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Physical-chemical properties of exotic and native Brazilian fruits

Propiedades fisicoquímicas de frutas exóticas nativas de Brasil

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Abstract

Many fruit species are still not well-studied, despite being rich in bioactive substances that have functional properties. The objective of this article was to evaluate the antioxidant potential and characterize the physical-chemical characteristics of unconventional brazilian fruits (cabeludinha - *Myrciaria glazioviana*, sapoti - *Manilkara zapota*, pitomba - *Talisia esculenta*, yellow gumixama - *Eugenia brasiliensis* var. Leucocarpus and seriguela - *Spondias purpurea*). Total soluble solids, pH, titratable acidity, sugars, pigments, phenolic compounds and antioxidant capacity were measured. Mature fruits were used in the analyses. Pitomba had high levels of soluble solids, 24.6 °Brix, while sapoti had 0.05 g malic acid 100 g^{-1} pulp. Yellow grumixama and seriguela had the highest concentrations of anthocyanins and carotenoids. Cabeludinha had a high concentration of phenolic compounds, 451.60 mg gallic acid 100 g^{-1} pulp. With the exception of sapoti, all fruits had a high antioxidant capacity (> 95%).

Key words: *Eugenia brasiliensis*, *Manilkara zapota*, *Myrciaria glazioviana*, *Spondias purpurea*, *Talisia esculenta*.

Resumen

El objetivo de este trabajo fue evaluar el potencial antioxidante y caracterizar las propiedades fisicoquímicas de frutas exóticas en Brasil (cabeludinha - *Myrciaria glazioviana*, sapoti - *Manilkara zapota*, pitomba - *Talisia esculenta*, gumixama amarilla - *Eugenia brasiliensis* var. Leucocarpus y seriguela - *Spondias purpurea*). Para el efecto se realizaron análisis de sólidos solubles, pH, acidez titulable, azúcares, pigmentos, compuestos fenólicos y actividad antioxidante. Los frutos fueron cosechados en estado de madurez fisiológica y para los análisis se utilizaron las partes comestibles de la fruta. Los frutos presentaron elevado contenido de sólidos solubles y baja acidez titulable, sobresalieron la pitomba con 24.6 °Brix y sapoti con 0.05 g de ácido málico 100 g^{-1} pulpa. Grumixama amarilla y seriguela resentaron mayor contenido de antocianinas y carotenoides. Cabeludinha presentó elevado contenido de compuestos fenólicos, en promedio de 451.60 mg ácido gálico por 100 g de pulpa. Con excepción de sapoti, todas las frutas mostraron elevada actividad antioxidante (> 95%).

Palabras clave: *Eugenia brasiliensis*, *Manilkara zapota*, *Myrciaria glazioviana*, *Spondias purpurea*, *Talisia esculenta*.

Introduction

The consumption of fruits is increasing in recent years due to their functional properties. They contain bioactive substances that have antioxidant activities and beneficial effects, despite being present at low concentrations (Kaur and Kapoor, 2002, Mélo et al., 2008, Carvalho et al., 2016).

The native Brazilian Mata Atlântica fruits cabeludinha (*Myrciaria glazioviana)*, yellow grumixama (*Eugenia brasiliensis* var. Leucocarpus) and pitomba (*Talisia esculenta*) are poorly-studied species (Rocha et al., 2011) and their consumption is mostly restricted to their points of origin. At the same time, exotic species in Central America, sapoti (*Manilkara zapota*) and seriguela (*Spondias purpurea*) are cultivated in northern and northeastern parts of Brazil, but seldom elsewhere. However, such species may have antioxidant potential.

According Lorenzi et al. (2006) and Martins et al. (2002) cabeludinha (*Myrciaria glazioviana* – Myrtaceae Family) has a globose shape, the peel is thick, hairy and yellow. It contains one or two seeds that correspond to almost 50% of the fruit mass, the pulp is translucent-juicy and acidulated. Yellow grumixama tree (*Eugenia brasiliensis* var. Leucocarpus - Myrtaceae Family) has globular fruit, smooth and bright yellow peel, juicy and sweet pulp and contain one to three seeds. Pitomba fruits (*Talisia esculenta* – Sapindaceae Family) are subglobous, hard and rough with yellow or ferruginous color, contains one or two seeds covered by fine and translucent aril, acidulated taste. Sapoti fruit (*Manilkara zapota* – Sapotaceae Family) is rounded or ellipsoid, has sweet pulp, with four to ten seeds. Seriguela tree (*Spondias purpura* – Anacardeacea Family) has fruits with oblonga-ellipsoid shape, smooth, brilliant and red purple color peel, with sweet acidulated pulp.

