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Review Article

Jabuticaba Fruit Peel: Better Than the Pulp?

Flavia M. V. Farinazzi-Machado, Adriana M. R. Fiorini

Faculty of Food Technology of Marilia (FATEC) Marilia/SP – Brazil
Av. Castro Alves, 62, Marilia 17506-000, SP, Brazil

Corresponding Author: Flavia M. V. Farinazzi-Machado

ABSTRACT

The native Brazilian Jabuticaba fruit has a reddish, almost black peel and white pulp, and it is rich in vitamins, minerals and phenolic compounds. The peels are considered to be household and industrial waste in the manufacture of juices and pulps, but they have significant concentrations of phytochemicals, especially anthocyanins. The objective of this review was to gather references in the literature demonstrating the presence of important phytochemicals in the Jabuticaba fruit peel, its beneficial metabolic and physiological effects, and its use in processed foods for human consumption. To this end, the *Pubmed*, *Google Scholar*, *Scielo* and *Lilacs* databases were used to include in this review the relevant publications written mostly in the last ten years, although some older article citations and three technical papers were required to classify and characterize the genre.

Key words: *Myrciaria* – peels – phytochemicals – antioxidant – food

INTRODUCTION

The Jabuticaba tree is a Myrtaceae native to Brazil, which grows from the far south to the far north of the country. With the change in botanical nomenclature suggested by Sobral [1] due to the presence of seeds with separated cotyledons and congested inflorescences and cauliflora, which are typical characteristics of the Plinia genus, there is still disagreement regarding the classification of the species: *Myrciaria spp* O. Berg (1854) or *Plinia spp.* (O. Berg) Kausel (1956). The main species discussed in the literature, considering the first classification, are *Myrciaria cauliflora* and *M. jabuticaba*, and the species *M. jabuticaba* (Vell) Berg (Jabuticaba Sabará) and the *Plinia trunciflora* and P. *Cauliflora* stand out in the second classification. [2-4]

These plants produce globose berries with a reddish, almost black peel and a mucilaginous white pulp. The fruits generally have a single seed, but they can have up to four seeds per fruit. [5]

The 'Sabará' jabuticaba fruit occupies the largest cultivated area in Brazil and bears fruits of 20 to 30 mm in diameter and a smooth and juicy pulp with a sub-acid taste. [6] According to Mota et al., [7] the fruits have a small pedicel and are produced in large quantities along the trunk or in the axil of already abscised leaves (Figure 1).

Figure 1. Fruits of *Myrciaria cauliflora*

The fruit pulp has mean values ranging from 14.86 mg 100^{-1}g to 42.34 mg 100^{-1}g for vitamin C and minerals, including iron, calcium, phosphorus and potassium. [8,9] Some studies have also found the presence of phenolic compounds (408.9 mg 100^{-1}g and 460.80 mg 100^{-1}g) in the pulp of the jabuticaba fruit. [10, 11]

The Jabuticaba fruit can be consumed both *in natura* and in processed form as jellies, jams, brandy, liquor, wine and vinegar. [12] In the manufacture of jams and fermented products, the peels and seeds of the fruits represent around 50% of the total weight and are considered to be waste, being discarded by the food industry. [13]

However, studies have shown that the jabuticaba fruit peels have significant levels of phytochemical compounds with functional and technological properties, which are currently being included in processed foods. [14-16] The objective of this review was to show that several references in the literature have demonstrated the presence of important phytochemical compounds in the Jabuticaba fruit peel, in addition to its beneficial metabolic and physiological effects and its use in processed foods for human consumption.

METHODS

This literature review was carried out through the search of relevant scientific publications in the Portuguese and English languages in the *Pubmed*, *Google Scholar*, *Scielo* and *Lilacs* databases, mostly written in the last ten years, although older article citations and three technical papers were required for the classification and characterization of the genre.

RESULTS AND DISCUSSION

Phytochemicals in the Jabuticaba fruit peels

The coloring of the jabuticaba fruit peel has intensified the scientific research into the phytochemical compounds present in this waste for some years now, since it has always been discarded by the juice & pulp industry. The color of the peel is directly influenced by the expressive presence of anthocyanin compounds, chemically classified as flavonoids, which are the main natural pigments for the colors pink, red, violet and blue in vegetables, fruits, flower petals and leaves. [17, 18]

According to Abe et al., [19] the anthocyanin concentrations in jabuticaba fruit peels increase during the ripening process of the fruits, with the presence of these compounds not being identified in the seeds and pulp of this fruit during the ripening stages.

