





**Celebrating the
International Year of
Fruits and Vegetables**

Editor

Maximiliano Dini 
*Instituto Nacional de Investigación
Agropecuaria (INIA), Programa
Nacional de Investigación en
Producción Frutícola, Estación
Experimental INIA Las Brujas,
Canelones, Uruguay.*

Guillermo A. Galván 
*Universidad de la República,
Facultad de Agronomía,
Departamento de Producción
Vegetal, Canelones, Uruguay.*

Correspondence

Fernanda Zaccari
fzaccari@fagro.edu.uy

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Butia

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Butiá

propiedades físicas, nutricionales y antioxidantes de frutos rojos, anaranjados y amarillos

Butiá

propiedades físicas, nutricionais e antioxidantes dos frutos vermelhos, laranjas e amarelos

Zaccari, F. ¹; Del Puerto, M. ²; Cabrera, M. C. ²

¹*Universidad de la República, Facultad de Agronomía, Departamento de Producción Vegetal, Montevideo, Uruguay*

²*Universidad de la República, Facultad de Agronomía, Departamento de Producción Animal y Pasturas, Montevideo, Uruguay*



Abstract

The fruit of the butia palm [*Butia odorata* (Barb. Rodr.) Noblick] has cultural and economic value for the inhabitants of the protected landscape area in Los Palmares de Rocha, Uruguay. Determining the physicochemical and nutritional quality of the fruits can contribute to enhance them by preserving these biosystems. This study aimed to characterize fruits with red, orange and yellow epicarp physically and chemically. Color, dry matter, ash, crude protein, dietary fiber, carotenoids, vitamin C, total polyphenols (TP), and total antioxidant capacity were measured in peel and pulp of the three types of fruit. All data were reported for 100 g of fresh weight. Furthermore, the pH, the titratable acidity and the total soluble solids were determined in the pulp juice. The three types of butia had a higher content of β -carotene (≈ 1.28 mg), lutein (≈ 68.2 μ g) and TP (≈ 647.7 mg gallic acid equivalent) in peel than in pulp. In addition, the content of vitamin C (≈ 48.7 mg) and dietary fiber (≈ 7.1 g) was similar in the peel and in the pulp for the three colors of butia. Intake of 100 g of butia fruits in natura would provide up to 14% of the dietary fiber, 8% β -carotenes and 57% of the vitamin C required daily by an adult.

Keywords: *Butia odorata*, carotenes, xanthophyll, vitamin C, polyphenols, dietary fiber

Resumen

El fruto de la palma de butiá [*Butia odorata* (Barb. Rodr.) Noblick] tiene valor cultural y económico para los habitantes del área de paisaje protegido en los Palmares de Rocha, Uruguay. Determinar la calidad físico-química y nutricional de los frutos puede ser un aporte para valorizarlos preservando estos biosistemas. El objetivo de este trabajo fue caracterizar física y químicamente frutos con epicarpio de color rojo, anaranjado y amarillo. El color y el contenido de materia seca, ceniza, proteína cruda, fibra dietética, carotenoides, vitamina C, polifenoles totales (PT), y la capacidad antioxidante total fueron medidos en la cáscara y la pulpa de los tres tipos de frutos. Todos los datos fueron reportados cada 100 g de peso fresco. Además, en el jugo de la pulpa se determinó el pH, la acidez titulable y los sólidos solubles totales. Los tres tipos de butiá presentaron mayor contenido de β -caroteno ($\approx 1,28$ mg), luteína ($\approx 68,2$ μ g) y PT ($\approx 647,7$ mg ácido gálico equivalente) en la cáscara que en pulpa. Además, el contenido de vitamina C ($\approx 48,7$ mg) y fibra dietética ($\approx 7,1$ g) fue similar en la cáscara y en la pulpa para los tres colores de butiá. El consumo de 100 g de frutos de butiá in natura aportaría hasta un 14% de la fibra dietética, 8% β -carotenos y 57% de la vitamina C requeridos diariamente por un adulto.

