Artículo Original / Original Article

Bioactive compounds in fruits from different regions of Brazil

Compuestos bioactivos en frutas de diferentes regiones del Brasil

ABSTRACT

It is important to determine the chemical composition of fruits in order to establish their potential health benefits for human nutrition and thus stimulate their cultivation and consumption. Therefore, the objective of this study was to determine the physical and chemical parameters, vitamin C content, phenolic compounds, flavonoids and carotenoids, fatty acid profile and antioxidant activity of fruits from different regions of Brazil. We observed that the different regions and fruits studied presented very distinct characteristics. For example, the cupuaçu pit is rich in unsaturated fatty acids, while the genipap and java plum presented high flavonoid content and the butia had a high concentration of carotenoids. Guava was the fruit with the highest antioxidant activity through the ABTS radical, while the yellow mombim presented the best response when the activity was determined by FRAP.

Keywords: Antioxidant activity; Brazilian fruits; Fatty acid; Functional properties; Phenolic compounds.

RESUMEN

Es importante determinar la composición química de las frutas para establecer sus potenciales beneficios para la salud humana y, por lo tanto, estimular su cultivo y consumo. El objetivo de este estudio fue determinar parámetros físicos y químicos, el contenido de vitamina C, los compuestos fenólicos, los flavonoides y los carotenoides, el perfil de ácidos grasos y la actividad antioxidante de las frutas de diferentes regiones de Brasil. De los resultados obtenidos en este estudio se pudo observar que las diferentes regiones y frutas estudiadas presentaban características muy distintas, ya que la semilla de cupuaçu es rica en ácidos grasos insaturados, mientras que el genipapo y la ciruela java presentaron un alto contenido de flavonoides y el butia presentó alta concentración de carotenoides. La guayaba fue la fruta con la mayor actividad antioxidante determinada por el radical ABTS, mientras que el mombim amarillo presentó la mejor respuesta cuando la actividad fue determinada por FRAP.

Palabras clave: Ácidos grasos; Actividad antioxidante; Compuestos fenólicos; Frutas brasileñas; Propiedad funcional.

Deborah Otero^{1*}, Bruna Antunes², Bruna Bohmer²,
Cristina Jansen², Michele Crize², Alexandre Lorini²,
Fernanda Krumreich², Rui Carlos Zambiasi³.

1. Departamento de Ciência dos Alimentos. UFBA,
Campus Canela, Salvador, Ba, Brasil,

2. Programa de Pós Graduação em Nutrição e Alimentos.
UFPEL, Campus Porto. Pelotas, RS, Brasil.

3. Centro de Ciências Químicas, Farmacêuticas e de Alimentos.
UFPEL, Campus Capão do Leão. Pelotas, RS, Brasil.

*Dirigir correspondência a: Deborah Otero.
Departamento de Ciência dos Alimentos. UFBA, Campus
Canela, CEP: 40110-909. Salvador. Ba, Brasil,
Telefone: (71) 3283-7700 – Fax: (71) 328377XX;
E-mail: deborah.m.oterom@gmail.com.br

Este trabajo fue recibido el 09 de noviembre de 2018.
Aceptado con modificaciones: 28 de mayo de 2019.
Aceptado para ser publicado: 13 de agosto de 2019

INTRODUCTION

The search for healthy food sources that provide health benefits is a topic of growing interest, motivating diets based on fruits and vegetables, which are directly associated with reducing the incidence of chronic and degenerative diseases. Plants present considerable amounts of micronutrients, such as minerals, fibers, bioactive compounds, and a balanced profile of fatty acids¹. Brazil has a vast plant biodiversity, and is the third largest fruit producer in the world. Many fruits from Brazil have peculiar sensorial characteristics and nutritional and economic potential, influencing their consumption for national and international markets².

Fruit pulps and related co-products have become

popular and are now used in supplements, dietary additives and pharmaceuticals, with the aim of controlling and / or preventing diseases³. However, research on the composition of bio compounds, which are related to the functional properties of fruits grown in different regions of Brazil, is still scarce. Thus, it is important to study a number of fruit species and focus on the chemical characterization and number of bioactive compounds. This information would provide knowledge that could be incorporated in agribusiness, leading to more usage of raw materials hitherto little used in the food and pharmaceutical industries⁴.

Among the compounds with functional properties, substances with antioxidant activity receive special attention for protecting the human body against oxidative stress, and preventing several chronic degenerative disorders⁵. Fruits have a variety of antioxidant compounds, such as vitamin C, phenolic compounds and carotenoids. Vitamin C refers to all compounds which exhibit biological activity equivalent to L-ascorbic acid. It is one of the most important water-soluble vitamins for human health, known for its antioxidant activity and is also involved in many biochemical functions. It is often used as an additive by the food industry to avoid the oxidation of food products⁶. Vitamin C captures reactive oxygen species forming free radicals, such as semi dehydroascorbic acid or ascorbate radical, from the loss of one electron⁷.

Phenolic compounds are classified into groups according to their chemical structure, such as flavonoids, phenolic acids and tannins. The antioxidant activity and anticancer and antimutagenic effects of phenolic compounds have been widely reported^{1,8}. Their antioxidant action is attributed to the reduction in power of the aromatic hydroxyl group in addition to chelating transition metals^{3,9}. Carotenoids, which are liposoluble pigments, can act as natural antioxidants, protecting the cells against reactive oxygen species and free radicals, acting mainly via energy absorption that arises from the system of conjugated double bonds present in their structure¹⁰.