According to Giusti and Wrolstad, [20] several factors influence the stability of anthocyanins, such as their chemical structure (number of hydroxyls, degree of methylation and glycosylation); pH; temperature; light; the presence of oxygen; enzymatic degradation; and interactions with other food components, such as ascorbic acid, sugars, metal ions and copigments. Anthocyanins are very soluble in polar solvents, being easily extracted with water, methanol and ethanol. [21]

In a study conducted by Lima et al., [5] the peel of the Sabará variety had the highest levels of polyphenols (11.99 g 100^{-1}g) followed by the Paulista variety (11.18 g 100^{-1}g). Cyanidin 3-O-glucoside is the major pigment in the peel, followed by delphinidin 3-glucoside, malvidin and malvidin-3-O-glucoside. [21,22] Through mass spectrometry, Calloni [23] identified that the mass of the jabuticaba fruit peel not only contained the cyanidin 3-O-glucoside compound in greater quantities, but also kaempferol, hexadecanoic acid and octadecanoic acid. Plaza et al. [24] observed the presence of kuromanin, myrtillin, casuarictin, casuarinin, ellagic acid, pedunculagin and a non-identified phenolic compound in the jabuticaba fruit peels.

Extraction of the jabuticaba fruit peels with solutions of 4:1 methanol-water, 4:1 ethanol-water, 3:2 ethanol-water and 3:2 acetone-water, using the Folin-Denis method, revealed high phenolic compound contents (18.95; 14.06; 12.93; 11.99 mg $^{-1}$g of gallic acid, respectively) in a study by

Araújo et al. [25] In a study by Lenquiste et al., [26] the aqueous extract of lyophilized peels had higher levels of gallic acid when compared to the methanolic extract, but in this latter extract the concentration of ellagic acid was higher than in the aqueous extract.

As already mentioned, the phytochemical levels also vary according to the degree of ripening. The jabuticaba fruit peels of the Sabará cultivar had high concentrations of ellagic acid that ranged from 22.5 ± 1.3 g kg^{-1} to 43.95 ± 0.24 g kg^{-1}, depending on the ripeness stage of the fruit. These values were higher than the levels of ellagic acid observed in the pulp of the jabuticaba fruits (4.6 ± 0.2 g kg^{-1} to 36.8 ± 2.5 g kg^{-1}) in a study conducted by Abe et al. [19]

In addition to the significant levels of phenolic compounds, the jabuticaba fruit peels are also rich sources of food fibers. In a study by Lima et al., [5] the peel had expressive levels of total fibers: 33.80 g 100^{-1}g in the Paulista and 33.23 g 100^{-1}g in the Sabará variety, with the largest percentage being insoluble fibers. According to Araújo et al., [25] potassium is the element found in greater proportion in the peel of this fruit, followed by phosphorus, calcium, magnesium and iron.

In vitro and _in vivo_ antioxidant activity

Oxidative stress is a condition in which an imbalance between the production of free radicals and endogenous antioxidant defenses occurs, culminating in the decrease of the antioxidant capacity of the cells. [27] This imbalance has been implicated in a number of patho-physiologic processes related to many chronic and degenerative disorders. Studies have shown that the ingestion of phytochemical compounds has a protective effect against oxidative processes. [28-30] In this context, the jabuticaba fruit peels emerge as potential alternatives for the prevention and treatment of disorders related to oxidative stress, since they are important sources of the already described phenolic compounds.

The antioxidant capacity of the extracts of the jabuticaba fruit peels was measured through DPPH (2.2-diphenyl-1-picrylhydrazyl), ABTS (2.2 azinobis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt), FRAP (ferric reducing antioxidant power) and ORAC (oxygen radical absorbance capacity test) tests in a study by Lenquiste et al. [26] The study revealed that, in the DPPH and ORAC trials, the antioxidant capacity of the methanolic extract was more efficient (346.77 and 317.98 Trolox μM g^{-1}, respectively) than the aqueous extract. The results of the FRAP trials were statistically similar for both extracts, and in the ABTS trials, the antioxidant activity showed higher values in the aqueous extract (223.10 Trolox μM g^{-1}).

In a study conducted by Lima et al., [21] the jabuticaba fruit peels of the Sabará variety had a higher antioxidant activity (1.56 mmol L^{-1} g^{-1} in Trolox equivalents) when compared to the Paulista variety (2.06 mmol L^{-1} g^{-1} in Trolox equivalents). The pulps and seeds had the lowest antioxidant activity in both varieties, while the values were intermediate in the whole fruit.

