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Bamboo shoots - an evaluation of powders obtained from the processing residues of the species *Dendrocalamus asper*

Brotos de bambu - uma avaliação de pós obtidos de resíduos do processamento da espécie *Dendrocalamus asper*

Brotes de bambú - una evaluación de los polvos obtenidos de residuos del procesamiento de la especie *Dendrocalamus asper*

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Maria Gabriela Azevedo Barros
ORCID: https://orcid.org/0000-0002-4487-3175
Universidade Federal de Santa Catarina, Brazil
E-mail: mariagabiab@gmail.com
Lucas Bertoldi Watanabe
ORCID: https://orcid.org/0000-0001-9379-5516
Universidade Federal de Santa Catarina, Brazil
E-mail: lucasbwata@gmail.com
Ana Carolina Moura de Sena Aquino
ORCID: https://orcid.org/0000-0002-0832-5198
Universidade Federal de Santa Catarina, Brazil
carolsenaaquino@gmail.com
Edna Regina Amante
ORCID: https://orcid.org/0000-0001-9593-5674
Universidade Federal de Santa Catarina, Brazil
E-mail: e.amante@ufsc.br

Abstract
The aim of this study was to characterize the solid residue of bamboo shoot processing, which corresponds to more than 70% of the raw material, beyond the technological properties and cyanide removing. Pre-processing was carried out in boiling water for 30, 45, 60, and 90 minutes. Control, treated and pre-treated residue samples were dried in an oven with air circulation for 48 hours at 65 ± 5 °C followed by milling in knife mill and standardized in particle size 60 mesh sieve. The powder showed low lipids content and high fiber, protein and mineral contents proportional to the traditional flours. The technological properties were evaluated for water and oil retention capacity, showing high values, that was proved by analysis of scanning electron microscopy (SEM), which showed high porosity structure. Regarding the presence of cyanogenic glycosides, it was concluded that pre-processing and drying significantly reduced but not eliminated taxiphyllin, which generates an alert to the processing of this material as safe foods, however demonstrating to be an important absorbent material in the treatment of oil-contaminated waters and soils.
Keywords: Bamboo; By-products; Composition; Cyanide; Microstructure.

Resumo
O objetivo deste estudo foi caracterizar o resíduo sólido do beneficiamento de brotos de bambu, que corresponde a mais de 70% da matéria-prima, além das propriedades tecnológicas e remoção de cianeto. O pré-processamento foi realizado em água fervente por 30, 45, 60 e 90 minutos. As amostras de resíduos (controle, tratadas e pré-tratadas) foram secas em estufa com circulação de ar por 48 horas a 65 ± 5 °C seguida de moagem em moinho de facas e padronizadas em peneira granulométrica 60 mesh. O pó apresentou baixo teor de lipídios e alto teor de fibras, proteínas e minerais proporcionais às farinhas tradicionais. As propriedades tecnológicas foram avaliadas quanto à capacidade de retenção de água e óleo, apresentando valores elevados, comprovados por análise de microscopia eletrônica de varredura (MEV), que apresentou estrutura de alta porosidade. Em relação à presença de glicosídeos cianogênicos, concluiu-se que o pré-processamento e secagem reduziu significativamente, mas não eliminou a taxifilina, o que gera um alerta para o processamento deste material como alimento seguro, porém demonstrando ser um importante material absorvente no tratamento de óleo -águas e solos contaminados.
Palavras-chave: Bambu; Subprodutos; Composição; Cianeto; Microestrutura.

Resumen
El objetivo de este estudio fue caracterizar el residuo sólido del procesamiento de brotes de bambú, que corresponde a más del 70% de la materia prima, más allá de las propiedades tecnológicas y de remoción de cianuro. El

preprocesamiento se llevó a cabo en agua hirviendo durante 30, 45, 60 y 90 minutos. Las muestras de residuos de control, tratadas y pretratadas se secaron en un horno con circulación de aire durante 48 horas a 65 ± 5 °C, seguido de molienda en un molino de cuchillas y se estandarizaron en tamiz de malla 60 de tamaño de partícula. El polvo mostró bajo contenido de lípidos y alto contenido de fibra, proteína y minerales proporcional a las harinas tradicionales. Se evaluaron las propiedades tecnológicas para la capacidad de retención de agua y aceite, mostrando valores elevados, lo que se comprobó mediante análisis de microscopía electrónica de barrido (SEM), que mostró estructura de alta porosidad. En cuanto a la presencia de glucósidos cianogénicos, se concluyó que el preprocesamiento y el secado redujeron significativamente pero no eliminaron la taxifilina, lo que genera una alerta para el procesamiento de este material como alimentos seguros, sin embargo demostrando ser un importante material absorbente en el tratamiento del aceite. -aguas y suelos contaminados.

Palabras clave: Bambú; Subproductos; Composición; Cianeto; Microestrutura.

1. Introduction

The search for new materials which are inexpensive and have an absorbent property is considered relevant. Mainly regarding the oil absorption capacity, considering that contamination of soil and water with oils is frequent, hence it is a big problem to the environment (Hewelke et al., 2018). The presence of oil changes the dynamics of microorganism activity, vegetable growth, and animals live in the soil (Buzmakov et al., 2019; Klamerus-Iwan et al., 2015). Additionally, the oil reduces the permeabilization and alters the soil's physical properties (Hewelke et al., 2018; Klamerus-Iwan et al., 2015). Moreover, the oil in the water harms zoo and phytoplankton, among the other consequences caused by reducing dissolved oxygen, all of which contribute to the severe changes in the environment are consequences of this type of pollution (Kingston, 2002; Klamerus-Iwan et al., 2015).