As with bioactive compounds, the profile of fatty acids present in the oils of the seeds of some fruits influences functional properties, since a balanced composition of saturated and unsaturated fatty acids confers high nutritional values^{1,11}. Unsaturated fatty acids such as oleic acid (ω -9), linoleic (ω -6) and linolenic acid (ω -3) are considered indispensable components for the structure, development and function of cells, as they are directly related to a decrease in the risk of numerous diseases, especially cardiovascular, cancer and metabolic syndrome¹¹.

In this context, it is important to determine the chemical composition of fruits in order to establish their health benefits for human nutrition and thus to stimulate their cultivation and consumption. Therefore, the objective of this study was to determine some physical and chemical parameters, the vitamin C content, phenolic compounds, flavonoids and carotenoids, the fatty acid profile and the antioxidant activity of fruits from different regions of Brazil.

MATERIAL AND METHODS

Twenty-six mature fruits were purchased from local companies from different regions of Brazil from January to June of 2018, which are presented in table 1. The fruits were selected with respect to health, physical integrity, color uniformity and degree of maturity. After being sanitized, the seeds and husks were separated and the parts were crushed and stored in a freezer at -80°C until the analysis time.

Physical chemical determinations

Aluminum capsules were weighed after being kept in an oven at 105 °C for one hour. Next approximately 5 g of sample per capsule was weighed and placed in an oven (105 °C) for 4 hours, the results expressed in % of humidity¹².

The total soluble solids content was obtained by measuring the refractive index in an Abbé Analytik Jena refractometer with automatic temperature correction to 20 °C, calibrated with distilled water. Results were expressed in °Brix in accordance with the methodology of the AOAC¹².

Acidity was determined by titrating one gram of sample with sodium hydroxide solution, in accordance with the AOAC¹². The results were expressed as mg 100 g⁻¹ citric acid. The pH was determined in a bench pH meter in accordance with the methodology described by the AOAC¹².

Bioactive Compounds

The total content of phenolic compounds was determined following the methodology of Singleton and Rossi¹³. Absorbance was measured at 765 nm in a spectrophotometer, with white methanol PA and results were expressed in mg equivalent of gallic acid per 100 g of dry matter (mg EAG.100 g⁻¹).

Aliquots of 2 mL of fruit pulps at 20 µg mL⁻¹ were added with 1mL of 2.5% (w/v) aluminum chloride solution. The absorbance reading was taken after 30 minutes at 415 nm in a spectrophotometer, and the results were expressed in milligram equivalents of quercetin per 100 g of dry matter (mg EQ 100 g⁻¹).

The total carotenoid content was determined according to the methodology described by Rodriguez-Amaya¹⁴. The results expressed in milligrams per 100 g of dry matter. Vitamin C content was determined by titration following the method described by AOAC¹² and expressed as mg of ascorbic acid in 100 mL⁻¹ of juice.

Antioxidant Activity

Antioxidant activity was determined using Ferric Reducing Antioxidant Power (FRAP), according to the method described by Silva et al.¹⁵, and by the abduction of the radical ABTS (2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid), following the methodology described by Gülçin et al.¹⁶. The results were expressed with the aid of a calibration curve in 6-hydroxy -2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox); results were expressed as dry basis (mmol Trolox.g⁻¹).

Table 1. The scientific names of fruits and region of production.

Fruit	Scientific name	City-State
Pequi	Caryocar brasiliense	Goiás–Goiania
Caja-manga	Spondias dulcis	Goiás–Goiania
Assai	Euterpe oleracea	Belém–Pará
Pupunha	Bactris gasipaes	Belém–Pará
Cupuaçu	Theobroma grandiflorum	Belém–Pará
Java plum	Syzygium cumini	Pelotas, Rio Grande do Sul
Butia	Butia capitata	Jaguarão, Rio Grande do Sul
Persimmon	Diospyros kaki	Pelotas, Rio Grande do Sul
Guava	Psidium guajava	Bagé, Rio Grande do Sul
Bush banana	Bromelia antiachanta Bertol	Pelotas, Rio Grande do Sul
Jatoba	Hymenaea courbaril	Campo Grande, Mato Grosso do Sul
Custard apple	Annona squamosa	Campo Grande, Mato Grosso do Sul
Dragon fruit	Hylocereus undatus	Campo Grande, Mato Grosso do Sul
Winged stem passion fruit	Passiflora Alata	Campo Grande, Mato Grosso do Sul
Genipap	Genipa americana	Itapetinga-Bahia
Cajarana	Spondias Lutea	Itapetinga-Bahia
Biri-Biri	Averrhoa Bilimbi	Itapetinga-Bahia
West Indian gherkin	Cucumis anguria	Itapetinga-Bahia
Sapoti	Manilkara zapota L.	Fortaleza-Ceará
Yellow mombin	Spondias mombin	Fortaleza-Ceará
Starfruit	Averrhoa carambola	Fortaleza-Ceará
Seville orange	Citrus aurantium	Pelotas, Rio Grande do Sul
Peach	Prunus pérsica	Pelotas, Rio Grande do Sul
African horned cucumber	Cucumis metuliferus	Campo Grande
Bacuri	Scheelea phalerata Mart.	Belém
Pupunha	Bactris gasipaes Kunth	Belém
Uva Japão	Hovenia dulcis Thunb	Jaguari

Fatty acids

Fatty acid analysis was performed only on fruits that contained kernels (Butia, Pequi, Bacuri, Cupuaçu and Pupunha). Using the methodology of Hartman and Lago¹⁷, an aliquot which contains fatty acid methyl esters was collected in a vial and injected into a Perkin Elmer Clarus gaseous gas chromatograph equipped with a FID detector and Carbowax ID 20 M column of 0.25 µm and dimensions 30 m x 0.25 mm, coated with polyethylene glycol. Nitrogen was used as the entrainment gas at 1.5 mL.min⁻¹. Fatty acids were identified by comparison with the retention times of methyl esters (Sigma Chemicals Co., St. Louis, USA). Results were expressed as relative percentage of fatty acids.

