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Jabuticaba Skin Flour AsA Functional Food Ingredient: Phenolic Profile, Antioxidant Potential and Functional Technological Properties

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Abstract

Brazilian-native fruit, jabuticaba, is a member of the Myrtaceae family that is typically consumed naturally. The jabuticaba skin flour (JSF) is rich in phenolic compounds, the most active antioxidants present in plants, being able to stop oxidative damage and reduce the risk of oxidative stress linked to different degenerative diseases, thus become interesting to the consumer. Despite all this antioxidant potential, little is known about their characterization and about the functional-technological properties of this flour. The objective of this study was to identify and quantify phenolics, measure their antioxidant capacity and investigate the functional-technological properties of JSF, in order to verify the feasibility of its use in the food industry. The following analyzes were carried out: quantification of total phenolic compounds, determination of antioxidant activity, identification and quantification of phenolic compounds by HPLC, and the identification of Functional-technological properties: water and oil absorption, nitrogen solubility, foam volume and emulsion stability. Gallic, ellagic and salicylic acids were identified in JSF, as well as monomers of condensed tannins, e.g. epicatechin and gallocatechin. The phenolic compound which occurred in larger amounts was epicatechin. Analyses of functional-technological properties indicated that JSF has good water absorption and emulsion stability. JSF shows up as a promising alternative as an additive in formulations, such as yogurts, soups, sauces, sausages, pasta, cheese, pastries and bakery products.

Keywords: *Plinia jaboticaba*, phenolic compounds, functional-technological properties, natural antioxidant, additive.

INTRODUCTION

Jabuticaba is a fruit from the Myrtaceae family, native to and is normally consumed naturally. Jabuticaba trees are plants considered medium-sized evergreens, which can reach 3 to 6 m in height, and are believed to produce up to 1,000 kg of fruit annually per plant. The fruits are globose berries, purple in color, white and sweet pulp, and dimensions of 2.2 to 2.9 cm in diameter, with concentrated phenolic compounds, mainly anthocyanins. The residues produced by the consumption of this fruit are skins and seeds [1, 2].

The considerable content of anthocyanins in the Jabuticaba skins is responsible for their characteristic color [2, 3]. Among the most potent antioxidants found in plants are phenolic compounds. These substances are of interest a scientific community, because they exhibit a variety of physiological effects when ingested. Rich in polyphenols, the diet lowers the risk of oxidative

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stress associated with several degenerative diseases and protects lymphocyte deoxyribonucleic acid (DNA) from oxidative damage. The co-products made from plants with high antioxidant power co-products showed a similar protective effect. [4, 5].

In the literature, there are studies that demonstrate that jabuticaba has a high antioxidant [6-8], this high activity is related to the content of phenolic compounds [9]. Determining the composition and concentration of each phenolic compound can help in understanding the observed antioxidant activity.

Despite its high content of phenolic compounds in jaboticaba skin with potential health benefits, little research has been published that relates its functional properties and the quantification of phenolics. Phenolic compounds such as ellagic acid, quercetin and the anthocyanins: cyanidin-3-glucoside, delphinidin-3-glucoside, cyanidin 3-O-glucopyranoside and have already been found in this residue [3, 6, 10].

The Jabuticaba skins show up as promising alternatives for developing new products with antioxidant and functional characteristics are presented, because, besides a high antioxidant potential, they have a good nutritional value. It has high contents of soluble and insoluble fiber (27.03 and 6.77 g 100 g-1 dry matter (DM), respectively), are rich in minerals, such as potassium (1,496.67 mg 100 g-1 DM), magnesium (90.00 mg 100 g-1 DM), iron (1.68 mg 100 g-1 DM) and manganese (1.71 mg 100 g-1 DM), as well as in vitamin C (0.025 g 100 g -1 DM) [11].

Many studies emphasize the importance of fiber and antioxidants in the diet, which has increased the demand for products rich in these components [12]. This type of food plays an important role in human metabolism, promoting health benefits and preventing chronic diseases, as in addition to the food itself, it brings other long-term benefits. Therefore, because they are increasingly concerned about the health that food can provide, consumers have changed their relationship with food, opting for those that can bring more functional benefits. Consequently, knowing the functional-technological properties of JSF can aid in their application for the formulation of new products.