Treatments of soil and water are necessary to reduce the damage of oil contamination. Studies of pollution of oil in water are published in large quantities. So, in front of the soil complexity, many techniques are used to evaluate oil mineralization. Like microbes that use oil as carbon source; surfactants that help the acceleration of degradation; the use of electrodes or the combination of many techniques showed interesting results (Fan et al., 2020; Zhang et al., 2020). While these traditional treatments have a waste of the retained or degraded oil, this could be reused as energy if recovered. In this way, the application of absorption material is necessary. Relevant characteristics of those are capillary presence, low cost, facile production and hydrophobic capacity (Pinto et al., 2016).

Characteristics such as porosity and high absorption are common in residual fibrous from food industries. For example, king palm wastes with these properties were studied by Vieira et al. (2009) and de Simas et al. (2010) that constitute more than 90% of raw material on king palm heart processing. Bamboo is an important raw material, especially in Asian countries, where these are availed in different areas, be it in construction or foods such as shoots. More than 1000 species are of recognized distribution for all the planet, especially in countries such as China and India, hence Brazil has been in the spotlight with a promise in the world context, containing around 65% of the new bamboo species (Pandey & Ojha, 2014; Singh et al., 2013).

The bamboos belong to a botanic family of *Poaceae*, have a quick growth, and their use is common in Asia, around construction - mature culm, and food - shoots stage. A shoot is characterized up until 30 cm height, and the average weights 1 kg. The bamboo shoot could be divided into three areas - rhizomes, culm, and peel (Kleinhenz & Midmore, 2001; Pandey & Ojha, 2014). The intake of bamboo shoots increases every year, its global consumption being over 2 million tons in 2020 (Wang et al., 2020). However, the edible parts of bamboo shoots only represent 27% of the shoot. Consequently, for each ton of this raw material 730 kg corresponds to residue from this process (Satya et al., 2010). The species *Dendrocalamus asper*, also known as giant bamboo, is the target of this study.

Bamboo shoot processing residues can be an important source of oil absorbers. However, for a better evaluation of the potential applications, it is critical to consider that the bamboo shoots present varied contents of taxiphyllin, a cyanogenic glycogen, which amount also varies with species, environmental conditions, and age of shoots (Rana et al., 2012; Watanabe et al., 2021). The presence of taxiphyllin is critical because it is toxic when inhaled and ingested (WHO, 2004). Therefore, there is a need for monitoring its content to avoid environmental contamination. Although the processing residues of the bamboo shoot present interesting absorbent properties, the removal of cyanide must be guaranteed for its application to be viable.

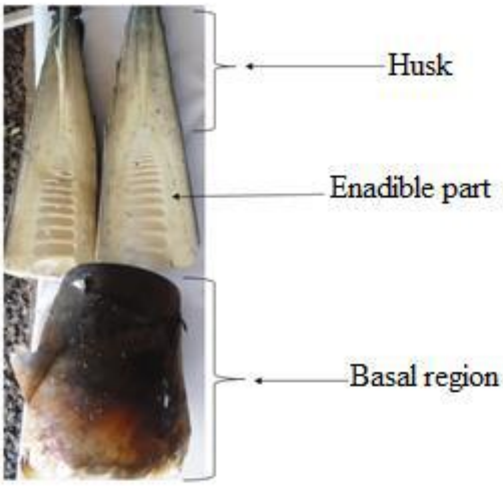
The waste minimization, as well as new alternatives for oil pollution decontamination, can be achieved depending on the bamboo shoot residues properties. The aim of this study is to propose another perspective of bamboo shoot productive chain with complete raw material application suggestions.

2. Methodology

The bamboo shoots of *Dendrocalamus asper* species were collected in Planalto city, Rio Grande do Sul, Brazil. All reagent used were of analytical grade.

After the shoot removal (Figure 1), a powder was produced from the solid residue. Different samples were studied: control (not heat treated) and pre-treated (in boiling water for 30, 45, 60 and 90 minutes). All samples were dried in an oven with air circulation (FABBE, São Paulo, Brazil) for 48 hours at 65 ± 5 °C followed by milling in knife mill and standardized in particle size 60 mesh sieve. Each sample was collected and processed in triplicate.

Figure 1. Bamboo shoot after harvest.



Source: Authors.

2.1 Bamboo shoot residues composition analysis

The cyanogenic glycosides were determined in the residue, control (not heat treated), treated by 30, 45, 60 and 90 minutes powder samples, through two methods. A quantitative, according to Surleva and Drochioiu (2013), in a spectrophotometer (HITACHI U-1800), and the extraction was based in Tsuge et al. (2001) adapted process. The qualitative analysis was made according to proposal by Drochioiu (2002).

After pre-treatment definition according to the cyanide remotion, control samples, treated by 30 minutes (T30) and 90 minutes (T90), were analyzed. Moisture, mineral, lipid and protein contents were determined through AOAC methodologies 925.10, 924.05, 945.39, 920.87, respectively. Total fiber according to method 985.29, and soluble and insoluble fiber according to 891.42, MEGAZYME kit (AOAC, 2005). Carbohydrates were calculated by difference. From mineral residue, iron, magnesium, sodium, and calcium were determined by flame atomic absorption, and potassium by atomic emission. The pH was determined according to the method 017/IV of Adolfo Lutz Institute (2008) adapted. The pH was measured with pHmether (QUIMIS®) model Q400A and calibrated previous to analysis.

The alcohol soluble acidity and the water-soluble acidity were determined according to methods 415/IV and 016/IV, respectively (Adolfo Lutz Institute, 2008), with adaptations due to the sampling.

Soluble solids content expressed as ºBrix was determined from a solution with 0.1 g of sample diluted in 10 mL of distilled water, homogenized in ultra-sound and reading was made through portable digital refractometer (Quick-BrixTM 90, Columbus, Ohio, United States). Reducing sugar was evaluated according to Miller (1959). The antioxidant capacity was determined by FRAP and DPPH methods, according to Cardador-Martínez et al. (2002) and Kunyanga et al. (2012). The results were measured in spectrophotometer model U-1800 (HITACHI®).

