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Characterisation of bamboo (*Bambusa tuldoides*) culm flour and its use in cookies

Crislayne Teodoro Vasques[1], Maiara Pereira Mendes[1], Denise de Moraes Batista da Silva[1], Claudia Cirineo Ferreira Monteiro[2], Antonio Roberto Giriboni Monteiro[1]*

[1]*Food Engineering Department, State University of Maringa (UEM), Maringa, Brazil*
[2]*Design Department, State University of Maringa (UEM), Cianorte, Brazil*

**Corresponding author: crislayne_vasques@hotmail.com*

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Abstract: This study aimed to develop a bamboo culm flour (BCF) to be used in the formulation of cookies, replacing 15% and 30% of wheat flour (WF). The parameters analysed for bamboo flour and cookies were moisture, ash, protein, fat, fibre and carbohydrates. For the flour, the water absorption index (WAI) and water solubility index (WSI) were also determined. BCF is a good source of protein, with a low lipid content and high fibre content, presenting the potential to be used in several food products. For the cookies produced, hardness, sensory analysis and purchase intent were analysed. In the sensory analysis of acceptability, the samples that showed better acceptance were the control formulation and the 15% BCF cookie; in the same sample, crude fibre increased from 5.92 g $(100\ g)^{-1}$ to 11.64 g $(100\ g)^{-1}$ compared to the control, and the intention to purchase the 15% sample was worse than for the control but still good: the majority of tasters said they certainly or maybe would buy. Thus, it is possible to conclude that the use of BCF is considered an excellent option to enrich cookies while keeping them acceptable nutritionally.

Keywords: dietary fibre; centesimal composition; sensory analysis; high nutritional value; unconventional foods

Product innovation to meet increasing consumer demand for foods that promote health and well-being has been the key to the survival of certain food industries. The addition of mixed flours in new products is a strategy to add value to products already on the market. Currently, various types of regional fruit flours or whole flours, which can contribute to the fibre and protein content, or have functional components, are commonly used in the baking industry to obtain innovative products (Oliveira and Marinho 2010; Ktenioudaki et al. 2015; Moro et al. 2018).

Bamboo, in addition to its many applications in construction and crafts, has huge potential to be introduced into food as it is rich in vitamins, minerals, amino acids and fibre; however, it has been little explored as an ingredient (Nongdam and Tikendra 2014).

With the increasing search for foods with natural appeal and functional benefits, bamboo shoot is gaining evidence because it is considered a functional food due to its antioxidant capacity (it contains phenolic compounds) and high fibre content, thus generating certain health benefits. Bamboo flour is an ingredient that can

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be used in various products such as bread, pasta, meat products, cheese and yoghurt, thereby increasing the fibre content (Sarangthem and Singh 2003; Nirmala et al. 2007; Chongtham et al. 2011; Choudhury et al. 2012).

Given its benefits, a young bamboo culm can be evaluated as a raw material alternative to meet market demands. *Bambusa tuldoides* is a medium-sized bamboo species, being well suited to a wide variety of climates and having high nutritional value (Choudhury et al. 2012).

Despite that, bamboo is rarely used industrially because of a lack of knowledge of varieties, characteristics and properties associated with its application. Thus, evaluation of the chemical composition of bamboo flour, as well as technological characterisation, may help considerably its use in future food products.

The objective of this study was to develop a flour using young bamboo culm, analyse its physicochemical and functional characteristics and, in addition, use it in cookie formulations as a partial substitute for wheat flour (WF) with the purpose of increasing the cookies' nutritional value and then evaluate their physicochemical characteristics and product acceptability by sensory evaluation and purchase intention.

MATERIAL AND METHODS

The bamboo was purchased in the region of Maringa, Parana, Brazil and used for the production of bamboo culm flour (BCF). Other ingredients used for the preparation of cookies were purchased locally. All analyses were carried out in the Department of Food Engineering at the State University of Maringa, Parana, Brazil.

The bamboo species *B. tuldoides*, with an approximate age of 36 months, was collected in March 2018. The first 30 cm of bamboo from the ground up was discarded. Each young culm was cut into four equal 8 cm by 3 cm parts, from the base to the top of the culm, and then oven-dried at 50 °C for 3 days (MA-70; Marconi, Brazil). After drying, the material was processed in a hammer mill (TRF80; Trapp, Brazil) to reduce the size and then in a knife mill (TE340; Marconi, Brazil). The material was placed in plastic containers, sealed tightly and stored at room temperature until analysed.

Cookies preparation. To prepare the cookies, three formulations were elaborated: 0 (control), 15, and 30% substitution of WF with BCF. The ingredients used for the three formulations are shown in Table 1.