Palabras clave: *Butia odorata*, carotenos, xantofilas, vitamina C, polifenoles, fibra dietética

Resumo

O fruto da palmeira butiá [*Butia odorata* (Barb. Rodr.) Noblick] tem valor cultural e econômico para os habitantes da área de paisagem protegida dos Palmares de Rocha, Uruguai. Determinar a qualidade físico-química e nutricional dos frutos pode ser uma contribuição para aprimorá-los, preservando esses biosistemas. O objetivo deste trabalho foi caracterizar física e químicamente frutos com epicarpo vermelho, laranja e amarelo. A cor e conteúdo de matéria seca, cinzas, proteína bruta, fibra alimentar, carotenoides, vitamina C, polifenóis totais (PT), e capacidade antioxidante total foram medidos na casca e polpa dos três tipos de fruta. Todos os dados foram reportados cada 100 g de peso fresco. Ademais, no suco da polpa foram determinados o pH, a acidez titulável e os sólidos solúveis totais. Os três tipos de butiá tinham um conteúdo mais alto de β -caroteno ($\approx 1,28$ mg), luteína ($\approx 68,2$ μ g) e PT ($\approx 647,7$ mg ácido gálico equivalente) na casca do que na polpa. Além disso, o teor de vitamina C ($\approx 48,7$ mg) e fibra alimentar ($\approx 7,1$ g) foi semelhante na casca e na polpa para as três cores



de butiá. O consumo de 100 g de frutas de butiá in natura fornecerá até 14% da fibra alimentar, 8% de β -carotenos e 57% da vitamina C necessária diariamente a um adulto.

Palavras-chave: *Butia odorata*, carotenos, xantofilas, vitamina C, polifenóis, fibra alimentar

1. Introduction

The butia is the fruit of palms of the genus *Butia* Becc. of which there are at least 20 reported species, among them *Butia odorata* (Barb. Rodr.) Noblick⁽¹⁾. These palms are part of a very particular ecosystem distributed in the area near the Río de la Plata in southeastern Uruguay, Argentina and up to northwestern Brazil⁽²⁾⁽³⁾⁽⁴⁾. The fruit has cultural, scenic and economic value, and is traditionally used for consumption and other uses by the inhabitants of the protected area of Los Palmares de Rocha, Uruguay⁽³⁾⁽⁵⁾⁽⁶⁾⁽⁷⁾⁽⁸⁾⁽⁹⁾. These palm groves make up biosystems declared national heritage and are part of the Bañados del Este World Biosphere Reserve⁽⁵⁾⁽⁶⁾⁽⁷⁾.

The fruits are eaten whole *in natura* and used in different preparations, such as jellies, sweets, liqueurs, ice creams, sweet and sour sauces, and chocolates⁽⁸⁾⁽⁹⁾⁽¹⁰⁾⁽¹¹⁾⁽¹²⁾. Most of these products include only the pulp⁽⁸⁾⁽¹⁰⁾⁽¹¹⁾, leaving the peel as a possible by-product, whose use is not yet defined. On the other hand, the palms from which the fruits are obtained are more than 100 years old and are located in livestock and agricultural production systems (rice) in which their natural replacement is very difficult⁽³⁾⁽⁴⁾⁽⁵⁾⁽⁷⁾⁽¹³⁾⁽¹⁴⁾⁽¹⁵⁾. One of the ways to preserve the palms and the biodiversity of these ecosystems is to find rational exploitation systems that include procedures for collecting and using the fruits⁽⁴⁾⁽¹⁶⁾. In the palm grove, some plants produce fruits with different epicarp colors from yellow to bright red⁽⁴⁾⁽⁵⁾.

Color is one of the first attributes that define fruit quality for the consumer. Pigments such as carotenoids, chlorophyll and phenolic compounds give color to fruits, providing nutrients and bioactive compounds with potential beneficial effects on human health⁽¹⁷⁾⁽¹⁸⁾⁽¹⁹⁾⁽²⁰⁾⁽²¹⁾⁽²²⁾⁽²³⁾. On the other hand, most of the studies in butia fruits do not differentiate the composition of the peel and the pulp. Consequently,

it is of interest to know and consider the chemical, nutritional and bioactive properties that these native fruits have, which can value their use and differentiate by-products such as the peel.

The study aimed to characterize chemically and physically the peel and pulp of fruits of *Butia odorata* (Barb. Rodr.) Noblick with three epicarp colors (red, orange and yellow), by color, total titratable acidity, pH, total soluble solids, dry matter, ash, crude protein, dietary fiber, carotenoids and xanthophylls, vitamin C, total polyphenols, and total antioxidant capacity.