RESULTS

Considering the moisture content of the fruits (Table 2), it was found that pequi, assai, pupunha, jatoba, custard apple and sapoti had moisture contents below 80%. Souza et al.¹⁸ reported moisture between 80.16 and 93.48% for fruit pulps of the Brazilian cerrado biome, whereas in the present study this variation was from 24.08 to 92.19%. The fruits showing these extremes were jatoba and biri-biri, respectively. The jatoba, which has a pulp with a farinaceous aspect, was the only fruit with humidity below 50%, so it can be suggested that the jatoba fruit is suitable for the elaboration of flour and other solid foods.

Among the fruit examined, pequi, caja-manga, assai, guava, bush banana, dragon fruit, passion fruit, genipap, biri-

Table 2. Moisture, total soluble solids, acidity and pH of Brazilian native fruits± standard deviation*.

Fruit	Moisture (%)	Total soluble solids (°Brix)	Acidity (% of citric acid)	pH
Pequi	50.4±5.80	2.0±0.01	0.15±0.02	4.84±0.19
Caja-manga	88.41±0.14	5.0±0.01	0.96±0.03	4.65±0.21
Assai	44.4±0.53	0.6±0.00	0.41±0.00	4.69±0.17
Pupunha	58.5±6.50	2.0±0.01	0.54±0.02	4.82±0.40
Cupuaçu	86.4±0.15	6.5±0.01	0.83±0.06	4.33±0.05
Java plum	83.1±0.78	6.0±0.01	0.51±0.00	3.53±0.25
Butia	84.6±0.61	6.2±0.01	0.96±0.00	3.69±0.18
Persimmon	83.6±0.05	7.2±0.01	0.08±0.01	5.30±0.23
Guava	84.5±2.58	3.0±0.01	0.28±0.01	3.66±0.11
Bush banana	86.1±0.63	3.0±0.01	1.54±0.01	3.79±0.11
Jatoba	24.1±2.65	10±0.02	1.18±0.00	5.48±0.01
Custard apple	74.3±0.79	15±0.02	nd**	nd**
Dragon fruit	87.1±0.15	3.0±0.01	0.32±0.01	4.36±0.05
Winged stem passion fruit	83.8±3.00	5.0±0.01	0.42±0.00	3.19±0.03
Genipap	81.9±0.20	4.0±0.01	0.76±0.01	3.84±0.13
Cajarana	87.5±0.03	9.0±0.02	nd**	nd**
Biri-Biri	92.2±0.81	4.0±0.01	nd**	nd**
West Indian gherkin	91.0±0.97	1.0±0.00	0.23±0.01	4.53±0.15
Sapoti	70.2±1.05	6.0±0.01	0.20±0.00	4.63±0.17
Yellow mombin	88.2±0.16	3.0±0.01	1.56±0.06	2.88±0.01
Starfruit	86.9±0.29	7.2±0.02	nd**	nd**
Seville orange	85.5±1.90	4.2±0.01	0.19±0.00	4.58±0.21
Peach	89.3±0.91	4.0±0.01	0.16±0.05	4.19±0.01
African horned cucumber	91.6±0.36	4.1±0.01	nd**	nd**

*± standard deviation **not determined.

biri, West Indian gherkin, yellow mombim, Seville orange, peach and African horned cucumber presented soluble solids content between 0.6 at 5.0°Brix; cupuaçu, java plum, butia, persimmon, jatoba, cajarana and star fruit presented total soluble solids content between 6.0 and 10°Brix; and only the custard apple had content above 10°Brix (15°Brix). Souza et al.¹⁸ evaluated fruits of the cerrado biome and found a variation of 1.0 to 13.3°Brix. Jatoba was the only fruit that presented a high sugar content and low moisture content, which suggests that the fruit lasts longer. However, other factors may be related, such as fruits harvested at less advanced stages of maturation that are exposed to water loss for a longer time; i.e. they perspire more, so the concentration of the cellular juice, and consequently the concentration of sugars, occurs.

Acidity is an important parameter in the quality of products of plant origin, besides being related to the conservation of the products for a longer period of time⁴. Among the analyzed fruits, pequi, caja-manga, assai, pupunha, guava, dragon fruit, passion fruit, genipap, West Indian gherkin, Seville orange, peach, cupuaçu, java plum, butia, persimmon and sapoti presented an acidity between 0.08 and 0.96% in citric acid. On the other hand, jatoba, bush banana and yellow mombim had an acidity between 1.18 and 1.56% in citric acid. A relationship between acidity and sugar content was not observed in the fruits analyzed. A high value in the ratio of total soluble solids and titratable acidity indicates an excellent combination of sugar and acid that correlates with the mild taste of the fruits; while low values correlate with higher acidity and consequently with less desirable flavor of the fruits.

The fruits studied presented pH values ranging from 2.88 to 5.48, with *caja* and *jatoba* representing these extremes, respectively. Most fruits and vegetables fall into the group of acidic foods (pH 4.0-4.5) or very acidic foods (pH <4.0), which restricts the growth of pathogenic microorganisms.