The fruits are main dietary sources of polyphenols with antioxidant activities and have variable composition of its phytochemical constituents (Mélo et al., 2008). Information on the physical-chemical characteristics and the functional value of native fruits are basic tools to encourage the consumption and the formulation of new products, since the knowledge of these characteristics will enable a better indication of their consumption and use in the food industry (Rocha et al., 2013). Besides, the information about the phytochemical contents contributes to add commercial and industrial value to the fruits (Alves et al., 2017). However, few data are available in the literature regarding the physicochemical composition of these fruits, highlighting the need for scientific research on the subject.

Given the importance of research on natural antioxidants and the scarcity of data related of Brazilian native fruits (Alves et al., 2017). The objective of this work was to characterize the physical-chemical properties and evaluate antioxidant potential in vitro of cabeludinha (*Myrciaria glazioviana*):yellow grumixama (*Eugenia brasiliensis* var. Leucocarpus) pitomba (*Talisia esculenta*,:sapoti (*Manilkara zapota*) and seriguela (*Spondias purpurea*).

Material and methods

Mature fruits were collected at the Fazenda Experimental da Faculdade de Ciências Agronômicas/UNESP in Botucatu, São Paulo (22° 53' 09" latitude south, 48° 26' 42" longitude west and 804 m altitude) and immediately subjected to laboratory tests. For cabeludinha (*M. glazioviana)* pitomba (*T. esculenta)* and sapoti (*M. zapota*) pulp was used for analysis and the fruits were manually peeled with knife help. For yellow grumixama (*E. brasiliensis* var. Leucocarpus) and seriguela (*S. purpurea*) pulp and peel was analyzed. Each sample was homogenized by mixer for a total of 200 g.

Physical-chemical analyses

The metodology of Instituto Adolfo Lutz (2008) was used: the levels of soluble solids (SS) were determined at 25 °C using an ABBE refractometer (model Atago-N1) and expressed as °Brix; the pH of the sliced and homogenized samples was determined using a digital DMPH-2 pH meter; the titratable acidity (AT) of 5 g of homogenized samples, diluted to 100 mL with distilled water, was determined using a 0.01 N solution of sodium hydroxide, the results were expressed as g (citric or malic) acid per 100 g of sample.

Reducing and total sugars

To determine total and reducing sugars, the method of Nelson (1944) modified by Somogyi (1945) was used. A Micronal B382 spectrophotometer was used to read the absorbance at 535 nm and the results were expressed as a percentage.

Pigments

The determination of the level of pigments was done by the method of Sims and Gamon (2002) using a UV/VIS spectrophotometer and measuring absorbances at 663 nm (chlorophyll A), 647 nm (chlorophyll B), 537 nm (anthocyanin) and 470 nm (carotenoids). The absorbance values were converted to $\mu g\ g^{-1}$ pulp.

Determination of solvents for phenolic compounds and antioxidant capacity

Three solvent mixtures were tested: 80% etanol + 20% distilled water, 80% metanol + 20% distilled water and 80% acetone + 20% distilled water. The concentration of phenolic compounds was done colorimetrically using the Folin-Ciocalteau reagent as described by Singleton et al. (1999). This method involves the reduction of the reagent by phenolic compounds and concomitant formation of a complex that absorbs light at 760 nm. Gallic acid was used as the standard. Results were expressed as mg gallic acid equivalents 100 g^{-1} fresh sample (GAE).

The in vitro antioxidant capacity was determined using the DPPH (2,2-diphenyl-1-picrylhydrazyl) as described by Mensor et al. (2001). The antioxidants in samples react with DPPH which is a stable free radical. It is converted to 2,2-diphenyl-1-picrylhydrazine. The degree of decolorization indicates the antioxidant potential of the extract. The absorbance at 517 nm was measured. Results were expressed as percentage DPPH reduced, according to equation 1.

$$\%_{DPPH\ Reduced} = ((Abs_{Control} - Abs_{Sample}) / Abs_{Control})*100$$

(Ec. 1)

where, $Abs_{Control}$ is the absorbance of the DPPH solution and Abs_{Sample} is the absorbance of the sample.