2. Material and methods

2.1 Plant material

The fruits were obtained in "Vuelta del Palmar" (Castillos, Rocha) in southeastern Uruguay, belonging to the Bañados del Este World Biosphere Reserve, 32° and 35° S latitude and 53° and 55° W longitude⁽⁴⁾⁽⁵⁾⁽¹⁴⁾. Palms with yellow, orange and red epicarp butia fruits were selected (Figure 1).

Figure 1. Whole fruits (top) and pulp (bottom) of butia with yellow, orange and red epicarp





The three types of fruit colors were harvested in a mature state, washed and disinfected in an immersion bath in water with NaOCl [100 ppm] stirred for 5 min. Three kg of fruits of each color without visible damage, rotting and/or alterations, were selected and rinsed. Within each color, three replications were randomly obtained (≈ 1 kg/replication). In each repetition, 20 fruits were weighed and peeled manually with a scalpel, separating the peel (epicarp) from the pulp (mesocarp). The peel and pulp were weighed to calculate their relative proportion to the total weight of the fruit. The color of the peel and the pulp was determined in 20 other fruits, and the pulp juice was extracted using a domestic juicer (Philips, Hr1854) to measure the content of total soluble solids, pH and titratable acidity. The remaining fruits of each repetition were preserved whole in a freezer (-20°C) to reduce the alteration of the chemical compounds of the peel and pulp that were subsequently analyzed.

2.2 Color

Peel and pulp color was measured instrumentally by the CIELAB system using a colorimeter (Minolta CR-10, Japan) at two opposite points on the equatorial zone of 20 fruits. The variables L^* (Lightness, 0 = black to 100 = white), a^* ($-a$ = green, a = red) and b^* ($-b$ = blue, b = yellow) were determined, and the color saturation (Chroma) and hue ($^{\circ}\text{hue}$) were calculated with the following equations⁽²⁴⁾:

$$\text{Chroma} = \sqrt{a^{*2} + b^{*2}}$$
$$\text{Hue } (^{\circ}\text{hue}) = \text{arc tan } (b^*/a^*)$$

In addition, a color index (CI) was calculated with the formula⁽²⁵⁾:

$$CI = a^* 1000 b^{*-1} L^{-1}$$

2.3 Soluble solids, pH, titratable acidity

The content of total soluble solids (TSS) was measured in the pulp juice with a digital refractometer (ATAGO Poquet PAL-10, Japan) expressing the data in $^{\circ}\text{Brix}$ ⁽²⁶⁾. The pH⁽²⁷⁾ and the total titratable acidity (TTA) were measured in the same pulp juice

by potentiometry in a 10 mL juice sample, with NaOH solution [0.1 N] and endpoint in pH 8.1⁽²⁸⁾. The results were expressed as a percentage of citric acid. In addition, the ratio between TSS and TTA was calculated as a measure of maturity index using the formula⁽²⁹⁾.

$$\text{ratio} = \text{TSS}/\text{TTA}$$

2.4 Dry matter, ash, protein and dietary fiber

The dry matter and ash content was determined from a 10 g fresh sample and dried in an oven (Blue.M, USA) with zenith ventilation at 105°C until constant weight. To determine the ash content, 15 g of fresh sample was incinerated in a muffle (Barnstead/ThermoLyne, 4800 Thermo Scientific, USA) at 550°C for 24 h. Data were expressed as a percentage of dry matter and ash. The content of dietary fiber and crude protein was quantified in the peel and pulp with the enzymatic-gravimetric method⁽³⁰⁾ and as total N * 6.25 by the Kjeldhal method⁽³¹⁾, respectively. Data were expressed as a percentage of dietary fiber and protein in fresh base.

