

Potential of young bamboos for food industry: production of ingredients from the use of their culms and shoots

Potencial dos bambus jovens para a indústria alimentícia: produção de ingredientes a partir do uso de seus colmos e brotos

Potencial de los bambúes jóvenes para la industria alimentaria: producción de ingredientes a partir de sus tallos y brotes

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Abstract

The food industry has been looking for alternatives to add fiber and other nutritional properties to products. The aim of this article was to investigate the potential of products formulated from young-aged bamboo culms and shoots for human consumption. This is an integrative review article, built from the study of scientific articles available in the databases of the CAPES Journal Portal, using the following descriptors 'bamboo shoot', 'young bamboo culm', 'food industry', 'flour', 'biscuits', 'cookies', and 'nuggets', both used in combinations, in the period between 2015 and 2022. Eight scientific papers were selected, a study for each year of the period of interest, which describe the use of young bamboo culms and shoots in fiber, flour and starch-based food products. It is noticed that in recent years the use of young bamboo culms and shoots has aroused the interest of the scientific community, mainly due to its high nutritional value, antioxidant capacity, good sensory acceptance, reduced fat and sugar content, stimulating the emergence of the market consumer. For the present moment, the use of young bamboo culms and shoots in culinary preparations is sufficiently tested and adds nutritional value to bakery and pastry formulations and to animal products such as dairy and meat products.

Keywords: Bamboo foods; Alternative farinaceous; Biscuits; Nuggets; Fiber; Starch.

Resumo

A indústria alimentícia tem procurado alternativas para adicionar fibras e outras propriedades nutricionais em produtos. O objetivo deste artigo foi investigar o potencial de produtos formulados a partir de brotos e colmos jovens de bambu para a alimentação humana. Trata-se de um artigo de revisão integrativa, construída a partir do estudo de artigos científicos disponíveis nas bases de dados do Portal de Periódicos da CAPES, empregando os seguintes descritores 'bamboo shoot' (broto de bambu), 'young bamboo culm' (colmo jovem de bambu), 'food industry' (indústria alimentícia), 'flour' (farinha), 'biscuits' (biscoitos), 'cookies' (bolachas) e 'nuggets' (empanados), ambos utilizados em combinações, no período compreendido entre 2015 e 2022. Foram selecionados oito artigos científicos,

um estudo para cada ano do período de interesse, que descrevem o uso de broto e colmo jovem de bambu em produtos alimentícios à base de fibras, farinhas e amido. Percebe-se que nos últimos anos o uso de brotos e colmos jovens de bambu tem despertado interesse do meio científico, principalmente devido ao seu alto valor nutricional, capacidade antioxidante, boa aceitação sensorial, reduzido teor de gordura e açúcar, estimulando o surgimento de mercado consumidor. Para o presente momento, a utilização de brotos e colmos jovens de bambu em preparações culinárias está suficientemente testada e agrega valor nutricional às formulações de panificação e pasteleria e aos produtos de origem animal, como os produtos lácteos e cárnicos.

Palavras-chave: Alimentos de bambu; Farináceo alternativo; Biscoitos; Empanados; Fibra; Amido.

Resumen

La industria alimentaria ha estado buscando alternativas para agregar fibras y otras propiedades nutricionales a los productos. El objetivo de este artículo fue investigar el potencial de los productos formulados a partir de brotes y tallos jóvenes de bambú para el consumo humano. Este es un artículo de revisión integradora, construido a partir del estudio de artículos científicos disponibles en las bases de datos del Portal de Periódicos de la CAPES, utilizando los siguientes descriptores ‘bamboo shoot’ (broto de bambú), ‘young bamboo culm’ (tallos jóvenes de bambú), ‘food industry’ (industria alimentaria), ‘flour’ (harina), ‘biscuits’ (galletas), ‘cookies’ (pastas secas) y ‘nuggets’ (empanizados), ambos utilizados en combinación, en el período comprendido entre 2015 y 2022. Se seleccionaron ocho artículos científicos, uno estudio por cada año del período de interés, que describen el uso de brotes y tallos jóvenes de bambú en fibra, harina y productos alimenticios a base de almidón. Se puede apreciar que en los últimos años el uso de brotes y tallos jóvenes de bambú ha despertado interés científico, principalmente por su alto valor nutritivo, capacidad antioxidante, buena aceptación sensorial, contenido reducido de grasas y azúcares, estimulando el surgimiento de un mercado consumidor. Para el momento, el uso de brotes y tallos jóvenes de bambú en preparaciones culinarias está suficientemente probado y agrega valor nutricional a las formulaciones de panadería y pastelería y a los productos de origen animal, como los productos lácteos y cárnicos.