Thus, the objective of this study was to identify and quantify phenolic compounds, measure their antioxidant capacity, and investigate the functional-technological properties of JSF, in order to verify the feasibility of its use in the food industry.

MATERIAL AND METHODS

Sample Preparation

The harvest of jabuticaba (*Plinia jaboticaba* (Vell.) Berg) ripe fruits, genotype Sabará, was made in October 2010, in the morning, by hand, on Fazenda São José do Ismeril, in the municipality of Coqueiral, MG, Brazil.

After choosing the fruits, they were cleaned with tap water and sanitized for 10 minutes with a solution of sodium hypochlorite (200 mg kg-1). The fruits were then squeezed, and the skins were weighed and divided into three portions, each weighing roughly 2.9 kg.

Over the course of 36 hours, the jabuticaba skins were dried in a food dehydrator using mesh baskets made of metallic materials at 45°C and 1 m s-1 air flow. After the skins were ground, three samples of the jabuticaba skin flour (JSF) were placed in hermetically sealed flasks, covered with aluminum foil, kept at room temperature, and then examined. In this flour, the particle size was determined using a sieve shaker, and most of the flour particles were retained on the sieves between 32 mesh (0.5 mm) and 60 mesh (0.25 mm). The uniformity index, as stated in [13], shows the relative fraction of coarse, medium, and fine particles. The sizes of the particles are specified as to diameters larger than 2 mm, between 2 and 0.60 mm, and smaller than 0.60 mm, respectively. JSF is so categorized as fine.

Research & Reviews: Journal of Food Science & Technology
Volume 13, Issue 3
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Determination of Antioxidant Phenolic Compound

Phenolic compounds were extracted (in three replicates) from JSF using 50% methanol under reflux three times in a row at 80°C and a 1:25 (w/v) ratio. Collected extracts were evaporated to yield 25 milliliters. Tannic acid was used as a standard in the Folin-Denis method, which was used to determine the concentration of phenolic compounds [14].

Antioxidant activity measurement

A method by [15] was used to determine the antioxidant activity; changes were made by [7]. The samples were diluted four times, and a calibration curve with standard was created. For the analyses, 3.0 mL of the ABTS•+ radical were placed in a test tube with a 30 µL aliquot of each extract dilution and homogenized on a magnetic stirrer. After the reaction lasted for six minutes, the absorbance was measured at 734 nm with ethanol serving as a blank.

Chromatographic Study of Phenolic Compounds

Chromatographic analyses were performed with a method proposed by [16].

Using liquid chromatography technique and comparing the retention time of standards with those of samples of the JSF, the phenolic components were found and validated. The external standardization method was applied to the quantification of phenolic compounds. The analytical curves of the compounds standard solutions found in the samples were obtained by dilutions of the stock solutions ($1{,}0 \times 10^{-3}$ mol L^{-1}), resulting in a concentration range from $5{,}0 \times 10^{-7}$ to $1{,}5 \times 10^{-3}$ mol L^{-1}. Calibration curves were constructed by plotting the average detector response ($n=3$) to the peak area as a function of concentration.

Functional-Technological Properties

Water and oil Absorption

JSF was suspended in water or oil, mixed at high speed (Robot Classic mixer - Mallory) and then centrifuged. The amount of water or oil absorbed was converted to grams by multiplying the measured volume of the supernatant by the corresponding densities [17].

Nitrogen Solubility

JSF was mixed in distilled water, and the pH was adjusted to 2, 3, 4, 5, 6, 7, 8 and 9 with NaOH or HCl solution. After that, it was centrifuged, and the Kjeldahl method [18] was used to evaluate the supernatant.

Foam Volume

JSF was suspended in distilled water and agitated for 3.5 minutes (Robot Classic mixer - Mallory); the blend was poured into a measuring graduated cylinder, where the foam volumes were measured at various intervals (0, 30, 60, and 120 minutes). The foam volume, expressed as a percentage, was calculated considering the foam volume at time 0 as 100% [19].

Emulsion Stability

JSF was dispersed in distilled water and the oil was slowly added under agitation for 30 seconds (Robot Classic mixer – Mallory); it was then homogenized at high speed for another 60 seconds. The volumetric change of foam, oil and aqueous phase was observed after 30 minutes, 2 hours and 6 hours [12].