A significant differentiation of vitamin C intake was made (Table 3). Values ranged from 0.55 to 3.70 mg.100g⁻¹

in *sapoti*, *pequi*, dragon fruit, *pupunha*, bush banana and Seville orange fruits in the states of Ceara, Goias, Mato Grosso do Sul, Para and Rio Grande do Sul, respectively. The effects of vitamin C on fruits may vary due to the variety and degree of maturity, as well as the region and cultivation practices, which are influenced by climatic conditions and soil composition¹⁹. Souza et al.¹⁸ found vitamin C content in

Table 3. Total content of phenolic compounds (mg E AG.100g⁻¹), flavonoids (mg EQ.100g⁻¹) and vitamin C (mg ascorbic acid.100g⁻¹) ± standard deviation of fruits from different regions of Brazil.

State	Fruit	Vitamin C	Phenolic compounds	Flavonoids
Bahia	Biri biri	nd*	757±136	0.02±0.01
	Cajarana	nd*	490±92.1	0.04±0.01
	Genipap	0.67±0.32	876±101	0.09±0.01
Ceara	Yellom mombim	2.36±1.43	424±3.93	nd*
	Star fruit	nd*	320±37.0	0.04±0.01
	West Indian gherkin	1.32±0.23	331±43.4	0.03±0.01
	Sapoti	3.31±0.73	123±7.03	0.25±0.01
Goias	Caja-manga	1.37±0.10	392±70.2	0.05±0.01
	Pequi	2.93±0.40	109±28.2	nd*
Mato Grosso do Sul	Passion fruit	1.60±0.23	nd*	nd*
	Jatoba	1.62±0.20	89.5±0.56	nd*
	Dragon fruit	3.07±0.53	nd*	nd*
Para	Assai	0.55±0.16	267 ±38.3	6.60±0.11
	Bacuri	2.33±0.53	nd*	nd*
	Cupuaçu	2.47±0.07	319±36.6	nd*
	Pupunha	3.70±0.40	346±21.5	nd*
Rio Grande do Sul	Bush banana	2.53±0.10	471±18.8	0.06±0.01
	Butia	1.59±0.94	557±62.0	1.56±0.63
	Persimmon	0.94±0.14	189±15.4	0.08±0.01
	Guava	1.55±0.43	596±113	0.06±0.02
	Java plum	0.73±0.91	472±28.2	77.7±20.11
	Seville orange	2.58±0.97	nd*	nd*
	Peach	0.69±0.24	nd*	nd*
	Uva Japão	1.57±0.47	nd*	nd*

*nd – not detected. Means followed by different letters in the column differ by the Tukey test (p <0.05) or by the t test (p <0.05), evaluating the production region.

Cerrado fruits between 21.83 and 59.05 mg.100g⁻¹

Among the studied fruits, the butia and the pupunha were those that presented the highest content of carotenoids, whereas the lower contents were found in the persimmon and jatoba fruits (Figure 1).

Both *butia* and *pupunha* presented zeaxanthin as the majority carotenoid (160.88 µg.g⁻¹ and 136.19 µg.g⁻¹, respectively). In *butia*, α-carotene (139.76 µg.g⁻¹) was the second most frequent carotenoid followed by lycopene (134.47 µg.g⁻¹) and β-carotene (91.99 µg.g⁻¹). Faria et al.²⁰ evaluated the content of carotenoids in *butia* and found the average concentration of total carotenoids of 36.1 µg.g⁻¹, with β-carotene the predominant carotenoid (16.1 µg.g⁻¹).

In *pupunha*, zeaxanthin was observed as the major carotenoid, followed by α-carotene (116.91 µg.g⁻¹), β-carotene (108.23 µg.g⁻¹) and lycopene (78.96 µg.g⁻¹). Rodrigues-Amaya¹⁴ evaluated carotenoid contents in *pupunha* fruits, where they found as the major carotenoids α (3.2 µg.g⁻¹) and β (22 µg.g⁻¹) carotenes. These concentrations were lower than those found in the present study.

Among the fruits analyzed, those with the highest potential antioxidants (Table 4) were guava, java plum and *butia* (Rio Grande do Sul) and *biri biri* (Bahia), for both methods tested. High values were also observed for custard apple, genipap and Seville orange by the ABTS method, and for the bush banana and yellow mombim by FRAP. The fruit with the lowest antioxidant potential by both methods was *sapoti*, and no reduction was observed by the FRAP method. Between FRAP and ABTS, the antioxidant activities were not similar, and it is possible to observe that the compounds that act to reduce iron to the FRAP method are not the same ones that act in the ABTS radical inhibition and vice versa. Similar results were observed in

the work of Almeida et al.²¹ when antioxidant activity was measured via the DPPH and FRAP methods.

The authors evaluated the antioxidant activity of the fruits, and reported 43.478 mmol TEAC.g⁻¹²² and 21 µmol TEAC.g⁻¹²³, 8.64 µmol and 35.03 µmol FeSO₄.g⁻¹ for *biri biri* and guava respectively, 27.37 mg ascorbic acid.g⁻¹ for custard apple²² and 14.26 mg ascorbic acid.100g⁻¹ for *sapoti*²⁴.

According to table 5, it can be observed that of the fruit pits analyzed, cupuaçu presented the highest content of unsaturated fatty acids, of which oleic acid was the main fatty acid found. This fatty acid belongs to the ω9 family and helps in the decrease of low-density lipoprotein in plasma and in the reduction of risk of cardiovascular diseases; followed by linoleic acid, which is not synthesized by the human organism and must be obtained from diet. Deficiency can result in squamous skin lesions, growth retardation and thrombocytopenia²⁵.