Palabras clave: Alimentos de bambú; Farináceo alternativo; Galletas; Empanados; Fibra; Almidón.

1. Introduction

The origin of bamboo is based on the evolution of the grasses, fossil evidence and the basal lineage, and these factors suggest the grass as a possible ancestor (Ahmad et al., 2021). Thus, this origin is attributed to the Cretaceous Period, before the beginning of the Tertiary Era, when the human species appeared, and the oldest historical records date from the beginning of civilization in Asia (Pereira & Beraldo, 2016). The most accepted etymology for the word bamboo is due to the bang caused by the explosion of its stalks when burned (López, 2003).

Bamboo is part of the Poaceae family of grasses, Bambusoideae subfamily, which is divided into the Arundinarieae, Bambuseae and Olyreae tribes, whose the first two tribes are xylematic, larger and have woody stalks as well as the last tribe is smaller and herbaceous (Bamboo Phylogeny Group, 2012; Yeasmin et al., 2014; Clark et al., 2015; Soreng et al., 2015). Adult individuals basically consist of a mixture of holocellulose (hemicellulose and cellulose) and lignin, organized into fiber bundles, conducting vessels and parenchymal cells (Rusch et al., 2018).

Bamboo is being hailed as a new super raw material due to its environmental aspects as large carbon fixations and positive effects on greenhouse gas, social benefits as the continuous provision of cash for some of the world’s poorest people, and multiuse features ranging from textiles to buildings (Wooldridge, 2012). This multipurpose application hardly rivaled with other plants of plant kingdom (Ahmad et al., 2021). The bamboo development in line with the humans explains the countless applications and straight relationships with people’s lives through abundant forestry supplies for dwelling, energy and food.

Scientific records evince the growth in the number of bamboo species – due to the identification of unknown species and genera – through phylogenetic analyzes (Bamboo Phylogeny Group, 2012). It estimated the existence of 119 genera and 1,482 species of bamboo (Clark et al., 2015; Nayak & Mishra, 2016). There are records of wide variability in size, where some non-lignified herbaceous have a few centimeters of and lignified individuals exceed 30 meters in height (Miranda et al., 2017).

Bamboos are found in almost all parts of the world, except in extremely cold regions, although some species can be easily introduced in the temperate zone. Its distribution is predominant in tropical, subtropical and temperate regions of Asia, America, Africa and Oceania.

However, in the Southeast Asia and South America, from sea level to 4000 meters of altitude, there is the greatest diversity of species; although herbaceous bamboos are not present at altitudes above 1500 meters (Panda, 2011; Hakeem et al., 2015). In practice, only about 50 bamboo species are currently used commercially worldwide.

Brazil has the greatest diversity and the highest rate of bamboo endemic forests in all of Latin America, with 258 native, of which 175 species are considered endemic (Filgueiras & Viana, 2017), and around 20-30 introduced. Given its wide distribution, it occupies about 36 million hectares, equivalent to 3% of the total forest area (Chaowana, 2013).

Regarding the regions of occurrence in Brazil, the existence of millions of hectares of bamboo forest of the genus *Guadua* spp. stands out, with emphasis on *G. weberbaueri* in the southwest of the Amazon, especially in the Acre state (Pereira & Beraldo, 2016); commercial plantations of more than 30 thousand hectares of *Bambusa vulgaris* in the Northeast, mainly in Maranhão, Pernambuco and Bahia states (Guarnetti & Coelho, 2014), in addition to experimental plantations of the genus *Dendrocalamus* spp. in the Brazilian universities of Goiás state in the Midwest region (Lima et al., 2016).