RESULTS AND DISCUSSION

The content of phenolic compounds in JSF was 8.45 ± 0.3 g tannic acid 100 g^{-1} DM. The work [11] found the content of 11.99 g tannic acid 100 g-1 DM in freeze-dried JSF, which is a higher value than that found in this work, in which the peels were dried at 45 °C, this probably occurred due to possible differences in variety, in dehydration, as it is already known that freeze-drying is capable of better preserving different compounds, but it is an expensive process that makes the use of the process unfeasible; as well as due to environmental factors such as: harvest time, rainfall and soil nutrition.

The phenolic extract of JSF showed good antioxidant potential (866.39 µmol L^{-1} g^{-1}) by the ABTS method. This method used in this study because in a previous study, in which the methods ABTS, phosphomolybdenum and β-carotene/linoleic acid was used to measure the antioxidant activity in JSF, the ABTS method resulted in better responses [3].

The phenolic profile of JFS was researched and the following were discovered: three phenolic acids were found along with two condensed tannin monomers, classified in the following order: epicatechin, salicylic acid, ellagic acid, gallic acid and gallocatechin (Fig. 1). The total content of phenolic compounds was 2.68 g per 100 g of dry matter (Table 1), lower than the one determined by the colorimetric method. However, it is possible to observe in Figure 1 that there are other non-identified peaks, which could lead to higher contents.

[3] studying jabuticaba Sabará skins, which were harvested from the same propoerty and the same plants as the jabuticabas used in this study in previous years identified in you work the anthocyanins cyanidin-3-glucoside and delphinidin-3-glucoside.

The amounts of gallocatechin and epicatechin together represent 71.27% of the total content of phenolic compounds quantified. Gallocatechin, when polymerized, forms prodelphinidin, which is a condensed tannin. Due to the occurrence of many hydroxyl groups in its structure, gallocatechins have a high antioxidant effect [19]. The gallocatechin detected in JSF may contribute to its good antioxidant potential.

Phenolic acids are reported as good antioxidants. This antioxidant action is probably due to the occurrence of an easily ionizable carboxyl group in its structure, which is an efficient hydrogen donor [4].

While studying the possible use of phenolic extracts of jabuticaba skin powder in the treatment of various diseases related to the action of snake venom toxins, [20] found that these extracts have inhibitory effects related to phenolic compounds (e.g., gallic acid, syringic acid). The acid is related to p-coumaric acid, in addition to catechins, epigallocatechin gallate, and epicatechin; jabuticaba skin powder extract contains resveratrol and quercetin, confirming their role as The potential of nutraceuticals.

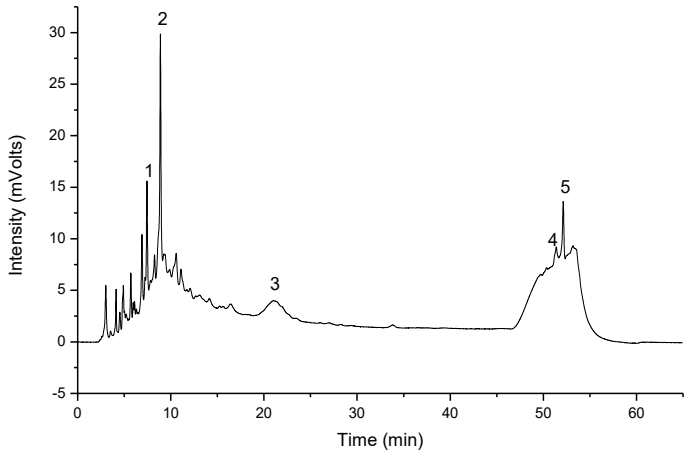

Figure 1. Chromatogram of total phenolics extract. Peak identification: 1- gallic acid; 2- gallocatechin; 3 – epicatechin; 4- ellagic acid; 5- salicylic acid.