Absorption of water was adapted from the method described by Sosusky (1962). 1.0 g of samples were weighted, 5 mL of distilled water added, the mixture was agitated to 1 minute on *Vortex*, then left to rest for 30 minutes and centrifuged at 1046.25 x g (centrifuge HERMLE® model Z 200A) for 30 minutes.

Absorption of oil was adapted from the method described by Lin et al. (1974). The methodology suggests the use of corn oil and soy oil was used instead, while another adaptation was the velocity of the centrifuge being 2092.5 x g (centrifuge HERMLE® model Z 200A), where suggested by the author was 2000 x g. 0.5 g of samples were weighted, 3 mL of distilled water added, the mixture was agitated to 1 minute on *Vortex*, then left to rest for 30 minutes and centrifuged for 30 minutes.

2.2 Microscopy

Scanning electron microscope (SEM) was used for the characterization of powder particles, the microscope utilized was JOEL JMS-6390LV, on Laboratory Central of Electronic Microscopy (LCME) of University Federal of Santa Catarina.

2.3 Statistical

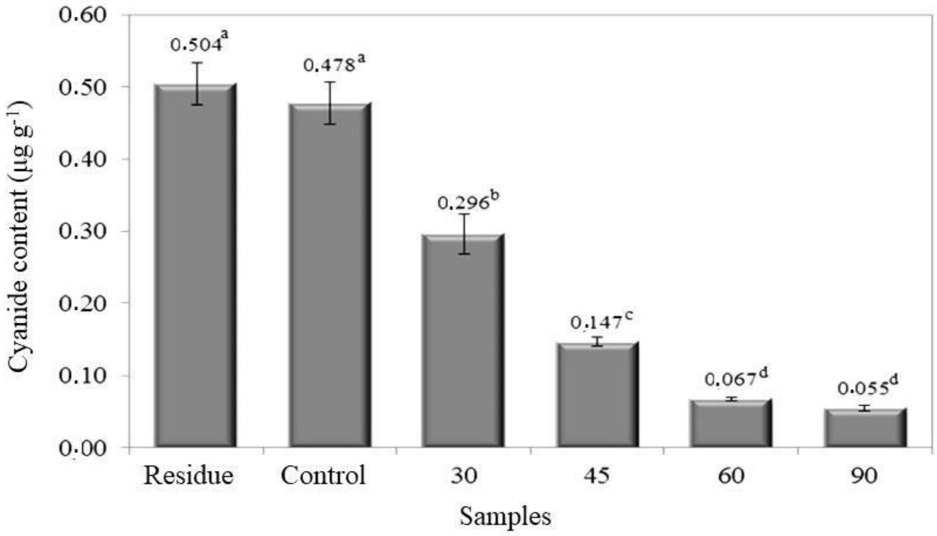
All analysis were carried in triplicate. The results expressed in media and standard deviation. The effects of treatments were compared for analysis of variance (Anova), at 5 % of probability level. The means performed in software Assistat 7.7 beta.

3. Results and Discussion

3.1 Cyanide content

Cyanide levels in powder residues of bamboo shoots give a limitation of what can be done in its application. This factor justifies the evaluation of an optimal time for decontamination of the residue studied. The removal of cyanide increases with time of thermal treatment (Figure 2). But preliminarily the glycoside taxiphyllin was measured by qualitative method with the extraction of glycoside using sodium carbonate, the control, the residue and the 30 minutes (T30) heat treated samples showed positive results. On the other hand, the result was negative for the samples of 45 (T45), 60 (T60) and 90 (T90) minutes of heat treatment. Making the decision about treatment through the results of the qualitative analysis would ensure that the T45 treatment would be sufficient. However, in the quantitative analysis, for the extraction of glycoside, sulfuric acid 10 % was used in cell of micro diffusion, where it was observed positive results for all samples. The sample which showed higher content was the residue powder, followed by the control of flour, T30, T45, T60 and T90, respectively. The results shown in Figure 2 demonstrate that the thermal treatment and drying process contributed to the reduction of cyanide content, if compared with that acid extractions on bamboo shoot performed by Haque and Bradbury (2002), the values could be reduced by 50% with the treatment proposed in this paper.

Figure. 2. Cyanide content in μ g^{-1} in flours and powder of bamboo shoot, obtained with different pre-treatments for taxiphyllin removal.



Source: Authors.

Bamboo shoot residue application should be controlled according to the cyanide content, which can select some suggested uses of this material.

A profound knowledge of the material is important to generate ideas of new applications, in this sense, the SEM analysis is interesting to show the microscopic and structural characteristics of this material and can be used to understand its physicochemical and technological properties. In Figure 3 it is possible to observe the microscopic characteristics of the residue, while Figures 3D to 3F present the control flour and the flours obtained from 30 and 90 minutes of heat treatment.