Just like woods, bamboos may start from plantations and managed cultivations under sustainable practices of the Forest Engineering and their respective bioresources may be harvested and industrially processed under rationalized activities of the Timber Industrial Engineering into sawn parts, engineered composites and panels, furniture, construction, packaging, flooring, household items, pulp and paper, and bioenergy (De Araujo et al., 2021). In addition, Bioengineering and Food Engineering may utilize culms, shoots and leaves for the food and medicine productions. In this way, bamboos may compose important matrices to globally supply the different manufacturing activities.

Bamboo shoots are considered a delicacy in human consumption, are a good source of dietary fiber, with low fat and calories content (Bal et al., 2012) and can be classified as a nutraceutical (Xuhe, 2003; Satya et al., 2009; Chongtham et al., 2011) due to its rich composition in phytosterols and high fiber content. The bamboo shoots trade in 2017 represented 19% of the total exports of the international bamboo market, with US\$ 323 million (Junqi & King, 2019).

In the search for healthier foods, different plants are used as alternative farinaceous (Ziegler et al., 2020). The shoots and the interior of young bamboo culms are sources of dietary fiber, with great acceptance in the international market, as they are applied for various products such as bread, pasta, meat products, cheese and yogurt, among others, increasing their levels of fiber, and consequently, providing healthier foods (Felisberto et al., 2017a,b; Ferreira et al., 2022). Flour from young culms is an alternative to the traditionally used wholegrain flours as they cited, with the advantage of not altering the color of the final product. Starch may be an alternative source to thickeners, enabling food formulations (and even cosmetics) with reduced fat.

Bamboo shoots, flour and starch can be used in a wide variety of culinary preparations in the domestic or industrial environment, with good performance in bakery and dairy products, without altering sensory attributes. For Satya et al. (2010), different bamboo species have mineral salts, vitamins C and E, fibers, elements such as cadmium, cobalt, copper, magnesium, manganese, phosphorus, sodium and selenium, and low sugar and fat content. In addition to the beneficial nutritional effects, its use adds some financial value and encourages the development of a bamboo production chain for human consumption.

The aim of this work was to identify, through a literature review published from 2015 to 2022, the potential of young bamboo culms and shoots for the production of ingredients for the food industry to highlight outcomes and possibilities.

2. Methodology

This research consists of an integrative review study, based on a survey from scientific papers and review articles. This practice has been globally utilized by authors, since broader perspectives on products and industries are possible such as Satya et al. (2010), Bal et al. (2012), Chaowana (2013), De Araujo et al. (2017, 2021), Rusch et al. (2018), and other studies.

Our methodology covered the 2015 and 2022 period, available on the 'CAPES Journal Portal' website (CAPES is the

acronym of the Brazilian higher education institute entitled Coordination of Superior Level Staff Improvement). To select the scientific papers, the following descriptors were considered: ‘bamboo shoot’, ‘young bamboo culm’, ‘food industry’, ‘flour’, ‘biscuits’, ‘cookies’, and ‘nuggets’, which were used in double combinations, with the operator Boolean ‘AND/E’, in the search engine available in the CAPES’ website for the Brazilian researchers, which is available in CAPES (2022).

Considering those aforementioned descriptors, numerous scientific articles were initially identified (table 1). After reading stage and preliminary analysis (steps 1 to 4), in order to delimit the maximum quantity and theoretical framework for the research without duplicities (step 5), a scientific paper was selected for each year of the period in analysis (step 6), which was chosen from among the most recent publications to support our discussions.

Table 1 – Route followed in this integrative review with the filtering process and outcome according to each step.

| STEP | CONSIDERATION AND GOAL | OUTCOME |
|------|--|--|
| 1 | Survey publications in the period (2015 to 2022) and databases* of interest | 3836 responses (general documents) |
| 2 | Consideration of documents written entirely in English | 3815 responses (documents in English) |
| 3 | Elimination of duplication and non-peer-reviewed papers | 3206 responses (scientific documents) |
| 4 | Full text reading and category identification (shoot/culm; fiber/flour ingredients; starch; recipes) | 3191 responses (scientific papers) |
| 5 | Elimination of publications with similar results in each year of interest for bamboo subject | 463 responses (non-repeated papers) |
| 6 | Selection of appropriate publications for the arguments | 8 responses (selected papers – one per year) |

* Nature Open Access, Wiley-Blackwell Full Collection, Taylor & Francis, Oxford Journals Current Collection, Sage Premier, ACS Publications, BioOne.1, SciELO Brazil, Latindex, DOAJ, ROAD, IRDB, SCFCJ, HighWire Press, Academic Search Premier, Computers & Applied Sciences Complete, DataCite, Medline Complete, BioMedCentral, MUSE-Project, and Single Journals. Source: Authors based on prospections in the CAPES (2022).