Cookies were made according to the method of Rigo et al. (2017); to prepare the dough, the dry ingredients were manually blended, and then the eggs, vanilla essence and melted butter were added. The dough was homogenised for 5 min at a fast velocity in a mixer (MES 25; Gastromaq, Brazil). Then, cookies were weighed and moulded manually and cooked in a gas oven (FTT 240G; Tedesco, Brazil) at 150 °C for 25 min. After cooling, cookies were packed in sealed containers and kept at room temperature until further analyses. All analyses were done in triplicate.

Table 1. Ingredients used in cookies made with different amounts of BCF (g)

Ingredients	WF replaced with BCF		
	0% (control)	15%	30%
WF	375.00	318.75	262.50
BCF	0.00	56.25	112.50
Biological yeast	6.6	6.6	6.6
Unsalted butter	187.5	187.5	187.5
Crystal sugar	195	195	195
Brown sugar	60	60	60
Vanilla essence	7	7	7
Egg	75	75	75

WF – wheat flour; BCF – bamboo culm flour

Product characterisation. The centesimal composition was determined for BCF samples and cookies. Moisture, ash, and protein content were determined according to the AOAC (2005), respectively methods 930.15, 950.46, and 990.03. Lipid analysis was performed using the cold extraction method according to the methodology described by Bligh and Dyer (1959). The fibre content was determined using the methodology described by Cecchi (2003). Carbohydrates were estimated by difference, subtracting from 100 the sum of proteins, lipids, ash, fibre, and moisture.

Colour analysis was performed for BCF samples and cookies, using a Minolta CR-400 colourimeter (Japan), analysing the colour components L^*, a^*, and b^* (Bible and Singha 1993).

For BCF, the water absorption index (WAI) and water solubility index (WSI) were also analysed according to the method described by Leach et al. (1959).

The hardness of the cookies was determined by the three break-point test according to Gaines (1991), using a texture profile analyser (TA-XT plus, Stable Microsystems, United Kingdom) with a 10 mm diameter acrylic cylindrical probe, load cell of 5 kg, 1.0 mm s^{-1} pre-test velocity, 3.0 mm s^{-1} test velocity, 10.0 mm s^{-1} post-test velocity, 5 mm distance and 50 g firing force.

Sensory analysis for cookie acceptance was held at the Sensory Analysis Laboratory of the Department of Food Engineering, at the State University of Maringa

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(Brazil), using the methodology used by Basso et al. (2015) to determine preferences between samples. The attributes of flavour, aroma, texture, colour, and appearance were analysed. There were 94 untrained panellists (18 to 34 years old) who received a portion of each sample (approximately 3 g), and each sample was coded with a random three-digit number using a 9-point hedonic scale.

A purchase intention questionnaire was applied to each of the samples using a 3-point scale: 1 – would certainly buy, 2 – maybe would buy/maybe would not buy, and 3 – certainly would not buy (Meilgaard et al. 2006). Sensory analysis and intention to purchase were carried out with the approval of the Research Ethics Committee of the State University of Maringa (Brazil) (CAAE 18718013.3.0000.0104).

The data were evaluated by analysis of variance (ANOVA) and mean comparison by the Tukey test, using Sisvar 5.6 software (Ferreira 2014).

RESULTS AND DISCUSSION

BCF is rich in fibre, being more than half of its chemical composition at 53.45 g (100 g)$^{-1}$, indicating that it is a valuable raw material for food enrichment or partial replacement of white flour since white WF contains about 0.30 g (100 g)$^{-1}$ of fibre (Mustafa et al. 2016).

The fibre in food has many health benefits, like blood pressure, hypertension and obesity control, and protection against coronary heart disease and potential carcinogens (George et al. 1982; Nongdam and Tikendra 2014).

Humidity is an important factor to be analysed in food products, because of its relation to microbial growth, chemical reactions and enzymes that can influence product integrity and quality (Gutkoski and Jacobsen Neto 2002; Felisberto et al. 2017a). The moisture content of BCF was 7.48 g (100 g)$^{-1}$; similar results were obtained by Felisberto et al. (2019): when evaluating starch in young *B. tuldoides* culm, the authors observed 7.56 g (100 g)$^{-1}$ average moisture. Both results are in accordance with Brazilian law for cereal flours, which allows maximum humidity of 15 g (100 g)$^{-1}$ (MAPA 2005).

The BCF presented mineral content of 1.5 g (100 g)$^{-1}$. The mineral content of bamboo shoot flour can range from 0.02 g (100 g)$^{-1}$ to 1.4 g (100 g)$^{-1}$ (Bhargava et al. 1996) and that of white WF is 1.30 g (100 g)$^{-1}$ (Mustafa et al. 2016). According to a study done by Felisberto et al. (2017b), similar results were observed for ash content, 0.80 g (100 g)$^{-1}$ to 2.77 g (100 g)$^{-1}$ in young BCF from three varieties, *Dendrocalamus asper*, *B. tuldoides* and *Bambusa vulgaris*. Nongdam and Tikendra (2014), in characterising bamboo ash, observed that it consists of potassium, phosphorus, sodium, calcium, magnesium and iron.