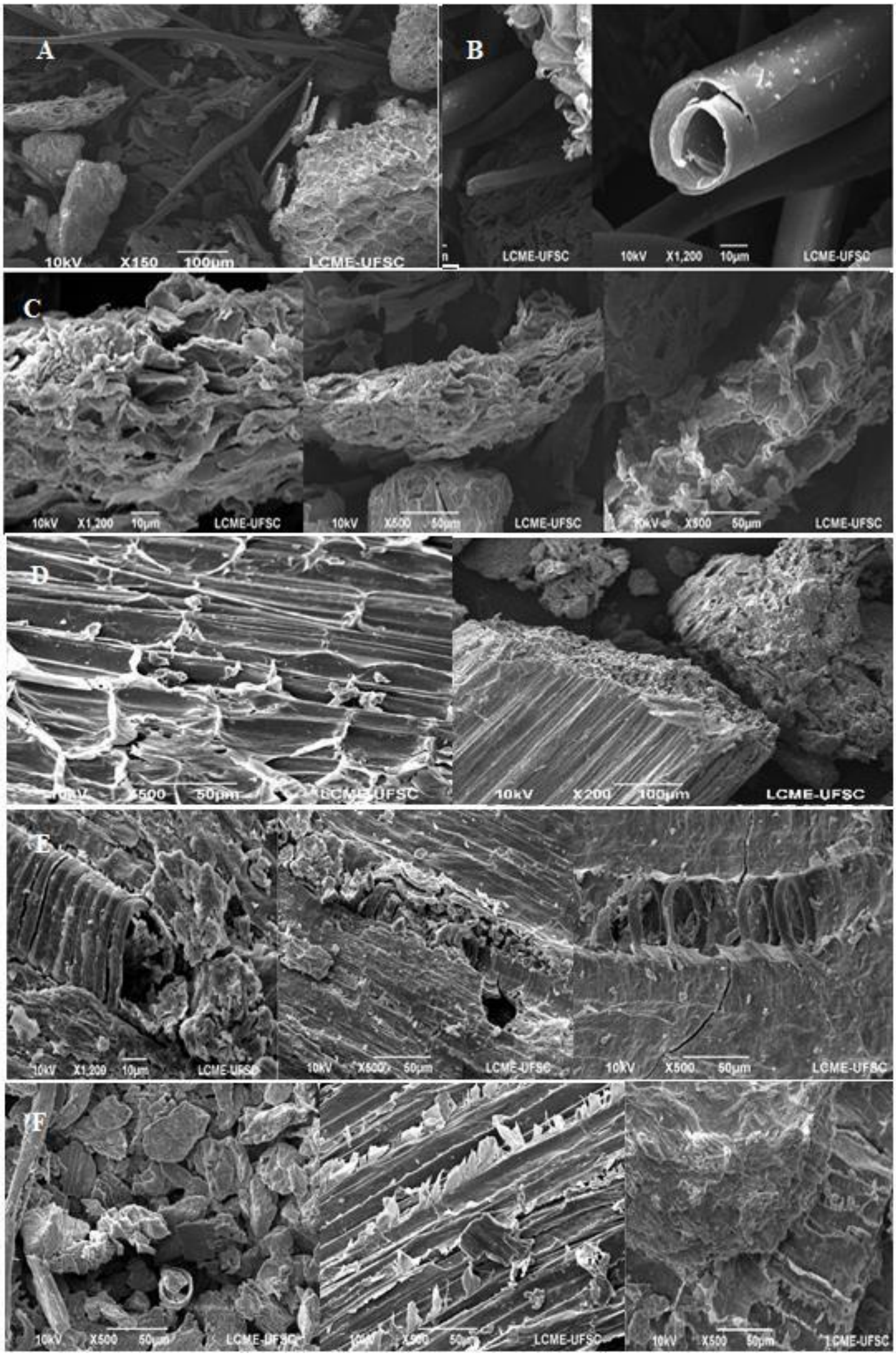
Considering that the residue represents over 70% of shoot's mass, their appreciation is important given the relevant reduction of impact in the environment. The SEM figures showing the microscopic structures are remarkably interesting, as in Figure 3A where the general characteristics of the bamboo shoot residue powder can be seen, while in Figure 3B it is possible to observe the tubules that cover the peel.

Characteristic of a sponge structure (Figure 3C) from the powder, was similar to the ones described by Khalil et al. (2006) of wood powder, which can suggest similar applications.

In the Figures 3D to 3F it is possible to see the profile of flour control and T30 and T90 heat treated, as well as the control sample. The time of treatment directly influences the microstructure, which can be observed from the difference between both samples, with T90 presenting a more damaged structure than T30 and control. With this analysis it is possible to justify the properties of this powder to absorb oil in water.

The profile of control sample (Figure 3D) could be compared to the one shown by Yin et al. (2020) of Pinus sawdust used to prepare a superhydrophobic magnetic material, with a rugose superficial demonstrated in Pinus sawdust CW-coated Fe3O4@PLS. While de sophora Pinus sawdust is similar to the residue powder (Figure 3A). So, these observations corroborate the results that this paper found of the absorption capacity of the samples in question.

Figure 3. Bamboo shoot residue microstructure. A – General vision of powder of bamboo shoot residue (150x). B – Tubule structure (1200x). C – Sponge structure (1200x; 500x). D – Profile of bamboo shoot residue control samples (500x; 200x). E – Profile of bamboo shoot residue flour sample 30 minutes of heat treatment (1200x; 500x). F. Profile of bamboo shoot residue flour sample 90 minutes of heat treatment (500x).



Source: Authors.

3.2 Proximal composition and technological characteristics of bamboo residue flour

Samples were selected according to the results of cyanide content analysis. The 30 minutes (T30) sample was chosen as it was the lowest time of heat treatment, as well as the 90 minutes (T90), which presented the lower amount of cyanide content. The control was also taken as parameter for the nutritional and physicochemical changes as it was not heat treated.

When comparing the results obtained for moisture content it is possible to observe that the T30 sample presented the highest loss of moisture while the control presented the lowest loss. For proteins content, the T30 sample presented the highest amount, while the control presented the lowest one, which was a similar pattern for lipids content. For dietary fiber there was no meaningful difference among samples, and in relation to the ashes content, the highest amount was identified in the T90 sample and the minor amount in the control. Lastly, the carbohydrates content was higher in the T90 sample and lower in the T30 sample. These results can be seen in detail in Table 1.