The *cupuaçu* pit also presented a high relative percentage of gadoleic acid (11.50%). In relation to saturated fatty acids, *cupuaçu* pit oil presented only 9.38%. The oil of the *pequi* pit also stood out in relation to unsaturated fatty acids, of which oleic acid presented 52.76% and linoleic acid 8.52%.

DISCUSSION

Moisture is one of the most important factors affecting food, as it has a direct effect on maintaining quality. Moisture is the total amount of water contained in a food, i.e. water that is closely bound to the constituent molecules of the product, cannot be removed or used for any kind of reaction (water combined), and free water, which is available for physical (evaporation), chemical (darkening) and microbiological reactions, becoming the main cause of its deterioration. High moisture content contributes to a lower conservation

Figure: 1.

Table 4. Antioxidant activity determined by different methods (mmol Trolox.g⁻¹).

Fruit	ABTS	FRAP
Pequi	3.72 ± 0.51	1.75 ± 0.07
Caja-manga	13.1 ± 1.05	10.5 ± 2.88
Assai	18.0 ± 1.33	12.8 ± 3.98
Pupunha	3.68 ± 0.67	11.9 ± 4.63
Cupuaçu	7.67 ± 0.75	1.72 ± 0.27
Java plum	34.9 ± 8.11	30.7 ± 6.14
Butiá	25.4 ± 3.76	22.3 ± 4.02
Persimmon	3.12 ± 0.40	2.02 ± 1.14
Guava	51.2 ± 3.71	36.1 ± 9.55
Bush banana	11.4 ± 2.13	20.9 ± 3.79
Jatoba	5.80 ± 0.03	4.00 ± 1.58
Custard apple	24.8 ± 1.27	13.1 ± 2.02
Dragon fruit	5.80 ± 0.67	7.95 ± 0.05
Passion fruit	5.35 ± 0.54	11.3 ± 3.47
Genipap	31.4 ± 1.20	3.22 ± 1.95
Cajarana	14.5 ± 0.82	17.3 ± 3.08
Biri Biri	24.4 ± 1.74	27.0 ± 9.21
West Indian gherkin	12.7 ± 1.27	-
Sapoti	1.92 ± 0.22	-
Yellom mombim	12.6 ± 1.85	37.5 ± 1.48
Star fruit	18.1 ± 0.51	4.61 ± 0.70
Seville organe	29.5 ± 3.17	16.9 ± 4.12
Peach	16.0 ± 1.83	4.41 ± 0.40
African horned cucumber	4.53 ± 1.04	7.76 ± 2.10

of the product, reducing shelf life, since it increases the available water for the development of microorganisms and for chemical reactions.

The total soluble solids content is used as an indirect measure of the sugar content. Although other substances are also dissolved in the vacuolar sap, sugars are the most representative, accounting for 85% to 90% of total soluble solids. Soluble solids content is an important characteristic of products that are consumed fresh, as consumers prefer sweeter fruits²⁶.

pH values below 4.5 are desirable to prevent the proliferation of microorganisms. There was no direct relationship between high acidity and the lowest pH value in the fruits. The relationship between pH and the dissociation of organic acid molecules is directly proportional, i.e., the lower the pH value, the greater the number of dissociated acids. Therefore, the pH value tends to decrease as the acidity increases.

The results obtained in the present study were similar to those reported by Carbonaro et al.²⁷ who worked with different peaches cultivated in the region of São Paulo. They found significant differences in the ascorbic acid content between peaches cultivated in organic versus conventional systems. Brunini et al.²⁸ observed significant differences in vitamin C content in acerolas produced at different growing sites (243.48 to 818.17 mg.100g⁻¹). Denardin et al.³ found 9.35 mg.100g⁻¹ of ascorbic acid in butiá cultivated in Rio Grande do Sul, while in the present study the value obtained was 1.59 mg.100g⁻¹, demonstrating the influence of region of cultivation on vitamin C content. When evaluating fruits of the Amazon, Canuto et al.⁴ obtained lower values than those observed in this study for bacuri (0.20 mg.100g⁻¹) and yellow mombim (0.30 mg.100g⁻¹), and higher results for assai (10.10 mg.100g⁻¹) and cupuaçu (3.30 mg.100g⁻¹).

The fruits with the highest concentration of phenolic

Table 5. Composition (relative %) of fatty acids in fruit pits found in Brazilian fruits.

Fatty acids (%)	Butia	Pequi	Bacuri	Cupuaçu	Pupunha
C8	10.7	-	-	-	4.16
C10	11.9	0.04	0.15	-	2.46
C12	24.3	0.03	0.04	-	47.9
C13	2.28	-	-	-	0.22
C14	5.81	0.32	0.06	0.01	18.5
C16	7.20	35.8	50.0	7.20	5.93
C16:1	-	-	15.2	-	-
C17	0.02	0.18	-	0.18	0.01
C18	-	-	-	-	1.56
C18:1	26.5	52.8	29.3	53.4	13.6
C18:2	7.81	8.52	4.52	23.8	4.28
C20	0.14	0.72	0.31	1.15	0.08
C20:1	0.18	0.19	0.03	11.5	0.08
C20:3	0.02	0.04	0.02	1.77	-
C22	0.01	-	0.00	0.17	0.00
C23	1.54	0.20	0.36	0.45	0.54
C24	0.28	0.86	0.01	0.19	0.31
Others	1.29	0.34	0.03	0.18	0.42
Saturated (%)	64.3	38.2	50.9	9.38	81.7
Unsaturated(%)	35.7	61.9	49.1	90.6	18.3