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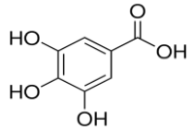
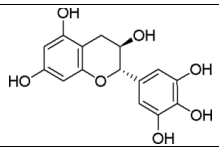
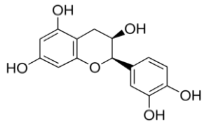
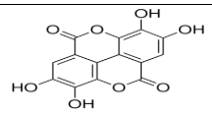
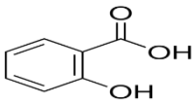
Table 1. Phenolics average (g 100 g^{-1} DM) in JSF, by HPLC

Phenolic compound	Structure	Retention time (min)	Phenolic content (g 100 g^{-1} DM)
Gallic acid		7.44	0.11
Gallocatechin		8.89	0.01
Epicatechin		21.95	1.9
Ellagic acid		51.39	0.12
Salicylic acid		52.14	0.54

Gallic acid and ellagic acid have similar concentrations.

Ellagic acid has four OH groups linked to the benzofuran structure and is a dimeric derivative of gallic acid. Low water solubility and low bioavailability are reported, this characteristic implies that ellagic acid can act as a good lipophilic antioxidant [21]. Several studies confirm the variety of health benefits, many of them related to oxidative stress [21-23]. The presence of ellagic acid confirms the high antioxidant power of JSF, which makes it an interesting alternative as a substitute for synthetic antioxidants used in the food industry, as previously reported [22-23].

Gallic acid (3,4,5-trihydroxybenzoic acid) is a naturally occurring low molecular weight trisphenol compound that has been shown to be a potent antioxidant and potent inducer of apoptosis. Its structure contains one carboxyl and three hydroxyl groups that possibly contribute to the antioxidant activity of JSF (Table 1).

Water absorption by JSF was 350 % and oil absorption was 475.55%. JSF had a good water absorption, when compared to the water absorption of proteins isolated from legumes and yam bean flour varieties Country Ekona and Sosso Chad [24-25]. This high water absorption can be attributed to the presence of a considerable amount of fibers and carbohydrates in the flour. Flours that absorb water well and expand to thicken food products (hyperabsorbency) have beneficial applications in doughs, processed meats, and puddings. [26].

At 30 minutes, there was a retention of only 50% of the initial foam volume. At 60 minutes, there was no longer foam, indicating that the foam formed by JSF is not very stable, and therefore has no good foaming characteristics. Foam stability in good flours suggest that the native proteins, which are soluble in the continuous phase (water), are very active on the surface of these flours [26]. The protein content in JSF is low, corresponding to 1.16 g $100g^{-1}$ DM [11], which may explain the low stability of the foam formed.

Table 2. Emulsion stability: average volume of foam, oil and aqueous phase at times: 0.5, 2.0 and 6.0 hours.

Time after agitation (hours)	Average volume (mL)		
	Foam	*Oil*	*Aqueous phase*
0.5	2	10	9
2.0	1.5	10.5	9
6.0	1.5	10.5	9

Changes in pH resulted in variations in the sample nitrogen solubility. The isoelectric point of vegetable proteins is between 3 and 5. In general, nitrogen solubility is minimal at this point and increases as the pH moves away [27]. Nitrogen solubility in JSF remained constant from pH 2.0 through 5.0 and increased in pH 6.0, keeping constant again up to pH 9.0.

The average volumes of foam, oil and aqueous phase observed when analyzing the emulsion stability in JSF are shown in Table 2. After 2 hours of agitation, a 25% reduction in foam was observed, as well as a small increase in the oil volume. Thus, JSF has a considerable emulsion stability. The results indicate that JSF can be used in the production of sausage, soups and pastries.

The evidence found in this study confirms that JSF has great potential as a natural antioxidant to replace the synthetic antioxidants used in the food industry. JSF was also demonstrated to have good water absorption and emulsion stability, properties that indicate it as a promising alternative to be used as an additive in formulations such as soups, sauces, sausage, pasta, cheese, pastries and bakery products.

CONCLUSIONS

JSF has a high content of phenolic compounds, in which three phenolic acids and two monomers of condensed tannins were identified.

JSF has a good antioxidant potential, therefore, the JSF extract shows up as a promising alternative to be used as a natural antioxidant in food industry, in replacement of synthetic antioxidants.

The functional-technological properties of JSF indicate that this flour can be used in the formulation several of foods.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper

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The study was performed without financial support.

Data Availability

manuscript has no associated data

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the currrent work.

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