Table 1. Centesimal composition of bamboo shoot residues flour samples.

g 100g^{-1}							
Samples	**Moisture**	**Protein***	**Lipids***	**Dietary Fiber***		**Ashes***	**Carbohydrates***
				Soluble	**Insoluble**		
Control	16.59 ± 0.37^a	12.19 ± 0.09^c	1.19 ± 0.05^c	2.7 ± 0.40^a	22.5 ± 0.10^a	6.05 ± 0.73^c	44.83
T30	14.12 ± 0.23^c	14.63 ± 0.25^a	1.87 ± 0.06^a	2.50 ± 0.26^a	23.07 ± 0.51^a	9.30 ± 0.73^b	43.81
T90	14.99 ± 0.27^b	13.11 ± 0.10^b	1.66 ± 0.01^b	2.90 ± 0.20^a	22.30 ± 0.20^a	14.29 ± 1.01^a	45.04

*Dry base. Average ± standard deviation. Average follow same letter on column, no significative difference shown between each, to Turkey test on 5 % of probability. Source: Authors.

These differences in results were caused by the heterogeneity of the samples, and the alteration in the powder particles structure also was caused by the thermal process, followed by milling process. The moisture content is similar to the one found in peanuts and corn flour (Brazil, 1978).

The content of protein is higher than literature describes for fresh bamboo shoot, that is 3.5 g 100g^{-1} (Nongdam and Tikendra, 2014; Sood et al., 2013), this difference may be attributed to the concentration of compounds caused in the dried samples.

As for the lipids content, literature shows that variation occurs, starting value from 0.40 g 100 g^{-1} to 3.64 g 100 g^{-1}, the results of this paper being within this range (Chongtham et al., 2011, 2007; Nongdam & Tikendra, 2014).

Bamboo shoot residue samples presented a profile of insoluble fiber higher than soluble fiber, however the difference between samples was not statistically significant. According to ANVISA (National Agency of Sanitary Vigilance of Brazil), these samples should be considered a source of fibber, once they presented more than 3 g 100 g^{-1} (Brazil, 2012).

The values found for ashes are superior to those described in literature, which could be attributed to basal piece, that is not usually used in traditional preparation, and can be characteristic from the soil where the shoot was grown (Sood et al., 2013).

In the mineral analysis (Table 2), the results reveal that samples are rich in potassium and sodium, considerable values of calcium and magnesium were found and the content of iron was average, but not too expressive as other minerals analysed. These results indicate that previous thermal treatment as well as drying process does not influence the proximal composition, but influence in minerals content.

Table 2. Mineral contents in bamboo shoot residues flour.

	Minerals mg $100g^{-1}$				
Samples	**Calcium**	**Iron**	**Magnesium**	**Potassium**	**Sodium**
Control	43.00 ± 1.00^c	2.70 ± 0.10^b	74.00 ± 0.40^a	2740.00 ± 170.00^a	1140.00 ± 90.00^c
T30	66.00 ± 1.00^b	2.90 ± 0.10^a	74.00 ± 0.30^a	1600.00 ± 10.00^c	1680.00 ± 130.00^b
T90	79.00 ± 1.00^a	2.30 ± 0.20^c	55.00 ± 0.10^c	16500.00 ± 30.00^b	8790.00 ± 53.00^a

*Dry base. Average ± standard deviation. Average follow same letter on column, no have significative difference shown between each, to Turkey test on 5 % of probability. Source: Authors.

Thermal treatment reduces the acidity level, probably due to inhibition of degradation caused by enzymatic or bacterial influence. In this work, the antioxidant potential presented by the control sample was higher than the others, which has almost total inhibition in the FRAP analysis, and almost half in DPPH, while T90 sample presented the lowest potential. Looking at the results, it is clear that cooking interferes with the antioxidant properties of the material, since the control sample was the one with the highest potential, followed by T30 and finally T90 samples. When comparing the two methodologies employed (FRAP and DPPH), there is a positive correlation between them, whose Pearson's linear correlation coefficient was 0.9772. The values can be seen in Table 3.

When the obtained results are compared to those presented by Kunyanga et al. (2012) in a study with different roasted seeds, it was observed that antioxidant capacity for bamboo is lower than that of sunflower seeds (84.67 ± 1.18 µmol L^{-1} of Trolox g^{-1}) and pumpkin (83.67 ± 0.59 µmol L^{-1} of Trolox g^{-1}). But when compared to the results presented by Barbosa et al. (2006) for flours of whole soybean (4.0 ± 0.4 µmol L^{-1} of Trolox g^{-1}), the bamboo shoot flour presented greater potential.

Table 3. Characterization of physicochemical properties and antioxidant capacity of bamboo shoot residues flour.

Samples	pH	Acidity* (mL of NaOH $1molL^{-1}$ $100g^{-1}$)		Solid soluble total (°Brix)	Reductors Sugar* (g $100g^{-1}$)	Antioxidant capacity* (µmolL^{-1} de Trolox g^{-1})	
		Aquo soluble	Alcohol soluble			DPPH	FRAP
Control	4.37 ± 0.01^c	64.44 ± 1.07^a	9.28 ± 0.20^a	60.00 ± 0.01^a	62.63 ± 0.89^a	43.47 ± 3.39^a	94.23 ± 3.56^a
T30	4.40 ± 0.01^b	39.67 ± 0.83^b	7.47 ± 0.19^b	55.00 ± 5.00^a	33.36 ± 1.94^b	22.24 ± 2.22^b	65.50 ± 1.10^b
T90	4.46 ± 0.01^a	30.72 ± 0.58^c	5.54 ± 0.23^c	56.67 ± 5.77^a	29.78 ± 1.51^b	13.77 ± 1.76^c	39.53 ± 1.65^c

*Dry base. Average ± standard deviation. Average follow same letter on column, no have significative difference shown between each, to Turkey test on 5 % of probability. Source: Authors.