2.5 Carotenoids

The extraction and quantification of carotenoids were carried out according to Zaccari and others⁽³²⁾ from 1 g of pulp and 0.5 g of peel in a tetrahydrofuran and methanol extraction solution (1:1 v/v; Mallinckrodt Baker, USA). The amount of α and β -carotene and xanthophylls (lutein, zeaxanthin and β -cryptoxanthin) was quantified by high-performance liquid chromatography (HPLC) (Spectral Series P100, Thermo Separations Products, USA), with a column C30 YMC TMCarotenoid S-5; $4.6 \mu\text{m} \times 250 \text{mm}$ (Waters, USA), and a UV/Visible detector (UV-2000 SpectralSystem®, USA) set at a wavelength of 450 nm. The standards for the calibration curves were *trans* β -carotene type I (95%), a mixture of carrot carotene isomers (β : α 2:1, $\geq 95\%$); and xanthophylls of *Tagetes* spp. (α -carotene-3,3'-diol, β , ϵ -carotene-3, 3'-diol, β , ϵ -carotene, lutein, $>75\%$), all Sigma Aldrich. The xanthophylls zeaxanthin (RT 5.02 min) and β -cryptoxanthin (RT 7.40 min) were identified by their retention time (RT) with regard to *trans*- β -carotene, according to Rodriguez-



Amaya⁽²²⁾ and Maurer and others⁽³³⁾. Results were expressed in milligrams (mg) of carotenes and micrograms (μg) of xantophylls every 100 g of fresh weight.

2.6 Vitamin C

Vitamin C content was quantified according to Schaffert and Kingsley⁽³⁴⁾ in UV-Visible spectrophotometer (Genesys10 VIS; Thermoelectro Corporation) at 521 nm wavelength, with some alterations. Briefly, the extraction was performed with oxalic acid (0.1% v:v) in 1 g of peel and 2 g of pulp quantifying the reaction of 2-4 dinitrophenylhydrazine (20 g DNPH L⁻¹) acidified with H₂SO₄ (85%). The calibration curve was prepared with L-ascorbic acid (99.9%, Baker). The results were expressed in mg of ascorbic acid (AA) in 100 g of fresh weight of peel or pulp.

2.7 Total polyphenols

The total polyphenols were determined in the peel and pulp in a methanolic extraction using the Folin-Ciocalteu microscale protocol⁽³⁵⁾ and at a wavelength of 765 nm in UV-Visible spectrophotometer (Genesys10 VIS; Thermoelectro Corporation). Data were expressed in milligrams of gallic acid equivalent in 100 g of fresh sample (mg GAE 100 g⁻¹).

2.8 Total antioxidant capacity

The total antioxidant capacity was determined in the same extracts and with the spectrophotometer used to quantify the total polyphenol content. The total antioxidant capacity was determined as inhibition of the 1,1 diphenyl-2-picrylhydrazil radical (DPPH, Sigma Aldrich), by measuring the absorbance at wavelength 517 nm, based on the method described by Brand-Williams and others⁽³⁶⁾. The determinations were performed in triplicate and expressed as a percentage of inhibition calculated with the following equation:

$$DPPH \text{ inhibition}(\%) = \frac{Absf - Absi}{Absi} * 100$$

where: *Absf* is the absorbance of DPPH radical and *Absi* is the final absorbance of the sample.

2.9 Statistical analysis

The data obtained from the evaluated variables were analyzed using a one-way ANAVA with 95% confidence. The means were separated by Tukey's test ($p \leq 0.05$) when applicable. Peel and pulp content was compared for the same color of fruit using Student's test ($p \leq 0.05$). In addition, the Pearson linear correlation (r , $p \leq 0.05$) was analyzed for peel and pulp, between the hue, the color index, the content of total polyphenols and the total antioxidant capacity, with the content of carotenoids and vitamin C.

3. Results and discussion

The fruits studied had an average weight of 9.3 g fruit⁻¹, where the peel (epicarp) contributed 12.4% of the total weight, the pulp (mesocarp) 61.3%, and the core (endocarp and seeds) 26.3%. No statistical differences were found in the weight of the fruit, the peel, the pulp and the core of the three studied types of butia (data not shown). These results were similar to those reported in *Butia capitata* fruits for the epicarp and mesocarp (72.5%) and the endocarp and seeds (27.8%)⁽⁴⁾⁽¹¹⁾⁽¹⁵⁾⁽³⁷⁾⁽³⁸⁾. Other authors⁽¹¹⁾ determined that the epicarp constituted 64.5%, the mesocarp 10.8% and the endocarp with seeds 24.7% of the total weight of yellow and orange fruits. Fruit weight from 6.52 to 16.59 g was obtained in 11 butia genotypes with potential for genetic improvement, with 14.3 to 24.2% endocarp⁽¹⁵⁾. The fruit size is highly correlated with the weight of the pulp ($r=0.93$ to 0.98), which is useful to define the use of the fruits and to estimate the efficiency of industrialization processes⁽⁴⁾⁽¹⁵⁾.