Data analysis

Four repetitions of the physical-chemical analyses, sugars and pigments were done, average results are presented. The determination of phenolic compounds and antioxidant activities were done in triplicate for each repetition. An ANOVA, F and Tukey tests for average comparison were done.

Results and discussion

Physical-chemical analysis

Pitomba, a species native to Brazil, had 24.60 °Brix SS, which was higher than the others (Table 1). Yellow grumixama had the highest titratable acidity, 1,33 g acid 100 g^{-1} pulp. Sapoti had the lowest titratable acidity. The pH values ranged from 3.06 for yellow grumixama to 3.66 for cabeludinha, with the exception of sapoti, which had a pH of 5.08.

Table 1. Soluble solids, pH and titratable acidity of unconventional Brazilian fruits. Faculdade de Ciências Agronômicas/UNESP in Botucatu, São Paulo

Fruit	Physical-Chemical*		
	Soluble solids (°Brix)	pH	Titratable acidity* (g acid 100 g^{-1} pulp)
Cabeludinha	15.90±0.32	3.66±0.09	0.22±0.01
Sapoti	16.68±0.10	5.08±0.19	0.05±0.01
Pitomba	24.60±0.63	3.40±0.09	1.05±0.12
Yellow grumixama	15.63±1.70	3.06±0.13	1.33±0.09
Seriguela	15.07±0.64	3.12±0.04	0.74±0.08

*Cabeludinha, yellow grumixama and seriguela: titratable acidity expressed as g citric acid 100 g^{-1} pulp. Sapoti and pitomba: acidity expressed as g malic acid 100 g^{-1} pulp. Average ± standard deviation.

Lira Jr. et al. (2010) when evaluating seriguela clones from the germoplasm bank of Itambé-PE/Brazil, found SS values from 16.47 to 23.87 °Brix and titratable acidity from 0.73 to 1.15%. Ramírez-Hernández et al. (2008) found that wild mexican seriguela had 7.0 to 10.8 °Brix SS, while cultivated seriguela had 8 to 15.6 °Brix SS, with a tendency to increase under ideal climactic conditions. The levels of SS found in the present study were consistent with the literature cited.

Research on sapoti done by Morais et al. (2006) found 0.2 to 0.25% malic acid total titratable acidity after being stored 12 days and a pH ranging from 5 to 6, which conforms with those found in the present study. The pH depends on the concentration of free H^{+} ions, while SS depends on the sugar content of the fruit.

Total and reducing sugars

Sapoti and yellow grumixama had the highest values of reducing sugars, 13.04 and 16.68%, respectively. Total sugars and sucrose were not obtained (Table 2), while cabeludinha, pitomba and seriguela had reducing sugars, total sugars and sucrose, with more in pitomba and seriguela compared to cabeludinha that had only 0.82%.

Table 2. Total and reducing sugars, as well as saccharose (sucrose) of unconventional Brazilian fruits. Faculdade de Ciências Agronômicas/UNESP in Botucatu, São Paulo.

Fruit	Sugars (%)		
	Reducing sugars	Total sugars	Sucrose
Cabeludinha	8.10±0.42	8.97±1.78	0.82±1.90
Sapoti	13.04±1.35	*—	*—
Pitomba	9.27±0.31	14.93±1.17	5.38±1.29
Yellow grumixama	16.68±1.09	*—	*—
Seriguela	5.21±0.28	10.14±0.15	4.68±0.20

*—: Absence of total sugars and sucrose. Average ± standard deviation.

Maldonado-Astudillo et al. (2014) reported total sugar values ranging from 4.4 to 22.3% and for reducing sugars from 0.1 to 14.4% for seriguela. These differences are due to differences in climactic and geographic conditions. The present study found 5.21% and 10.14% for reducing and total sugars, respectively.