C 8:0 – acid caprylic, C10:0 – acid capric, C12:0 – acid lauric, C13:0 – tridecanoic, C14:0 – miristic, C16:0 – acid palmitic; C16:1 – acid palmitoleic; C17:0 – acid margaric, C18:0 – acid estearic, C18:1 – acid oleic; C18:2 – acid linoleic, C20 – acid arachidic, C20:1 – acid gadoleic, C20:3 – acid di-homo- γ -linolenic, C22:0 – behenic acid, C23:0 – acid tricosanoic and C24:0 – acid lignoceric.

compounds were genipap (876.85 mg EAG.100g⁻¹) and *biri-biri* (757.82 mg EAG.100g⁻¹), both from Itapetinga, in the state of Bahia. The total flavonoid content (Table 3) in fruits ranged from 0.02 to 77.65 mg of quercetin per 100g⁻¹ of dry pulp (mg EQ.100g⁻¹). Among the analyzed fruits, java plum from the Rio Grande do Sul state presented the highest flavonoid content, with 77.65 mg EQ.100g⁻¹, likely due to the large amount of anthocyanins, a subgroup within the flavonoids present in this fruit. The assai fruit, obtained in Belem in the state of Para, presented 6.60 mg EQ.100g⁻¹, followed by *butia* from Pelotas in the Rio Grande do Sul state, with 1.56 mg EQ.100g⁻¹.

The samples that presented the lowest content of these compounds were from *jatoba* fruit (89.52 mg EAG.100g⁻¹) from Campo Grande, Mato Grosso do Sul state, *pequi* (109.53 mg EAG.100g⁻¹) from Goiania, in the Goias state and *sapoti* (123.70 mg EAG.100g⁻¹) obtained from Fortaleza, in the Ceara state.

According to Vasco et al.²⁹, the samples can be classified

according to the phenolic compound content in three different categories: low (100 mg EAG.100g⁻¹), medium (100-500 mg EAG.100g⁻¹) and high (> 500 mg EAG.100g⁻¹). In the present study, 72.2% of the fruits presented average phenolic compound content; this percentage comprises all samples from Fortaleza (West Indian gherkin, *sapoti*, yellow mombim and star fruit), from Belem, Para (*assai*, *pupunha* and *cupuaçu*), in addition to a sample from Itapetinga, Bahia (*cajarana*) and two from Pelotas, Rio Grande do Sul (*jambolão* and bush banana). The class with a high content of phenolic compounds corresponded to 22.2% of the samples was represented by two fruits obtained in Pelotas (*butia* and guava), and two from Itapetinga (*genipap* and *biri-biri*). Only *jatoba* presented a low content of phenolic compounds, in the sample from Campo Grande.

Silva et al.³⁰ found levels close to the present study for Brazilian tropical fruits. Faria et al.²⁰ reported a content of 91.2 mg of catechin per 100g⁻¹ for the java plum from the city of Pelotas, which is very close that reported in the

present study. Paz et al.³¹ reported higher levels than the present study for assai pulp from Fortaleza. Flavonoids are present in the plants as color-conferring pigments, which corroborates the results obtained for the *jambolão* and assai pulps, which present intense purple-colored pulp.

Hoffmann et al.³² analyzed *butia* from the town of Capão do Leão (Rio Grande do Sul) and reported higher levels than that obtained in the present study, of 682 mg of catechin per 100g⁻¹. Silva et al.²⁶ reported average contents close to the present study in pulp (15.06 - 102.45 mg 100 g⁻¹ on dry basis) and by-products (27.47 - 207.87 mg 100g⁻¹ on dry basis) of Brazilian tropical fruits. According to Morales-Soto et al.³³, differences in flavonoid content can be attributed to the extraction procedure of the compounds, differences in agronomic factors (agricultural practices, soil composition), as well as climatic and physiological conditions (phase of maturity). Fruits with a low percentage of flavonoids, such as *pequi*, *caja-manga*, persimmon, guava, banana, *jatoba*, *genipap*, *cajarana*, *biri-biri*, West Indian gherkin, star fruit, *pupunha* and *cupuaçu* probably present a higher percentage of phenolic acids.

Rocha et al.³⁴ investigated the carotenoid content in fruit of the Piauí Cerrado, among them the *jatoba*. Low values of these components were found, 0.0996 µg.g⁻¹ of lycopene and 1.1068 µg.g⁻¹ of β-carotene. Variation in the carotene composition of fruits has been widely reported in the literature, as a result of the effects of several factors such as genetics, soil type, climate conditions and exposure to sun light¹⁴.

Both zeaxanthin and lutein are xanthophylls resulting from the hydroxylation process of α-carotene and β-carotene, respectively, which have provitamin A activity; these are important micronutrients for health. During fruit maturation, the conversion of lutein and zeaxanthin causes a decrease in the levels of α-carotene and β-carotene³⁵, which was observed for yellow *mombim*, *butia*, assai and *pupunha*.

Other health-promoting effects have been attributed to carotenoids in their action as antioxidants, protecting the body against chronic diseases and certain cancers, macular degeneration, cataracts, neurological disorders, gastric antiulcer activity and a strengthening of the immune system³⁶.