3.1 Color

Table 1 shows the results obtained in the peel and pulp color. The peel of the butia fruits presented shades of orange-yellow color (55 to 76°hue). The peel of the red fruits presented a dark orange value of instrumental color tonality and was less saturated than the orange and yellow fruits. On the other hand, the color tone of the pulp of the three types of fruits was less orange (76 to 84 °hue) than the peel (Table 1). The color tones of the peel and/or pulp presented in Table 1 were similar to those reported by various authors in fruits of *B. odorata*, *B. capitata*



and *B. yatai* harvested in the Pampa biome⁽³⁹⁾⁽⁴⁰⁾⁽⁴¹⁾⁽⁴²⁾. These authors obtained peel and/or pulp colors with reddish-orange (46.49 - 68.4 ° hue) and yellow (75.7 - 88.0 ° hue) tones but with higher average lightness (L^* 68.3 - 73.4)⁽³⁹⁾⁽⁴⁰⁾⁽⁴¹⁾⁽⁴²⁾. Color variation in butia fruits, apart from being determined by the species (*Butia* Becc.), could be affected by the local edaphoclimatic conditions in which the palms develop⁽⁴²⁾. In this regard, Ferrão

and others⁽⁴²⁾ observed that the color tone of the butia pulp in *B. odorata* was different according to the harvest region in Brazil, with light yellow pulp in the Santa Rosa region and dark orange in Santa Maria⁽⁴²⁾. The color index (CI) allowed categorizing the fruits by the peel color in yellow with CI values \approx 5; orange with CI \approx 7 and red with CI values \geq 14 (Table 1).

Table 1. Lightness (L), hue (°hue) and saturation (Chroma) and color index (CI) of the peel and pulp of butia fruits

Fruit	Peel				Pulp			
	L*	°hue	Chroma	CI	L*	°hue	Chroma	CI
Yellow	44,6±0,34 ^{aB}	76,2±0,35 ^{aB}	45,8±0,59 ^{aA}	5,5±0,16 ^{cA}	48,2±0,39 ^{aA}	84,4±0,32 ^{aA}	46,5±0,55 ^{bA}	2,0±0,11 ^{cB}
Orange	42,0±0,42 ^{bB}	69,7±0,44 ^{bB}	45,6±0,67 ^{aB}	8,9±0,26 ^{bA}	46,3±0,49 ^{bA}	78,5±0,29 ^{bA}	50,5±0,73 ^{aA}	4,5±0,13 ^{bB}
Red	36,9±0,34 ^{cB}	55,5±0,60 ^{cB}	41,2±0,47 ^{bB}	18,9±0,52 ^{aA}	44,4±0,38 ^{cA}	76,2±0,77 ^{cA}	46,9±0,81 ^{bA}	5,6±0,36 ^{aB}

Mean \pm SE (n = 40). In the same column, different lowercase letters indicate statistical differences between different colored fruits (Tukey $p \leq 0.05$). For each color variable, different capital letters in the row indicate statistical differences between the peel and the pulp (Student's test, $p \leq 0.05$).

Table 2. Content of total soluble solids (TSS), pH, total titratable acidity (TTA) and ratio in pulp juice of butia fruits

Fruit	TSS (°Brix)	pH	TTA (% citric acid)	Ratio (TSS/TTA)
Yellow	12,92 \pm 0,12 ^a	3,50 \pm 0,24 ^a	1,99 \pm 0,01 ^a	6,49 \pm 0,01 ^b
Orange	12,97 \pm 0,14 ^a	2,99 \pm 0,01 ^a	1,79 \pm 0,01 ^b	7,25 \pm 0,12 ^a
Red	11,48 \pm 0,12 ^b	3,53 \pm 0,08 ^a	1,69 \pm 0,02 ^c	6,79 \pm 0,18 ^{ab}

Mean \pm SE (n = 3). Different lowercase letters in the same column indicate statistical differences (Tukey $p \leq 0.05$).