The hydroalcoholic extract of the jabuticaba fruit peels showed significant antioxidant activity, with a DPPH radical sequestering percentage from 83.6% to 91.88% in a study conducted by Pitz et al. [31]

According to Kumar and Pandey, [32] the free radical sequestering capacity is attributed mainly to the high reactivity of the hydroxyl substituents of the flavonoid structure. The presence of hydroxyl in position on the ring, B 3' and 4', is the most significant factor in the capture of nitrogen species (RNS) and reactive oxygen species (ROS) because it confers a high stability to the formed radical. The presence and the total number of hydroxyl groups, therefore, can substantially influence the various antioxidant activity mechanisms.

The antioxidant activity of lyophilized jabuticaba fruit peels was tested in male Wistar rats for a period of 28 days. [33] The study revealed that the dose used to achieve maximum antioxidant capacity was

2% (20 g kg^{-1}) of lyophilized jabuticaba fruit peels), with plasma ORAC values of 22.96 Trolox equiv μL^{-1}, representing an antioxidant capacity 1.3 times greater than the control group.

In a study by Plaza et al., [24] ellagitannins and gallotannins (hydrolysable tannins) were the phenolic class that contributed most to the total antioxidant capacity of *M. jabuticaba* (43%), followed by anthocyanins (38%), other unidentified phenolic compounds (12%), ellagic acid and derivatives (6%) and flavonols (1%), when analyzed through high-performance liquid chromatography.

Red wine made with the jabuticaba fruit had a superior antioxidant activity than wine made with grapes when using the carotene/linoleic acid system in a study conducted by Barros et al., [34] who obtained oxidation inhibition values close to BHT (a synthetic antioxidant used in the food industry), with an inhibition of around 65%. This study also revealed that jabuticaba wines are good free radical sequesters.

Physiological and metabolic effects

In popular medicine, jabuticaba fruit peels are often used for the treatment of diarrhea and skin irritations, in inflammations of the intestines and hemoptysis, in addition to traditionally showing anti-asthmatic and anti-inflammatory properties of the amigdalas in the decoction from). [35-37] Currently, some *in vivo* studies have shown the metabolic and antimutagenic properties of jabuticaba fruit peel extracts.

Lage et al. [38] observed that the addition of 3% of jabuticaba fruit peel flour increased the HDL-c (high density lipoprotein) plasma levels by 20.23% in experimental models, in addition to reducing hepatic lipid peroxidation by 50% when compared to the control group. These findings corroborate the results from Lenquiste et al., [39] who treated obese rats with jabuticaba fruit peels and observed an increase in the HDL-c levels and a significant improvement in insulin resistance, with the doses used not showing cytotoxic properties in the animals under study.

In a study by Araujo et al., [40] experimental models treated with a diet rich in fats and jabuticaba fruit peel flour in different concentrations had their levels of total cholesterol, plasma triglycerides and glucose levels significantly reduced after four weeks of treatment.

In a study by Batista et al., [41] the serum levels of triglycerides and total cholesterol observed in groups of animals treated with 4% of lyophilised jabuticaba fruit peel flour not only reduced, but a reduction in hyperinsulinemia and hepatic inflammation was also observed. These authors also observed in this study that the daily consumption of bioactive compounds from jabuticaba fruit peels improved the antioxidant status of the plasma, even in the conditions of 12 hours of fasting to which the animals were subjected.

On the other hand, the administration of a feed with lyophilized jabuticaba fruit peels did not exert a protective effect on the weight gain induced by a diet rich in fats, on hyperleptinemia, and on the glucose intolerance of the rats. The supplementation was effective, however, in reducing insulin resistance and in the expression of such pro-inflammatory cytokines as IL-1b and IL-6 in all rats treated with jabuticaba. [42]

Lobo de Andrade et al. [43] conducted studies with hydroalcoholic extracts of *M. cauliflora* in experimental models, revealing that the intravenous infusion of the extract produced hypotension and vasodilation in the rats, increasing the flow of blood without changes in heart rhythm.

Calloni [44] found in his *in vitro* studies that the jabuticaba fruit peel extract (*P. trunciflora*) minimized the increase in lipid peroxidation, the levels of nitric oxide and the loss of viability induced by H_2O_2 in fibroblasts of the human lung, revealing the ability to reduce oxidative/nitrosactive damage via modulation of the mitochondrial function in mammalian cells.

