T222 cm-11
Acid-soluble lignin	Goldschimid (1971)
Acid hydrolysis	TAPPI T 249 cm-85
Sugars	WALLIS *et al.* (1996)
Uronic acids	SCOTT (1979)
Acetyl groups	SOLAR *et al.* (1987)
Ashes	TAPPI T264 cm-97

The starch was extracted using the mechanical chip defibration method with a hammer mill, followed by a leaching in water (AZZINI, 1984). The bamboo shredded in a mill was mixed for 15 seconds in a domestic blender with 1:10 water. The starch suspension was collected and kept static for 96 hours, adding a few drops of formaldehyde to inhibit the appearance of microorganisms. After 96 hours, the supernatant was removed and the starch was dried in an oven at 105ºC, with its yield determined by gravimetry.

Results and discussion

The results obtained in the chemical characterization of *Bambusa vulgaris* are shown in Table 2.

As can be calculated by the values in Table 2, 23.2% of total lignin and 63.4% of holocellulose were obtained, which is favorable for the production of cellulosic kraft pulp (GOMIDE *et al.*, 1981).

Table 2. Chemical characterization of *Bambusa vulgaris*

Parameters	Values, %
Total extractives	8.9
Ash	0.65
Acid-insoluble lignin	22.1
Acid-soluble lignin	1.1
Total lignin	23.2
Acetyl groups	2.7
Uronic acids	1.1
Arabinan	0.9
Galactan	0.5
Glucan	46.2
Xylan	15.7
Mannan	0.1

It was observed that *B. vulgaris* has a lower lignin content than pine and eucalyptus, which are the conventional raw materials for the cellulosic pulp production (THOMAS, 1977). These outcomes are expected for grasses in general and represent another advantage for the delignification process. However, the portion of p-hydroxyphenyl lignin present in bamboo must be taken into account, as it is the most condensed and least reactive lignin in alkaline media when compared to syringyl and guaiacyl ones. It is noted, therefore, that the low content of lignins in bamboo contributes to an easier delignification, but the characteristic of the lignin present in grasses may be a drawback to the pulping process.

A 0.65% ash content was obtained, which is close to that usually noted for pine and eucalyptus in the literature (GOMIDE, 1986). The presence of inorganics is unfavorable for the industrial process, since it makes more difficult to cut the stalks, affects the cooking process properties and causes operational damage to the fiber line, such as incrustations and corrosion of machinery. Therefore, the low ash content

present in this bamboo sample is positive for the production of cellulose.

There is an average of 8.9% in the total extractives content of this sample. This value is very high when compared to wood, which, in this case, is unfavorable for cellulose technological purpose (SJÖSTRÖM,1993; IRANMAHBOOB *et al.*, 2002).

The starch yield obtained after extraction in this study was 3.59%, obtained by difference from the total fiber yield, assuming that all the extracted content is, in fact, starch, as proposed by the applied methodology. Azzini (1984) obtained a yield of 8.53% for *Guadua flabellata*, which corresponds to 32% of the starch in the culm of that species. In his work with *Bambusa vulgaris* for the joint production of paper and starch, Azzini (1987) found 46% of cellulose yield and 6.5% of starch. The starch yields obtained in this study was lower than those found in the literature probably due to an insufficient mechanical defibration of the chips in the initial stage of starch extraction or due to the difficulty in separating the suspended starch.

Conclusion

It is concluded that bamboo has a great potential as an alternative source for the production of cellulosic kraft pulp, since it has competitive chemical characteristics when compared to the conventional raw materials used in this industry. Finally, it is observed that it is possible to extract starch from bamboo using the mechanical chip defibration methodology followed by leaching in water, for its later conversion into bioethanol. Due to the great variety of products that can be obtained and the possibility of using bamboo in its entirety, it appears to be, in fact, a very interesting biomass for industrial application in biorefineries.

References

ALVIM, J. C. *et al.* Biorrefinarias: Conceitos, classificação, matérias primas e produtos. **Journal of Bioenergy and Food Science**, v. 1, n. 3, p. 61–77, 2014.

AZZINI, A. Amido a partir de bambu. **Bragantia**, v.43, n.1, p.45-50, 1984.

AZZINI, A.; ARRUDA, M. C. Q. de; CIARAMELLO, D.; SALGADO, A. L. de B. e TOMAZELLO FILHO, M. Produção conjunta de fibras celulósicas e etanol a partir do bambu. **Bragantia**, v.46, n.1, p.17-25, 1987.

BASTOS, V. D. Biorrefinarias, biocombustíveis e química renovável: revolução tecnológica e financiamento. **Revista do BNDES**, p. 85-128, dezembro de 2012.

BATALHA, L. A. R.; BORGES, F. P.; JAMEEL, H.; CHANG, H.; COLODETTE, J. L.; GOMES, F. J. B. Produção de açúcares fermentáveis a partir do bagaço de cana-de-açúcar. In: Proceeding of the 49th ABTCP International Pulp and Paper Congress, 2016, São Paulo. **Anais**… 2016

BERALDO, A. L.; AZZINI, A. **Bambu:** características e aplicações. Editora Guaíba: Agropecuária, 2004. Guaíba – RS, 2004.128p.

FILGUEIRAS, T.S. e GONÇALVES, A.P.S. A checklist of the Basal Grasses and Bamboos in Brazil (Poaceae). Bamboo Science & Culture. **The Journal of the American Bamboo Society**. Vol. 18.2004. p7-18

GOMIDE, J. L.; OLIVEIRA, R. C; COLODETTE, J. L. Influencia da idade do *Bambusa vulgaris* nas suas características químicas a anatômicas visando a produção de polpa celulósica. **In:** Congresso Anual da ABCP, 14, 1981, São Paulo, v. 1, p. 5-29.

GOMIDE, J. L. Estudo sobre a constituição química do *Bambusa vulgaris*, visando a produção de polpa celulósica**. O papel**, v.47, n.10, p.64-68, 1986.

IRANMAHBOOB, J.; NADIM, F.; MONEMI, S. Optimizing acid-hydrolysis: a critical step for production of ethanol from mixed wood chips. **Biomass and Bioenergy**, v. 22, p. 401-404, 2002

JUDZIEWICZ, E.J. *et al.* **American bamboos**. Washington, D.C.: Smithsonian Institution Press. 1999. 392 p

LONDOÑO, X. Evaluation of bamboo resource in Latin America. Beijing: **INBAR**, 2001. 30p.

REUBENS, R. **Bamboo in Sustainable Contemporary Design**. INBAR Working Paper, Beijing, n.60, 2010.

SJÖSTRÖM, E. Wood chemistry: fundamentals and application. London: **Academic Press**, 1993. 293 p.

THOMAS, R. J., Wood structure and chemical composition. **In:** GOLDSTEIN, I. S. Wood technology: chemical aspects. Washington, D. C.: American Chemical Society, 1977. p.1-23. (ACS Symposium Series, 43).

XUHE, C. Promotion of Bamboo for Poverty Alleviation and Economic Development. **In**: Proceeding of International Workshop on Bamboo Industrial Utilizations, October, 2003: International Network for bamboo and Rattan-INBAR, Nanjing Forestry University of China, 2003.