The levels of total and reducing sugars can be low at the initial stages of maturation, and increase gradually during ripening (Maldonado-Astudillo et al., 2014). In fruits with a high level of sugar, like sapoti, there is a high correlation between the increase in soluble sugars and soluble solids (Alves et al., 2000). This is verified in the present study, with values of 16.68 °Brix and 13.04% of reducing sugars. The amount of sugars in sapoti increases during maturation. This is provided by the degradation of amides and hemicellulose, as well as degrading the latex of the fruits, due to the actions of microrganisms or latex enzymes (Pathak and Bhat, 1952).

Pigments

Yellow grumixama had 74.03 and 65.62 µg g^{-1} pulp chlorophylls A and B, respectively, as well as anthocyanins 473.56 µg g^{-1}. This anthocyanins level is 2.5 higher than seriguela with 185.71 µg g^{-1} pulp (Table 3). Seriguela had the highest value of carotenoids, 185.83 µg g^{-1} pulp, average between the values obtained by Vargas et al. (2017) in ripe seriguela fruits (143.8 and 853.6 µg g^{-1}). It should be noted that yellow grumixama and seriguela are consumed with the peels. So, the pulp along with the peels of the fruits probably contribute to the high levels of pigments.

Carotenoids, besides being pigments, have several functions such as vitamin A activity, cancer prevention, cardiovascular protection and the ability to reduce the risks of cataracts (Chirinos et al., 2010). So, seriguela is noteworthy due to its high concentration of carotenoids.

Determination of solvents for phenolic compounds

80% acetone was the most effective for sapoti, pitomba and seriguela (Table 4). For yellow grumixama and cabeludinha the three different solvents performed similarly ($P < 0.05$). Note that cabeludinha had a high level of phenolic compounds, in average 451.60 mg gallic acid 100 g^{-1} fresh weight.

Table 4. Evaluation of extraction solvents for phenolic compounds in unconventional Brazilian fruits. Faculdade de Ciências Agronômicas/ UNESP in Botucatu, São Paulo.

Fruit	Total Phenolic Compounds (mg gallic acid 100 g^{-1} fresh weight)			CV
	Ethanol 80%	Methanol 80%	Acetone 80%	
Cabeludinha	412.15 a*	502.83 a	439.83 a	20.60
Sapoti	16.51 b	13.88 b	23.67 a	11.06
Pitomba	105.95 b	100.18 b	191.41 a	23.19
Yellow grumixama	168.51 a	192.02 a	183.72 a	14.71
Seriguela	95.95 b	95.83 b	185.85 a	13.31

*Averages followed by the same letter in lines don't differ significantly by the Tukey test ($P > 0.05$). CV (%): coefficient of variation.

According to Vasco et al. (2008) fresh fruit species can be classified as low (< 100 mg GAE/100 g), medium (100 to 500 mg GAE/100 g) or high (> 500 mg GAE/100 g). According to this classification, sapoti and seriguela have low levels of phenolic compounds, yellow grumixama and pitomba are intermediate and Cabeludinha has high content.

Roesler et al. (2007) studied the in vitro antioxidant activities of fruits from the do Cerrado (*Annona crassiflora*, *Solanum lycocarpum*, *Eugenia dysenterica*, *Caryocar brasilense* and *Swartzia langsdorfii*) and verified that water did not extract as many phenolic compounds as ethanol and that

Table 3. Levels of chlorophyll A, chlorophyll B, anthocyanins and carotenoids of unconventional Brazilian fruits. Faculdade de Ciências Agronômicas/UNESP in Botucatu, São Paulo.

Fruit	Pigments (µg g^{-1} pulp)			
	Chlorophyll A	Chlorophyll B	Anthocyanins	Carotenoids
Cabeludinha	10.61±2.49	13.14±3.32	64.87±5.19	67.78±8.70
Sapoti	54.95±22.78	30.58±15.83	38.78±11.59	23.56±10.87
Pitomba	8.33±2.26	13.22±2.65	57.51±17.67	13.77±5.25
Yellow grumixama	74.03±31.35	65.62±39.07	473.56±160.96	185.83±36.98
Seriguela	11.64±6.64	12.22±12.07	185.71±36.70	275.31±53.51

Average ± standard deviation.

ethanol and that the concentration was higher in the seeds and peels. Although cabeludinha's peels were not analyzed in the present study, the pulp had a high concentration of phenolic compounds.