Studies using an ethanolic extract of the jabuticaba fruit peel demonstrated an *in vitro* anti-proliferative effect on tumor cells of the prostate (PC-3) and leukemia (K-562), and an *in-vivo* antimutagenic effect in mice treated with the extract of the jabuticaba fruit peel, administered by gavage for a period of 15 days. [45]

Adding jabuticaba fruit peels to food

Considering the results of the scientific studies, the jabuticaba fruit peels have been incorporated in food products in order to make use of the fruit's typical coloring phytochemical pigments and the beneficial functional properties in its composition.

Color is often lost during the food processing stages, and dyes are added to these products in order to restore the original color and/or make them more visually appealing. The anthocyanins present in the jabuticaba fruit peels are a viable alternative to provide the color red in foods from natural sources, in addition to being soluble in water, which facilitates their incorporation in aqueous systems. [46] According to Rosso, [47] however, there are limitations to the commercial application of anthocyanins due to their stability, which depends, among other factors, on the chemical structure of the pigments, pH, temperature, the presence of oxygen, light and the concentrations of ascorbic acid in the food.

Silva et al. [48] extracted food colorings from the jabuticaba fruit peel through atomization in a mini spray drier system, conveyed with the stabilizers maltodextrin and gum arabic. Through colorimetric analysis and the determination of anthocyanins, they found, however, that there was a significant degradation of anthocyanin pigments in the colorings exposed to light at an average temperature of 25 ºC. Santos et al., [49] on the other hand, used extraction methods with low-cost ultrasonic irradiation and obtained a low degradation of anthocyanins and a higher antioxidant activity with jabuticaba fruit peels.

Dessimoni-Pinto et al. [50] developed jellies with jabuticaba fruit peels, showing the presence of total phenolic compounds (148.00 mg to 216.44 mg $100g^{-1}$ of gallic acid) and flavonoids (10.42 mg 12.10 mg.100 g^{-1} of catechin), in addition to an acceptability index of 80% among the tasters who performed the sensory evaluation of the developed jellies.

Baldin et al. [15] added microencapsulated extracts of jabuticaba fruit peels to fresh sausages, and observed antioxidant and anti-microbial effects during a period of 15 days under refrigeration, in addition to an improvement of some sensory characteristics of the products. Almeida et al., [51] on the other hand, did not observe microbial stability during storage when adding jabuticaba peel extracts to Bologna-type sausages, but the peels did positively influence the oxidative stability of the sausages.

Pereira et al. [16] studied the interfering effects of incorporating the extract obtained by the supercritical extraction of jabuticaba fruit peels obtained from jelly manufacturing waste, in the formulation of a probiotic Petit suisse. The study revealed that the samples with the jabuticaba extract had better viscosity after 28 days of storage, but the scores awarded by the tasters in the sensory analysis were between 4.68 (flavor) and 6.25 (aroma), which was lower than the scores attributed to the commercial samples. Faria et al. [52] observed good stability in the growth of *Lactobacillus* ssp in fermented milk with the addition of lyophilized jabuticaba fruit peels.

Jabuticaba fruit peel flour was also added to cookie dough in a study by Ferreira et al. [53] The researchers found that the flour had a positive influence on texture and softness, but at concentrations above 10% in the formulations, they did not result in good acceptability regarding taste, sweetness and acidity. Padilha and Basso, [54] on the other hand, observed a high acceptability index

(87.1%) in cookies made with dehydrated jabuticaba fruit peels from industrial waste. In cereal bars, the addition of dried and ground jabuticaba fruit peels in different concentrations also revealed high levels of acceptability, especially for the attributes color, taste and texture, in a study by Appelt et al. [55]

Isotonic drinks were prepared with extracts from the jabuticaba fruit peels in a study conducted by Cipriano, [56] and with the ultrafiltration permeate of the milk with the addition of anthocyanic extracts from the jabuticaba fruit peels in a study by Valente. [57] In the first study, the drink had 9.44 mg L^{-1} of anthocyanins and showed no significant difference in the sensory acceptance when compared to commercial beverages, revealing a high antioxidant activity through the radical cation ABTS test. In the second study, the anthocyanins content was 15.98 mg L^{-1} and the antioxidant activity through the radical ABTS and DPPH tests were 2.43 and 2.72 µM, Trolox equivalent mL^{-1}, respectively.

Concluding remarks

Jabuticaba fruit peels have significant concentrations of phytochemical compounds, especially anthocyannins and ellagic acid, and they have shown antioxidant effects and hypolipidemic and antimutagenic activity in *in vitro* experiments and in experimental models. As such, jabuticaba fruit peels may have great potential as a functional ingredient incorporated into processed foods for human consumption.

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