The protein content of BCF is 4.37 g (100 g)$^{-1}$ and the lipid content is 1.13 g (100 g)$^{-1}$, therefore making it a good source of protein and food with a low lipid content which makes it an ideal raw material that can provide healthy nutrition for people with diabetes and cardiovascular diseases (Nongdam and Tikendra 2014). On the other hand, WF has a higher protein content than BCF, so the total protein content in cookies should be lower than that produced only with WF but they could still be characterised as a protein source product.

In the WAI and WSI analyses, results of 14.25 g g^{-1} and 15.24% were found, respectively. These values are much higher than those found by Felisberto et al. (2017b) in their study with bamboo culm starch that presented WAI of 4.10 g g^{-1} and WSI of 7.54%; these differences were caused by bamboo fibres being more hydrophobic than starches. Santana et al. (2017), when studying the technological characteristics of commercial flour, found WAI values of 1.15% and WSI of approximately 8% for WF.

Centesimal composition results for the cookies formulated are set out in Table 2. For moisture, the averages obtained are in the range of 4.59 g (100 g)$^{-1}$ to 5.46 g (100 g)$^{-1}$, demonstrating that when substituting WF by BCF, a reduction in this parameter occurs. Low moisture content can make the cookies more stable and it is expected to increase shelf life (Cheng and Bhat 2016).

The values for lipids showed no significant difference between samples; this is due to the use of standardised formulations during the study and the low lipid content of BCF.

When looking at protein content results we noticed that the data ranged from 6.92 g (100 g)$^{-1}$ to 9.05 g (100 g)$^{-1}$. There were no significant differences between the control sample and the 15% substitution cookies, with these two samples having the highest average protein. The reduction in the percentage of protein in the 30% sample could be related to the reduction in the amount of WF added to the formulation, and also a significant increase in the amount of fibre in this sample.

The mean obtained as a result of ash analysis shows that BCF increases the ash content of the cookies. On the other hand, carbohydrates decreased as BCF was added.

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Table 2. Centesimal composition of cookies (%) (mean ± SD; n = 3)

Content	Formulation		
	0% (control)	15%	30%
Moisture	5.46 ± 0.07[a]	4.77 ± 0.06[b]	4.59 ± 0.28[b]
Protein	9.05 ± 0.46[a]	8.28 ± 0.25[a]	6.92 ± 0.24[b]
Lipid	22.25 ± 0.01[a]	21.61 ± 0.01[a]	23.78 ± 0.02[a]
Crude fibre	5.92 ± 0.72[c]	11.64 ± 0.30[b]	13.45 ± 0.64[a]
Ash	0.42 ± 0.04[a]	0.48 ± 0.04[a]	0.68 ± 0.11[b]
Carbohydrate	56.90 ± 1.13[a]	53.22 ± 0.53[ab]	51.21 ± 3.38[b]

[a–c]Means followed by equal letters in the same row do not differ significantly (P > 0.05)

The results of fibre analysis show that there were significant differences between samples, the values varying between 5.92 g (100 g)$^{-1}$ and 12.79 g (100 g)$^{-1}$; the samples that had WF replaced by BCF presented the highest average fibre content, as a result of the centesimal composition of BCF. Data on the centesimal composition of cookies presented in this work are similar to those presented by Cheng and Bhat (2016) when developing cookies with leguminous flour (*Pithecellobium jiringa* Jack), and also those for the supplementation of cookies with mung bean flour present in the research of Noor Aziah et al. (2012).

For colour analysis of BCF, a high value for luminosity was observed, the average being 75.09. For chroma *a**, an average of –1.94 was observed, allowing the conclusion that there is a predominance of green over red colour. The average observed for chroma *b** was 27.80, evidencing the predominance of yellow over blue.

Table 3 shows the colour of cookies, which is one of the main attributes that influence cookie acceptability (Baumgartner et al. 2018). Hadiyanto et al. (2007) say that the colour of cookies is attributed mainly to the Maillard reaction between reducing sugars and amino acids promoted by high temperature during cooking, as caramelisation has been achieved above 150 °C.

When comparing the results obtained (Table 3), it can be seen that the luminosity (L^*) of the 15% BCF sample presented a significant difference when compared with the control and the 30% sample; this difference could come from small differences in oven temperatures. The values ranged from 59.82 to 63.39, representing a typical colour of baked products, made by the Maillard reaction and caramelisation. For chroma a^*, the mean presented significant differences, with values ranging from 3.34 to 4.99; one can observe a predominance of red over green, which could be the result of baking since the samples had a different composition in terms of carbohydrates and proteins.