Jiménez and others⁽²⁵⁾ used this index (CI) as an objective measure to define citrus ripeness stages with peel color. The CI values were statistically different in the peel and the pulp, observing a greater range in the peel (5.5 to 18.9) than in the pulp (2.0 to 5.6). On the other hand, the pulp in the yellow fruits presented the lowest CI (2.0), with a higher and brighter yellow hue than their peel (5.5) (Table 3). The color tone and CI results could indicate a higher content of carotenoid and/or flavonoid pigments in the peel than in the pulp⁽²²⁾⁽⁴³⁾, in agreement with the data presented below (Figure 2, Table 3).

3.2 Soluble solids, pH, titratable acidity and Color index

The TSS content and the pH of the pulp juice were similar between the three types of fruits (Table 2). They were also similar to the values reported by other authors, with TSS content of 9.33 to 15.5 °Brix and pH of 2.93 to 3.95⁽¹¹⁾⁽¹⁵⁾⁽³⁷⁾⁽³⁹⁾⁽⁴²⁾⁽⁴⁴⁾⁽⁴⁵⁾. The titratable acidity expressed as a percentage of citric acid was lower in the pulp of red fruits, followed by orange and yellow fruits (Table 2). These results determined the ratio values calculated as TSS/TTA (Table 2), and together with the polyphenols in ripe



fruit, it could be an organoleptic indicator associated with the particular bittersweet flavor of the fruit⁽¹⁴⁾⁽¹⁵⁾⁽²⁹⁾⁽⁴⁶⁾. The TSS in the juice of the vast majority of fruits are made up of sugars (80 to 90%), followed by organic acids and in a very low proportion: phenols, amino acids, proteins, fructans, minerals and water-soluble vitamins⁽²⁹⁾. The results obtained by the ratio (TSS/TTA, Table 2) would indicate that the orange fruits appear sweeter to the consumers compared to the yellow fruits, although the TSS content does not differ from the other fruits. Organic acids such as vitamin C (L-ascorbic acid and L-dehydroascorbic acid) and vitamin B (folic acid and folates) are involved in the acidity of pulp juice and are of nutritional interest due to their action as anticoagulant and anti-inflammatory with impact on the cardiovascular and immune system⁽⁴⁷⁾.

3.3 Dry matter, ash, protein and dietary fiber

The dry matter content of the peel was similar between the three types of fruits. However, the pulp of orange fruits had the highest dry matter content (17.8%), followed by the pulp of red (15.7%) and yellow (14.2%) fruits (Table 3). The ash content was similar between the different butia colors, both in the peel and pulp. The peel and pulp of the butia types presented low protein content and high dietary fiber content (Table 3). In the peel, 47% more dietary fiber ($\approx 7.08\%$) was determined than in the pulp ($\approx 3.73\%$), similar to the results of a mixture of orange and yellow butia pulp (4.6% fiber)⁽¹¹⁾. The peel contains more dry matter than the pulp, and probably, the structure of the epicarp cell walls has a higher proportion of hemicellulose, cellulose and lignin than the pulp tissues⁽⁴⁸⁾. Fiber is considered to be very important in the diet, maintaining the body weight, acting in the prevention of some coronary diseases, reducing cholesterol, obesity, diabetes, lowering the postprandial concentration of glucose and the risk of colon cancer⁽⁴⁸⁾⁽⁴⁹⁾. The intake of 100 g of butia fruits *in natura* without peeling would provide 10 to 14% of the daily dietary fiber requirements of an adult⁽⁵⁰⁾.

3.4 Carotenoids

The quantified carotenoid content per 100 g of peel and pulp is presented in Figure 2. The peel accumulated a higher content of total carotenoids (≈ 1.38 mg) than the pulp (≈ 0.97 mg). These results were

consistent with a lower hue and a higher CI in the peel (Table 1, Figure 2), linked to the quantified carotenoids and their proportion in each matrix. In the peel, the content of β -carotene was 39% higher (≈ 1.28 mg) than that determined in the pulp (≈ 0.78 mg) (Figure 2). The peel of the yellow fruits presented the lowest content of β -carotene, differing statistically from the peel of orange and red butia. A similar result was obtained for the content of β -carotene in the pulp (Figure 2). In the peel, α -carotene was not detected in any of the three types of butia, while the content was similar in the pulps (≈ 0.15 mg). The lutein content was also higher in the peel (≈ 67.9 μg) than in the pulp (≈ 33.9 μg). The pulp of yellow fruits had twice the lutein than the pulp of fruits of other colors of butia. Other xanthophylls identified were zeaxanthin and β -cryptoxanthin. The zeaxanthin content in the peel and the pulp was similar between the three types of fruits, and β -cryptoxanthin was not detected in the pulp of any of the types of fruits analyzed (Figure 2). In the peel, the presence of a higher content of β -carotene and β -cryptoxanthin would contribute to pigment this part of the fruit with a more orange color⁽²²⁾.