According to the simple correlation analysis between variables, phenolic compound content had a strong influence on the antioxidant potential determined by ABTS, presenting a correlation coefficient of 0.7403, and no correlation was observed among the other compounds analyzed. Almeida et al.²¹, when evaluating fruits from the Brazilian Northeast, among them sapoti, observed that the polyphenol content and the antioxidant activity by the ABTS method showed a correlation of 0.94, reinforcing the results obtained in the present study. Barreto et al.³⁷ evaluated 18 tropical fruits and also observed a high correlation between the phenolic compound content and antioxidant activity (r = 0.998). Between the antioxidant activity by FRAP and the bioactive compounds, no significant correlation was

observed between any compound. This is probably due to the bioactive composition of the fruits and the method of determining antioxidant activity³⁸.

The oils from *butia*, *bacuri* and *pupunha*, in turn, showed higher levels of saturated fatty acids in comparison with unsaturated fatty acids, and the pits of *bacuri* and *pequi* presented a prominence for palmitic acid. According to some studies, the consumption of high amounts of palmitic acid in the diet increases the concentration of plasma cholesterol in the blood, while other studies indicate that this acid has antioxidant properties, preventing atherosclerosis in rats²⁵.

Palmitic acid is used in the food industry for the production of margarines and cosmetics, in the manufacturing of creams and soaps and candles, for fabric waterproofing, in paraffin, and also in the form of liquid crystal used in the electronics industry. Kim et al.³⁹ studied fatty acids present in oil seeds for the application of absorption of medicinal products via cutaneous and concluded that palmitic acid was the most effective.

Palm oil (*Elaeis guineensis*) is one of the main sources of palmitic acid, reaching a content of about 40%, which was lower than that found in the *bacuri* pit (50%) and close to that found in *pequi*, *Butia* and *pupunha* pits, on the other hand, had a high percentage of short chain fatty acids, 62 and 79%, respectively. Among these fatty acids, lauric acid was the majority, presenting 24% in *butia* and 48% in *pupunha*.

CONCLUSIONS

From the results obtained in this study it was possible to observe that the different regions and fruits studied presented very distinct characteristics. The *cupuaçu* pit was rich in unsaturated fatty acids, while the *genipap* and java plum presented high flavonoid content and the *butia* had a high concentration of carotenoids. Guava was the fruit with the highest antioxidant activity through the ABTS radical, while the yellow *mombim* presented the best response when the activity was determined by FRAP. The production and valorization of native fruits is of great importance, since it can boost the availability of fresh fruits with high nutritional value, contributing to food security and the strengthening of the economy of small-scale farming communities, due to the best use of the existing natural resources.

Acknowledgements. The authors would like to thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for a scholarship.

REFERENCES

1. Malta L. Tessaro E. Eberlin M. Pastore G. Liu R. Assessment of antioxidant and antiproliferative activities and the identification of phenolic compounds of exotic Brazilian fruits. *Food Res Int* 2013; 53: 417-425.
2. Ayala-Zavala J. Yega-Yega V. Rosas-Dominguez C. Palafox-Carlos H. Villa- Rodriguez J. Siddiqui M. Agro-industrial potential of exotic fruit byproducts as a source of food additives. *Food*