3. Results and Discussion

From methodological route described by Table 1, numerous documents were identified for the period under evaluation (2015 to 2022) and filtered to 463 non-repeated peer-reviewed papers in the step 5. From that, a scientific paper per year within the expectations to evince the potentiality of bamboo culms and shoots for the food industry was selected in the step 6.

The by-products obtained from young bamboo culms and shoots (fiber, flour and starch) have aroused the interest of the consumer market, above all, due to their high content of dietary fiber, antioxidants and nutrients, low fat and energy content; these ingredients can partially or totally replace wheat, which is an appeal of special interest due to the absence of gluten, given the growing market for celiac and non-celiac patients. In Table 2, the methodological procedures exemplified in table 1 and results of each article were presented towards potential of young bamboo culms and shoots in the food industry.

The results organized in Table 2 demonstrated that young bamboo culms and shoots enable the production of different products, both for addition to formulations and for the replacement of traditional ingredients of the food industry, with positive sensory and nutritional effects on the final product. In addition to these benefits, the culinary application of flour of young bamboo culm and shoot or their derivatives reduce the lipid and sugar content, and increase the fiber content of foods.

In the food industry, the addition of 10% of *Bambusa balcooa* shoot powder, replacing wheat flour in the production of cookies, enabled improvements in terms of moisture, proteins, fibers, fats, ashes, phenolics, antioxidant activity, dimension, hardness, color and sensory acceptability (Choudhury et al., 2015), with emphasis on the increase in fiber content, antioxidant activity and phenolic content, by 82%, 410% and 831%, respectively. Thus, wheat flour fortified with bamboo shoot powder emerges as an innovative product that can bring a change in the production of functional foods with greater precision.

Table 2 – Development of food products using bamboo-origin shoots and flour.