The analysis of alcohol soluble acidity is relevant for flours, showing the level of organic acids soluble in alcohol. Compared with the acidity presented by other flours in the CNNPA (Food Standards National Commission) resolution 12 of ANVISA (National Health Surveillance Agency) (Brazil, 1978) for this class of foods, it was found that the control and T30 sample presented higher acidity than the majority of foods from this resolution, while the T90 presented an acidity closer to other flours, such as oats, rye, and cornmeal. The control presented an acidity of 9.28 ± 0.20 mL of 1 molL^{-1} NaOH $100g^{-1}$, while T30 showed a value of 7.47 ± 0.19 ml 1 $molL^{-1}$ NaOH $100g^{-1}$ and T90 of 5.54 ± 0.23 mL de NaOH 1 $molL^{-1}$(Table 3). These difference in values beforementioned were statistically significant.

With the aquo soluble acidity it is possible to observe the alterations undergone by the food during processing, and to determine standards for possible product shelf life. In the result it is observed that the organic acids present are very soluble in water, once compared with soluble alcohol acidity it was lower. However, it is possible to observe that the acid content in the control sample is significantly higher than T30 and T90, having 64.44 ± 1.07 mL of NaOH 1 $molL^{-1}100g^{-1}$, 39.67 ± 0.83mL 1 $molL^{-1}$ NaOH $100g^{-1}$ and 30.72 ± 0.58 mL NaOH 1 $molL^{-1}100g^{-1}$, respectively (Table 3). This likely indicates that the enzymatic activity led to the higher release of acids for the previously non-treated samples, or by the loss of acids during cooking process.

The result for soluble solids presented a coherent value when related to the carbohydrate content of the samples, where the control had the highest value (60.00 ± 0.01 ºBrix), followed by T90 which was 56.67 ± 5.77 ºBrix, and T30 presented the lowest value, with 55.00 ± 5.00 ºBrix (Table 3). These solids account for mono and disaccharides, besides organic acids present in the samples, but influenced by the respective thermal treatments.

The evaluation of the reducing sugars content is important on a broad spectrum. The presence of reducing sugars in flours influences their color, which changes due to caramelization and Maillard reactions, as well as the sensorial characteristics. In addition, they may indicate prospects of use, mainly for the residue, in production of second-generation alcohol and other fermented products. It also indicates an important reason for many eastern processes of bamboo to have a stage of fermentation, contributing to the safety of the final product.

It is also possible to observe that the pre-treatment influenced the final amount of reducing sugars of the flour samples studied. The control presented almost double the amount compared to T30 and T90, 62.63 ± 0.89g $100g^{-1}$, 33.36 ± 1.94 g $100g^{-1}$and 29.78 ± 1.51 g $100g^{-1}$, respectively (Table 3). It is possible to conclude that the largest loss occurs early in the process, within 30 minutes of treatment, which little differs from 90 minutes of treatment. The results of reducing sugars indicate that for the production of fermented products other than for human consumption, such as ethanol fuel, the highest yield would be obtained from the bamboo without heat treatment. However, further studies should indicate the best way for the preparation of shoots considering its application in fermented products.

It is possible to observe that the properties found in the powder of the bamboo shoots residues in the different treatments are like many nutritious flours in the food market. While the analysis of cyanide by qualitative route would indicate the use of this powder as an ingredient in the elaboration of foods with high fiber content and other properties, the quantitative analyses suggest more caution around its use. Despite the practice of boiling time before the consumption of the sprouts, the tests with the residues suggest its application in other important sectors, considering the microstructure presented. The fibrous characteristics of the bamboo shoot plant matrix signal to some differentiated technological properties, among them, the retention capacity of oil. The evaluation of the oil retention capacity (CAO) has promising results in comparison with other flours such as sunflower and wheat, which were evaluated by Lin et al. (1974), where wheat presented a CAO of 84.2%, and sunflower of 207.8%, while the control sample presented a value of 353.13 ± 9.56%, followed by the residue sample 348.33 ± 0.32%. The T90 sample obtained a CAO equal to 297.39 ± 6.50%; and, finally, T30 sample a value of 288.59 ± 3.22% (Table 4), not being this difference statistically significant. However, between control and residue, T30 and T90, there was a statistically significant difference. This positive result may be related to the fibers and their characteristics. However, there is great heterogeneity in the thickness, length, and fiber characteristics, which justifies some variations between the samples.

Table 4. Evaluation of absorption capacity of bamboo shoots residues flour.

Samples	CAA (%)	CAO (%)
Control	454.49 ± 9.33[a]	353.13 ± 9.56[a]
T30	406.13 ± 5.16[b]	288.59 ± 3.22[b]
T90	371.45 ± 0.20[c]	297.39 ± 6.50[b]

*Dry base. Average ± standard deviation. Average follow same letter on column, no have significative difference shown between each, to Turkey test on 5 % of probability. Source: Authors.

Water absorption capacity (CAA) is an important property to predict the flours' applications. The results found for CAA (Table 4) indicate promising potential of shoot flour, when compared to other flours such as sunflower and wheat, which were evaluated by Lin et al. (1974). In that study, wheat flour yielded a CAA of 60.2% and sunflower of 107.1%, while that of the powder of residue presented an absorption capacity of 485.45 ± 14.7%, with a high deviation, however justified by the characteristics of the sample. The control also presented a high capacity 454.49 ± 9.33%, followed by the T30 that had a CAA equal to 406.13 ± 5.16%, and finally T90 which was 371.45 ± 0.12%. That positive result may be related to the fiber content, the fiber characteristics, and their interaction with water.

The structural characteristics, the fibers, the oil and water retention capacity, suggest applications in new materials, with modified surfaces to increase the specificity of the retained material, in special filtration systems.