The camu-camu (*Myrciaria dubia*) is known to be an important source of antioxidants, such as vitamin C, beta-carotene and phenolic compounds (Vidigal et al., 2011). Total phenolic content obteined by Tietbohl et al. (2017) in *Myrciaria floribunda* fruits was 0.23 g GAE g^{-1}. Cabeludinha is in the same family (Myrtaceae) and genus (Myrciaria) of this fruits. Based on the results of the current study, it also has a high potential to become a good source of antioxidants with beneficial characteristics for consumers.

Silva et al. (2018) studied uvaia fruits (*Eugenia pyriformis*) and obtained values between 402.69 and 483.25 mg GAE 100 g^{-1} for phenolic compounds. While in the present study, yellow grumixama (*Eugenia brasiliensis* var. Leucocarpus), a plant of the same genus and family, values between 168.51 and 192.02 GAE 100 g^{-1} were observed.

In sapoti fruits, phenolic compounds are important for astringency. During maturation, this change due to the polymerixation of these compounds and this decreases their concentrations (Lakshminarayana e Subramanyam, 1966, Taira et al., 1997). Thus, the reduction in the concentrations of tannins tend to reduce the total phenolics (Abe et al., 2011). This can explain the low levels found in the current study (from 13.88 to 23.67 mg gallic acid 100 g^{-1} fresh weight).

Determination of solvent for antioxidant capacity

Sapoti had the lowest in vitro antioxidant capacity, 21.54%. It was not affected by the solvent chosen (Table 5). For cabeludinha, 80% ethanol and 80% methanol, did not differ statistically. Similar results were obtained with yellow grumixama. In contrast, 80% methanol and 80% acetone were best for pitomba. For seriguela 80% acetone was best.

According Alezandroa et al. (2013) lower levels of phenolic compounds and consequently, lower antioxidant capacity were observed in mature jabuticaba fruit (Myrtaceae family and native Brazilian specie) pulps. The seeds had high in vitro antioxidant capacities, followed by the peel and the pulp, regardless of the method used (Folin-Ciocalteu, or DPPH). This can be explained by the fact that some compounds undergo modifications in ripe fruits due to enzyme activities, such as the hydrolysis of glycosides by glycosidases, the oxidation of phenolic compounds by phenol oxidases and the polymerization of free phenols. Besides this, soluble phenolic compounds are present at higher concentrations in the peel, compared to the pulp (Robards et al., 1999). This fact should be double-checked with sapoti, since it had lower antioxidant capacity. Neri-Numa et al. (2014) studied pitomba fruits. They suggested that they can be explored as a good source of antioxidants that can have anti-cancer properties. Engels et al. (2012) found 21 phenolic compounds using mass spectrometry. In the present study, high antioxidant capacity in pitomba (from 70.66 to 96.80%) and seriguela (from 92.41 to 96.17%) was evaluated.

By means of the obtained results, the fruits studied presented high antioxidant potential, being able to be rich sources of bioactive compounds in the feeding besides the possible stimulation of the consumption of native fruits, valorization of the species and diversification of the consumption of vegetables.

Table 5. Evaluation of extraction solvents for determining the antioxidant capacity using DPPH (2,2-diphenyl-1-picrylhydrazyl) of unconventional Brazilian fruits. Faculdade de Ciências Agronômicas/UNESP in Botucatu, São Paulo.

Species	Antioxidant capacity (% DPPH reduced)			CV
	Ethanol 80%	Methanol 80%	Acetone 80%	
Cabeludinha	94.71 ab*	95.89 a	93.25 b	0.77
Sapoti	19.93 a	28.88 a	15.80 a	15.30
Pitomba	70.66 b	95.58 a	96.80 a	10.15
Yellow grumixama	95.11 a	95.31 a	91.32 b	1.25
Seriguela	92.41 c	94.06 b	96.17 a	0.58

*Averages followed by the same letter in lines don't differ significantly by the Tukey test (P > 0.05). CV (%): coefficient of variation.

Conclusion

The fruits cabeludinha, pitomba, yellow grumixama and seriguela represent sources of phenolic compounds with important antioxidant capacity. Cabeludinha stands out from other fruits due to its relevant contents of phenolic compounds and yellow grumixama and seriguela due to its relevant contents anthocyanins and carotenoids.

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