| AUTHOR (YEAR) | METHODOLOGICAL PROCEDURES | RESULTS AND CONCLUSIONS |
|---------------------------|--|---|
| Choudhury et al. (2015) | <i>Bambusa balcooa</i> shoots were taken; edible parts of shoots were boiled, dried, crushed, sieved, analyzed for nutritional composition and used in the biscuit manufacture. Shoot powder was added at levels of 0% (control), 5, 10 and 15% in dry ingredients, partially replacing wheat flour. Other ingredients were held constant, and a sprout-free control formulation was used for comparative purposes | Cookies were analyzed for moisture, water activity, ash, proteins, fibers, fats, phenolics, antioxidant activity, color, dimension, hardness, and sensory acceptability. Contents for fibers, antioxidant activity and phenolics between 1.08 to 1.97%, 3.50 to 17.85% and 0.45 to 4.19 mg / 100 g were reached, respectively. Results showed acceptance of cookies formulations with up to 10% of flour. Functional properties were better than controls. |
| Zeng et al. (2016) | Breaded and breaded fish cakes were prepared with additions of 0 (control) and 10% bamboo shoot dietary fiber, fried at 170 °C /50 s followed by 190 °C /10 s; fat absorption, texture characteristics and other quality parameters were evaluated. | The addition of 6% bamboo shoot dietary fiber to the pasta improved the sensory quality of both cakes with greater brightness and golden-yellow crust. In the face of controls, fat content of the crust and core decreased from 25.5% and 2.4% to 17.7% and 1.3%, respectively. Crust and core hardness and chewing were improved. |
| Felisberto et al. (2017a) | Young culms of the <i>Bambusa tuldooides</i> , <i>Bambusa vulgaris</i> and <i>Dendrocalamus asper</i> varieties were collected, cut into three sections (lower, middle, upper), processed into flour and analyzed physically, chemically and technologically. | Flours had low moisture values (< 10g/100g), protein, lipid and ash content (< 3g/100g), and they significantly differed in terms of sugar, starch and fiber. Flour samples showed fiber extraction potential (> 60g/100g). <i>B. vulgaris</i> (16g/100g) and <i>D. asper</i> (10g/100g) species have potential for starch extraction. Flours were bright yellow, slightly acid (pH > 5.0), and water solubility below 2.5%, except for <i>D. asper</i> . |
| Nirmala et al. (2018) | A comprehensive compilation of the antioxidant properties of bamboo shoots and their prospects for use in the development of functional foods and nutraceuticals was carried out. Antioxidants are vital constituents of the food and pharmaceutical industry as they scavenge free radicals that cause products to spoil during processing and storage. They also promote human health by neutralizing cell damage caused by free radicals. | Antioxidants confer health benefits such as preventing cancer and degenerative diseases, slowing the aging process and promoting cardiovascular health. In bamboo shoots, the main antioxidants are phenols, vitamin C and E and mineral elements such as selenium, copper, zinc, iron and manganese. Natural antioxidants are regarded today, as synthetic antioxidants used in medicine and food can be harmful to health. Bamboo is an alternative for the production of natural antioxidants for industries. |
| Felisberto et al. (2019a) | Effects of partial replacement (15%) of wheat flour by young bamboo culm flour in cookies were evaluated, using a central composite design with two variables (sugar and fat reduction) and three repetitions in the central point. The formulations were selected by surface response methodology (p < 0.10) and evaluated at 28 days of storage for stability and nutritional composition. | Formulations with 50% reduced sugar and fat were selected, in addition to a control formulation. Moisture content and water activity of the cookies remained low throughout storage, as recommended for the crispness maintenance. Cookies were light in color, similar to the control formulation and had a lower energy value. Sugar reduction led to significant differences in the diameter of the cookies. Results indicate that young culm flour is a promising ingredient for bakery, as it contains high fiber levels and allows a reduction of 50% of sugar and fat. |
| Silva et al. (2020) | A comprehensive review of the potential use of young bamboo culms for fiber and/or starch extraction for food applications was carried out. | Studies were identified that demonstrated the potential of young bamboo culms for fiber and starch extraction. Shoot fiber improves the sensory features of some foods. |
| Watanabe et al. (2021) | Development and characterization of a new product from the <i>Dendrocalamus asper</i> shoot for pasta without cyanide. | Bamboo shoot paste was evaluated on microbiological, texture and color features after storage. Microbiological results show a safe consumption. Texture was stable and color changes were typical even with browning reaction. |
| Ferreira et al. (2022) | A comparative study to partially replace <i>Triticum durum</i> semolina in fettuccine pasta with <i>Bambusa tuldooides</i> fiber and young culm flour to get pasta as an alternative option for the Italian cuisine. | Optimal cooking time, weight gain, volume increase, loss of soluble solids in cooking and force to cut were verified in cooked pasta. There was no significant effect on optimal cooking time, mass gain, volume increase, loss of soluble solids, and force to cut of samples. |

Source: Authors.

The use of powdered bamboo shoots provides health benefits, cheaper sources and excellent nutritional constitution for the production of high quality bakery products. A recent study (Mustafa et al., 2017) revealed that its composition contains a high amount of fiber and protein, with 24.44% and 19.32%, respectively, in addition to a lower amount of fat (1.46%). In the same study, the sensory evaluation showed that cookies prepared with a content of up to 6% of bamboo shoot flour showed better acceptance results when compared to the control group.

Meat or fish cakes are traditionally products with low fiber content and high fat content, due to their preparation process, especially in fried foods. In this context, Gazi et al. (2017) considers it essential for industries that produce these foods to evaluate the physical, chemical and sensory characteristics of dumplings that combine animal collagen and bamboo fiber. After all, food is not only consumed to curb hunger and provide basic nutritional needs, it is also used to prevent nutrition-related illnesses.

Regarding meat processing, storage and maintenance of acceptability, Thomas et al. (2016) evaluated the physical, chemical, microbiological and sensory characteristics of pork nuggets with the incorporation of carambola fruit juice (*Averrhoa carambola*) and bamboo shoot extract (*Bambusa polymorpha*), after 35 days of refrigeration. The authors concluded that the addition of juice (4%) and bamboo shoot extract (6%) increased storage time by at least two weeks, that is, from 21 to 35 days at 4 ± 1 °C compared to the control group.