4. Conclusion

From the results obtained, it is possible to affirm that more studies are necessary, especially in determining the ideal pre-processing, since even with the drying process the presence of cyanogenic compounds was still detected. The standardization of methodology for measuring the cyanide content is important due to the sensitivity of the employed method, which could have incurred the significant variance. It is advised that more studies addressing the harvesting season as well as the period and size of the shoots are conducted, since it is already known that the shoot size has a big influence, but no studies have been found on the harvest season. Such pre-processing results generate an alert to bamboo shoot producers and to the scientific community, since this stage is decisive for food safety.

It was observed that the centesimal composition suffered alterations due to heat treatment, also to the drying process, as expected to a concentration of compounds such as proteins and lipids.

It was also shown that even with the heat treatment, the samples presented antioxidant activity, with a tendency of loss of antioxidants with pre-processing.

As for the technological properties, the flours presented excellent absorbent capacity, and can be utilized in the preparation of non-food creams, and the residue could also be used as sawing is utilized in environmental disasters, such like oil leak.

For its consumption as food, it is suggested that the pre-processing cooking time is always monitored to ensure the total elimination of taxiphyllin and to ensure food safety.

In regard to drying, the time and temperature used can be optimized by adaptation of the drying equipment, however the results obtained by the employed method were satisfactory.

Furthermore, this paper has proven its initial goal, showing the versatility of characteristics of bamboo shoots flour and their residue, especially the evaluation of capacity to absorbed oil, presenting high potential, while more studies would be required.

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References

AOAC (2005). *Official Methods of Analysis*. 18th edition, Gaithersburg, M.D., USA, Association of Official Analytical Chemists.

Barbosa, A.C. L., Hassimotto, N. M. A., Lajolo, F. M., & Genovese, M. I. (2006). Teores de isoflavonas e capacidade antioxidante da soja e produtos derivados. *Ciência e Tecnologia de Alimentos*, 26, 921-926 https://doi.org/10.1590/S0101-20612006000400032.

Brazil. ANVISA (National Health Surveillance Agency), Resolução CNNPN nº 12 de 1978.

Brazil. ANVISA (National Health Surveillance Agency), RDC nº 54 de 12 DE NOV. 2012.

Buzmakov, S., Egorova, D., & Gatina, E. (2019). Effects of crude oil contamination on soils of the Ural region. *Journal of Soils and Sediments*, 19, 38-48. https://doi.org/10.1007/s11368-018-2025-0.

Cardador-Martínez, A., Loarca-Piña, G., & Oomah, B. D. (2002). Antioxidant Activity in Common Beans (*Phaseolus vulgaris* L.). *Journal of Agricultural and Food Chemistry*, 50, 6975–6980. https://doi.org/10.1021/jf020296n.

Chongtham, N., Bisht, M. S., & Haorongbam, S. (2011). Nutritional Properties of Bamboo Shoots: Potential and Prospects for Utilization as a Health Food. *Comprehensive Review in Food Science and Food Safety*, 10, 153-168. https://doi.org/10.1111/j.1541-4337.2011.00147.x.

Chongtham, N., Elangbam, D., & Sharma, M. L. (2007). Changes in nutrient components during ageing of emerging juvenile bamboo shoots. *International Journal of Food Science and Nutrition*, 58, 612-618. https://doi.org/10.1080/09637480701359529.

de Simas, K. N., Vieira, L. do N., Podestá, R., Vieira, M. A., Rockenbach, I. I., Petkowicz, C. L. O., de Deus Medeiros, J., de Francisco, A., Amante, E. R., & Amboni, R. D. M. C., 2010. Microstructure, nutrient composition and antioxidant capacity of king palm flour: A new potential source of dietary fibre. *Bioresource Technology*, 101, 5701-5707. https://doi.org/10.1016/j.biortech.2010.02.053.

Drochioiu, G. (2002). Fast and highly selective determination of cyanide with 2,2-dihydroxy-1,3-indanedione. *Talanta*, 56, 1163-1165. https://doi.org/10.1016/S0039-9140(01)00609-9.

Fan, R., Ma, W., & Zhang, H. (2020). Microbial community responses to soil parameters and their effects on petroleum degradation during bio-electrokinetic remediation. *Science of the Total Environment*, 748, 142463. https://doi.org/10.1016/j.scitotenv.2020.142463.

Haque, R. M., & Bradbury, H. J. (2002). Total cyanide determination of plants and foods using the picrate and acid hydrolysis methods. *Food Chemistry*, 77, 107-114. https://doi.org/10.1016/S0308-8146(01)00313-2.

Hewelke, E., Szatyłowicz, J., Hewelke, P., Gnatowski, T., & Aghalarov, R. (2018). The Impact of Diesel Oil Pollution on the Hydrophobicity and CO2 Efflux of Forest Soils. *Water, Air, & Soil Pollution*, 229, 51. https://doi.org/10.1007/s11270-018-3720-6.

IAL (1985). Instituto Adolfo Lutz. Normas Analíticas do Instituto Adolfo Lutz: *Métodos Químicos e Físicos para Análise de Alimentos*, 3 ed. São Paulo: IMESP, 1, 32–33.

Khalil, H. P. S. A., Shahnaz, S. B. S., Ratnam, M. M., Ahmad, F., & Fuaad, N. A. N. (2006). Recycle Polypropylene (RPP) - Wood Saw Dust (WSD) Composites - Part 1: The Effect of Different Filler Size and Filler Loading on Mechanical and Water Absorption Properties. *Journal of Reinforced Plastics and Composites*, 25, 1291-1303. https://doi.org/10.1177/0731684406062060.

Kingston, P. F., 2002. Long-term Environmental Impact of Oil Spills. *Spill Science & Technology Bulletin*, 7, 53-61. https://doi.org/10.1016/S1353-2561(02)00051-8.