- Res Int 2011; 44: 1866-1874.
3. Denardin C. Hirsch G. Rocha R. Vizzotto M. Henriques A. Moreira J. Guma F. Emanuelli T. Antioxidant capacity and bioactive compounds of four Brazilian native fruits. *J Food Drug Anal* 2015; 23: 387-398.
 4. Canuto G. Xavier A. Neves L. Benassi M. Physical and chemical characterization of fruit pulps from Amazonia and their correlation to free radical scavenger activity. *Rev Bras Frutic* 2010; 32: 1196-1205.
 5. Tarrago-Trani M. Phillips K. Cotty M. Matrix-specific method validation for quantitative analysis of vitamin C in diverse foods. *J Food Compos Anal* 2012; 26: 12-25.
 6. Padayatty S. Katz A. Wang Y. Eck P. Kwon O. Lee S. Corpe C. Dutta A. Dutta S. Levine M. Vitamin C as an antioxidant: evaluation of its role in disease prevention. *J Am Coll Nutr* 2003; 22: 18-35.
 7. Koolen H. Da Silva F. Gozzo F. De Souza A. Souza A. Antioxidant, antimicrobial activities and characterization of phenolic compounds from buriti (*Mauritia flexuosa* L.). *Food Res Int* 2013; 51: 467-473.
 8. Plaza M. Pozzo T. Liu J. Ara K. Turner C. Karlsson E. Substituent effects on in vitro antioxidant properties, stability, and solubility in flavonoids. *J Agric Food Chem* 2014; 62: 3321-3333.
 9. Quiros A. Costa H. Analysis of carotenoids in vegetable and plasma samples: A review. *J Food Comp Anal* 2006; 19: 97-111.
 10. Jomova K. Valko M. Health protective effects of carotenoids and their interactions with other biological antioxidants. *Eur J Med Chem* 2013; 70: 102-110.
 11. González A. Martínez M. Paredes A. León A. Ribotta P. Study of the preparation process and variation of wall components in chia (*Salvia hispanica* L.) oil microencapsulation. *Powder Technol* 2016; 301: 868-875.
 12. Association of Official Agricultural Chemists. Official Methods of Analysis of the AOAC. 12 th ed. Washington, D.C., The Association, 1995.
 13. Singleton V. Rossi J. Colorimetry of total phenolics with phosphomolybdic phosphotungstic acid reagents. *Am J Enol Viticult* 1965; 16: 144-158.
 14. Rodríguez-Amaya D. Changes in carotenoids during processing and storage of foods. *Arch Latinoam Nutr* 1999; 49: 385-475.
 15. Silva E. Muniz M. Nunomura R. Nunomura S. Zilse G. Phenolic constituents and antioxidant activity of the geopropolis of two species of bees without Amazonian sting. *Quím Nova* 2013; 36: 1-6.
 16. Gülçin I. Polyphenol contents and antioxidant activity of lyophilized aqueous extract of propolis from Erzurum, Turkey. *Food Chem Toxicol* 2010; 48: 2227-2238.
 17. Hartman L. Lago B. A rapid preparation of fatty methyl esters from lipids. *Laboratory Practice* 1973; 22: 475-476.
 18. Souza V. Pereira P. Queiroz F. Borges S. Carneiro J. Determination of bioactive compounds, antioxidant activity and chemical composition of Cerrado Brazilian fruits. *Food Chem* 2002; 134: 381-386.
 19. Akbari V. Jamei R. Heidari R. Esfahlan A. Antiradical activity of different parts of Walnut (*Juglans regia* L.) fruit as a function of genotype. *Food Chem* 2012; 135: 2404-2410.
 20. Faria J. Siqueira E. Vieira R. Agostini-Costa T. Fruits of *Butia capitata* (Mart.) Becc as good sources of β -carotene and provitamina. *Rev Bras Frut* 2011; 33: 612-617.
 21. Almeida M. de Sousa P. Arriaga Â. do Prado G. de Carvalho C. Maia G. de Lemos T. Bioactive compounds and antioxidant activity of fresh exotic fruits from northeastern. *Brazil Food Res Inter* 2011; 44: 2155-2159.
 22. Cruz P. Pereira T. Guindani C. Oliveira D. Rossi M. Ferreira S. Antioxidant and antibacterial potential of butia (*Butia catarinensis*) seed extracts obtained by supercritical fluid extraction. *J Super Fluids* 2017; 119: 229-237.
 23. Kuskoski E. Asuero A. Morales M. Fett R. Frutos tropicais silvestres e polpas de frutas congeladas: atividade antioxidante, polifenóis e antocianinas. *Ciênc Rural* 2006; 36: 1283-1287.
 24. Silva K. Sirasa M. Antioxidant properties of selected fruit cultivars grown in Sri Lanka. *Food Chem* 2016; 238: 203-208.
 25. Cho K. Hong J. Lee K. Monoacylglycerol (MAG)-oleic acid has stronger antioxidant, anti-atherosclerotic, and protein glycation inhibitory activities than MAG-palmitic acid. *J Med Food* 2010; 13: 99-107.
 26. Silva P. As W. Marigule K. Barbosa A. Oliveira O. Distribution of the total soluble solids content in fruits of some temperate species. *Rev Caat* 2002; 15: 19.
 27. Carbonaro M. Mattera M. Nicoli S. Bergamo P. Cappelloni M. Modulation of antioxidant compounds in organic vs conventional fruit (Peach, *Prunus persica* L., and Pear, *Pyrus communis* L.). *J Agric Food Chem* 2002; 50: 5458-5462.
 28. Brunini M. Macedo N. Coelho C. Siqueira G. Physico chemical characteristics of West Indian cherry provenients of different regions of cultivation. *Rev Bras Frutic* 2004; 26: 486-489.
 29. Vasco C. Ruales J. Kamal-Eldin A. Total phenolic compounds and antioxidant capacities of major fruits from Ecuador. *Food Chem* 2008; 111: 816-823.
 30. Silva L. Da Figueiredo E. De Ricardo N. Vieira I. Figueiredo R. De Brasil I. Gomes C. Quantification of bioactive compounds in pulps and by-products of tropical fruits from Brazil. *Food Chem* 2014; 143: 398-404.
 31. Paz M. Gúllon P. Barroso M. Carvalho A. Domingues V. Gomes A. Becker H. Longhinotti E. Delerue-Matos C. Brazilian fruit pulps as functional foods and additives: Evaluation of bioactive compounds. *Food Chem* 2015; 172: 462-468.
 32. Hoffmann J. Zandoná G. Santos P. Dos Dallmann C. Madruga F. Rombaldi C. Chaves F. Stability of bioactive compounds in butiá (*Butia odorata*) fruit pulp and nectar. *Food Chem* 2017; 237: 638-644.
 33. Morales-Soto A. García-Salas P. Rodríguez-Pérez C. Jiménez-Sánchez C. Cádizgurea M. Segura-Carretero A. Antioxidant capacity of cultivars of fruits and vegetables grown in Andalusia (Spain). *Food Res Inter* 2014; 58: 35-46.
 34. Rocha M. Figueiredo R. Araújo M. Moreira-Araújo R. Physical and chemical characterization and antioxidant activity (in vitro) of fruit of the Piauí savanna. *Rev Bras Frutic* 2013; 35: 933-941.
 35. Marinova D. Ribarova F. HPLC determination of carotenoids in Bulgarian berries. *J Food Comp Anal* 2007; 20: 370-374.
 36. Zanatta C. Mercadante A. Carotenoid composition from the Brazilian tropical fruit camu-camu (*Myrciaria dubia*). *Food Chem* 2007; 101: 1526-1532.
 37. Barreto G. Benassi M. Mercadante A. Bioactive compounds from several tropical fruits and correlation by multivariate analysis to free radical scavenger activity. *J Braz Chem Soc* 2009; 20: 1856-1861.
 38. Whelen J. Fritsche K. Linoleic Acid. *Advances in Nutrition. Amer Soc Nut.* 2013; 4: 311-312.
 39. Kim M. Doh H. Choi M. Chung S. Shim C. Kim D. Kim J. Yong C. Choi H. Skin permeation enhancement of diclofenac by fatty acids. *Drug Del* 2008; 6: 373-379.