Dendrocalamus asper bamboo young culm flours, for three fractions: lower (B), medium (M) and upper (T) and different particle sizes ($d \leq 0.425$ mm, and; $d > 0.425$ mm), can be considered sources of fibers (67-79 g / 100 g) and starch (6-16 g / 100 g), in relation to color parameters, were all classified as yellowish white (Felisberto et al., 2017b).

The partial replacement of wheat flour by bamboo shoot flour in bakery products provides an increase in nutritional quality due to the total amounts of vitamins (C and E) and minerals, such as selenium, copper, zinc, iron and manganese (Nirmala et al., 2018), in addition to maintaining the technological properties of different products, such as crunchiness, it also enables an increase in fiber content and a reduction in sugar and fat content (Felisberto et al., 2019a). Despite the color change after cooking, the partial replacement of *Triticum durum* semolina with *Bambusa tuldoides* fiber and young culm flour showed desirable technological characteristics of texture and weight gain, with low solids losses and good sensorial acceptance, above all, in the condition with 1.75% of bamboo fiber and 3.5% young bamboo culm fiber (Ferreira et al., 2022).

The food industry is looking for natural and innovative ingredients, and the young and fresh culm of *Dendrocalamus asper* bamboo is a promising alternative, as it has more than 10% starch in its composition, in addition to having characteristics similar to those traditionally used (Felisberto et al., 2018). Starches obtained from young bamboo culms of *Bambusa tuldoides* species showed pale yellow color, high luminosity, polyhedral shape and small size. These showed characteristics of native starches and were similar to traditionally used starches. Thus, starch from young bamboo culms would be an alternative source to traditional starches such as rice, wheat or corn, sustaining its potential for industrial applications (Felisberto et al., 2019b).

Color changes after cooking were basically typical and texture features were stable and evince the technical viability of pasta from bamboo shoots. About microbiological results, the consumption of bamboo pasta is considered safe, even after the paste production and storage, since analyses confirmed the absence of *Salmonella* spp. as well as no heat-resistant spores after two months of conditioned storage (Watanabe et al., 2021). This health performance may suggest a possible certification as a safe food for short-term consumptions such as some dairy products.

From foregoing, bamboo culms and shoots are potentially viable for the global industry due to multiple applications in different types of food products, which were visibly nutritious for humans in the present suggested replacements or additions with other ingredients.

4. Final Considerations

The selected studies suggest that the products formulated on the basis of young bamboo culm and shoots ingredients presented satisfactory properties to the needs of the food industry, which their uses are stable and preserve nutritional benefits from the insertion of these new ingredients to the formulation in which they are used. In the sanitary aspect, bamboo pasta may be safe for consumption in short periods of storage.

Based on the existing literature, it can be concluded that young bamboo culm and shoots and their by-products have potential to be used in food industry formulations, especially because they contribute to a reduction in the sugar and fat content, in addition to increasing the fiber content of these products.

Despite the small number of publications towards the utilization of young bamboo culms and shoots for food industry, we see an extraordinary potential for the industrial food sector on the international scenario as well as for Brazilian companies, since the bamboo-based products has good cooking performance and favorable nutritional aspects related to excess of sugar, fat and gluten contents.

From foregoing, the available scientific contributions emphasize that bamboo shoots and culms are rich sources of fibers and natural antioxidants, whose products for industry include suggestions as biscuits, cakes, nuggets, cookies, and pasta. Due to the broad availability of mass-based food, we suggest that further studies should evaluate the inclusion of bamboo shoots and culms, either as flour or fiber, in the manufacture of different breads and other pastas, since they are produced using multiple types, decorations, shapes, and recipes. These future contributions should add bamboo ingredients to the manufacture of noodles for the Asian cuisine as well as other numerous solutions for the European cuisine such as flatbread for pizza and fugazza, filled flatbread for calzone and panzerotti, flat-shaped pasta for lasagna and cannelloni, tube pasta for macaroni and soup, filled pasta for cappelletti and ravioli, and stuffed pasta for conchiglioni and manicotti. In parallel, bamboo ingredients should be mixed with meat ingredients to characterize properties and test flavors in sausages, minced meats, and meatballs.

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