The variation observed for chroma b^* in the different treatments was from 36.39 to 38.16, evidencing the predominance of yellow over blue. The treatments presented no significant difference. The mean values presented in this study are similar to those found by Baumgartner et al. (2018) who worked with cookies made from leguminous flour.

The hardness of cookies increased with a greater degree of BCF substitution in the formulation. In the cookie break-point analysis, it was noticed that for 15% and 30% bamboo flour substitutions, greater effort was required to break the sample, probably due to the increased amount of long fibres from the BCF, as happened in the study of Monteiro et al. (2021). It is possible to correlate break-point with the texture parameters in sensory analysis, where 15% and 30% of samples had

Table 3. Instrumental hardness and colour analysis of cookies (mean ± SD; n = 10)

Attributes	Treatments		
	0% (control)	15%	30%
L^*	62.34 ± 1.45[a]	59.82 ± 1.75[b]	63.39 ± 1.05[a]
a^*	4.99 ± 0.53[a]	4.83 ± 0.40[a]	3.34 ± 0.32[b]
b^*	38.16 ± 0.98[a]	36.39 ± 3.48[a]	37.82 ± 0.70[a]
Hardness (kgf)	8.27 ± 1.07[c]	16.75 ± 2.95[b]	25.31 ± 6.12[a]

kgf – kilogram-force

[a–c]Means followed by the same letters in the same row do not differ significantly (P > 0.05)

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Table 4. Sensory analysis of cookies

Attributes	Treatments		
	0% (control)	15%	30%
Colour	6.73[a]	6.21[ab]	5.82[b]
Aroma	7.17[a]	6.83[a]	2.24[b]
Flavour	7.22[a]	6.70[a]	5.99[b]
Texture	6.57[a]	4.87[b]	3.59[c]
Overall appearance	6.78[a]	5.89[a]	5.08[c]

[a–c]Means followed by the same letters in the same row do not differ significantly ($P > 0.05$)

averages between 4.87 and 3.59 points on the hedonic scale, ranging from 'like moderately' to 'like slightly', probably because of the great effort required to break the cookie samples. Table 4 shows the data obtained from sensory analysis of the cookies.

Comparing the 15% and 30% samples with the control cookies, there was a significant reduction in the sensory score for the texture of cookies containing BCF.

It can be appreciated that the sensory data obtained for the control sample are higher in all parameters, always presenting a significant difference with respect to the 30% BCF substitution.

For aroma, the averages were between 'like moderately' and 'dislike very much'; the highest averages were the control sample and the 15% sample. Looking at the 30% sample, it is noticeable that the highest score that this sample received was for the flavour attribute, most likely because BCF is a product without a pronounced flavour that can interfere with other evaluated attributes. The averages obtained for texture and overall appearance showed significant differences between all samples developed in this study.

The samples that received the highest averages in sensory analysis remained those that tasters would probably buy. For samples with BCF, it can be seen in Figure 1 that the control showed the best purchase intention, but it is possible to see that 15% BCF had a slightly lower purchase intent, but still good. The 30% sample had the least purchase intention by tasters; this may be the result of the decrease in flavour and aroma, as shown in Table 4, and of texture: due to the high concentration of bamboo flour, the sample became too hard.

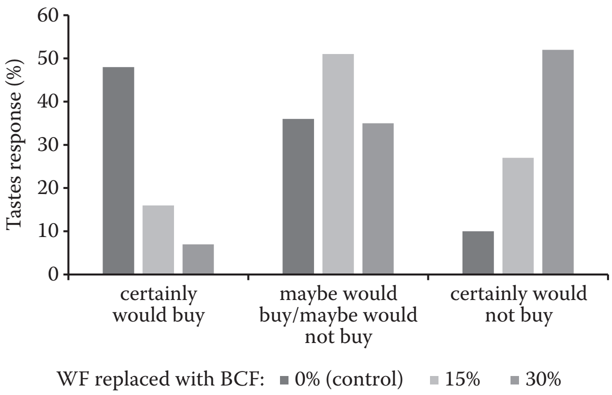

Figure 1. Purchase intention

WF – wheat flour; BCF – bamboo culm flour

CONCLUSION

Considering the results found in the present research, BCF shows great potential in food applications, mainly due to its low lipid content, and fibre content. Another advantage of the 15% substitution of WF by BCF is that its fibres do not impair the flavour and colour of the final product, making it ideal for food products, since some consumers may reject traditional whole grain products, due to a normally darker colour and differentiated flavour. In relation to consumer acceptance, the partial replacement of WF by BCF in cookies at the proportion of 15% presented the closest values to those of the control sample; however, it is suggested that an alternative product is prepared using BCF in proportions up to 15%, which should minimise the results in cookie depreciation. The 30% sample presented the least intention to purchase by tasters, due to the texture of this cookie, since the high concentration of bamboo flour made the cookies too hard, while at the same time there was a significant decrease in aroma and flavour.

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