Klamerus-Iwan, A., Błońska, E., Lasota, J., Kalandyk, A., & Waligórski, P. (2015). Influence of Oil Contamination on Physical and Biological Properties of Forest Soil After Chainsaw Use. *Water, Air, and Soil Pollution*, 226, 1-9. https://doi.org/10.1007/s11270-015-2649-2.

Kleinhenz, V., & Midmore, D. J. (2001). Aspects of bamboo agronomy. *Advances in Agronomy*, 74, 99-153. https://doi.org/10.1016/S0065-2113(01)74032-1.

Kunyanga, C. N., Imungi, J. K., Okoth, M. W., Biesalski, H. K., & Vadivel, V. (2012). Total phenolic content, antioxidant and antidiabetic properties of methanolic extract of raw and traditionally processed Kenyan indigenous food ingredients. *LWT - Food Science and Technology*, 45, 269-276. https://doi.org/10.1016/j.lwt.2011.08.006.

Lin, M. J. Y., Humbert, E. S., & Sosulky, F. W. (1974). Certain Functional Properties of Sunflower Meal Products. *Journal of Food Science*, 39, 368-370. https://doi.org/10.1111/j.1365-2621.1974.tb02896.x.

Miller, G. L. (1959). Use of Dinitrosalicylic Acid Reagent for Determination of Reducing Sugar. *Analytical Chemistry*, 31, 426–428. https://doi.org/10.1021/ac60147a030.

Nongdam, P., & Tikendra, L. (2014). The Nutritional Facts of Bamboo Shoots and Their Usage as Important Traditional Foods of Northeast India. *International Scholarly Research Nutrition*, 2014, 679073. https://doi.org/10.1155/2014/679073.

Pandey, A. K., & Ojha, V., 2014. Precooking processing of bamboo shoots for removal of anti-nutrients. *Journal of Food Science and Technology*, 51, 43-50. https://doi.org/10.1007/s13197-011-0463-4.

Pinto, J., Athanassiou, A., & Fragouli, D. (2016). Effect of the porous structure of polymer foams on the remediation of oil spills. *Journal of Physics D: Applied Physics*, 49, 145601. https://doi.org/10.1088/0022-3727/49/14/145601.

Rana, B., Awasthi, P., & Kumbhar, B. K. (2012). Optimization of processing conditions for cyanide content reduction in fresh bamboo shoot during NaCl treatment by response surface methodology. *Journal of Food Science and Technology*, 49, 103-109. https://doi.org/10.1007/s13197-011-0324-1.

Satya, S., Bal, L. M., Singhal, P., & Naik, S. N. (2010). Bamboo shoot processing: food quality and safety aspect (a review). *Trends in Food Science and Technology*, 21, 181-189. https://doi.org/10.1016/j.tifs.2009.11.002.

Singh, S.R., Singh, R., Kalia, S., Dalal, S., Dhawan, A.K., & Kalia, R.K. (2013). Limitations, progress and prospects of application of biotechnological tools in improvement of bamboo—a plant with extraordinary qualities. *Physiology and Molecular Biology of Plants*, 19, 21-41. https://doi.org/10.1007/s12298-012-0147-1.

Sood, S., Walia, S., Gupta, M., & Sood, A. (2013). Nutritional Characterization of Shoots and Other Edible Products of an Edible Bamboo - *Dendrocalamus hamiltonii*. *Current Research in Nutrition and Food Science*, 1, 169-176. https://doi.org/10.12944/CRNFSJ.1.2.08.

Sosusky, F. W. (1962). The centrifuge method for determination flour absorption in hard red spring wheats. *Cereal Chemistry*, 39, 344–350.
Surleva, A., & Drochioiu, G. (2013). A modified ninhydrin micro-assay for determination of total cyanogens in plants. *Food Chemistry*, 141, 2788-2794. https://doi.org/10.1016/j.foodchem.2013.05.110.

Tsuge, K., Kataoka, M., & Seto, Y. (2001). Rapid Determination of Cyanide and Azide in Beverages by Microdiffusion Spectrophotometric Method. *Journal of Analytical Toxicology*, *25*, 228-236. https://doi.org/10.1093/jat/25.4.228.

Vieira, M. A., Podestá, R., Tramonte, K. C., Amboni, R. D. de M. C., Simas, K. N. de, Avancini, S. R. P., & Amante, E. R. (2009). Chemical composition of flours made of residues from the king palm (*Archontophoenix alexandrae*) industry. *Brazilian Archives of Biology and Technology*, 52, 973-980. https://doi.org/10.1590/S1516-89132009000400021.

Watanabe, L. B., Aquino, A. C. M. S., & Amante, E. R. (2021). Pasta as a new product from bamboo shoot (*Dendrocalamus asper*): physicochemical and microbiological properties. *Research, Society and Development*, 10(3), e27610313353. https://doi.org/10.33448/rsd-v10i3.13353.

Wang, Y., Chen, J., Wang, D., Ye, F., He, Y., Hu, Z., &Zhao, G. (2020). A systematic review on the composition, storage, processing of bamboo shoots: Focusing the nutritional and functional benefits. *Journal of Functional Foods*, 71, 104015. https://doi.org/10.1016/j.jff.2020.104015.

WHO, Hydrogen cyanide and cyanides: Human health aspects. Concise International chemical assessment document; 61, 2004.

Yin, Z., Li, Yuhang, Song, T., Bao, M., Li, Yiming, Lu, J., & Li, Yang (2020). Preparation of superhydrophobic magnetic sawdust for effective oil/water separation. *Journal of Cleanear Production*, 253, 120058. https://doi.org/10.1016/j.jclepro.2020.120058.

Zhang, T., Liu, Y., Zhong, S., & Zhang, L. (2020). AOPs-based remediation of petroleum hydrocarbons-contaminated soils: Efficiency, influencing factors and environmental impacts. *Chemosphere*, 246, 125726. https://doi.org/10.1016/j.chemosphere.2019.125726.