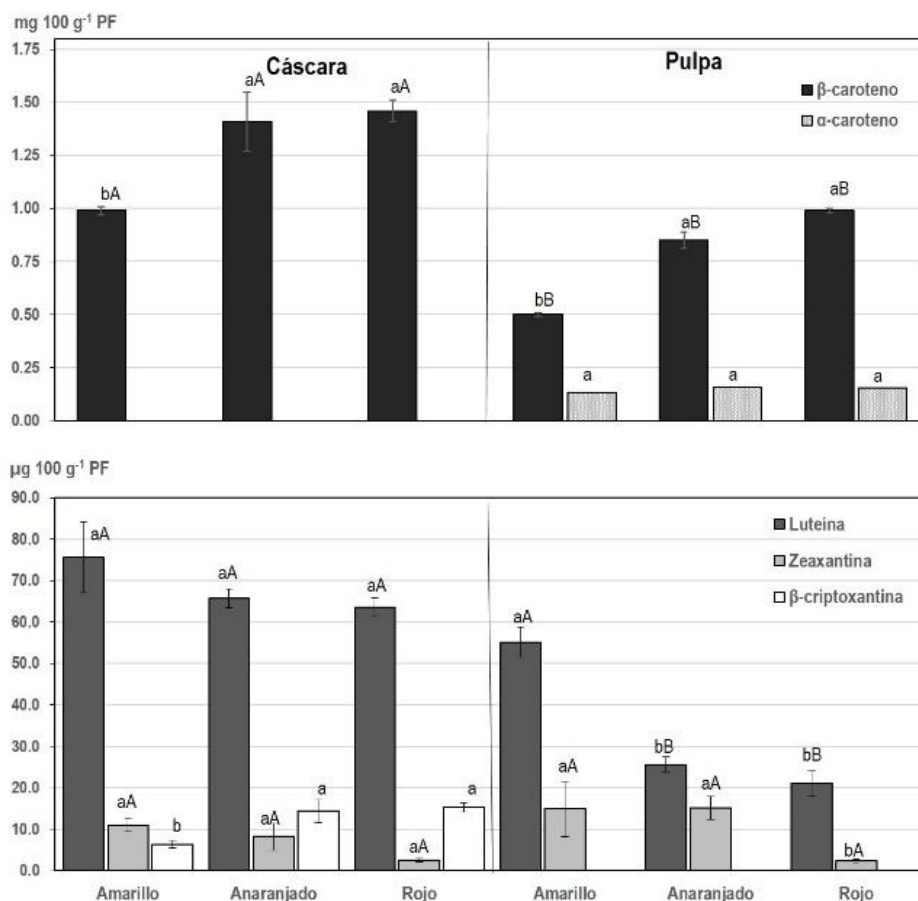
In pulp, similar results of β -carotenes equivalent 100 g^{-1} were obtained in yellow fruits of *B. capitata* from the regions of Brazil, Minas Gerais (0.88 and 1.6 mg)⁽⁵¹⁾ and *B. pindo* 1.83 mg⁽⁵²⁾. Between 0.013 and 1.95 mg of β -carotene were obtained in *B. capitata*, *B. eriosphata* from Capão do Leão and Pelotas (Brazil)⁽⁵³⁾, also quantifying β -cryptoxanthin (18.3 at 26.3 μg) and lutein + zeaxanthin (7 to 119 μg) in each species, respectively. The color of the fruits and the level of association with the type of chemical compounds they contain could constitute an indicator of nutrients and/or bioactive compounds of interest. In this regard, the results obtained from the three types of butia studied, show that the color tone ($^{\circ}$ hue) and the CI of the peel and pulp had a high correlation with total carotenoids and polyphenols (Table 4). The correlation of tonality was negative with the content of β -carotene ($r = -0.9088$) and with the TP ($r = -0.7202$). A higher hue (90 $^{\circ}$ hue) is associated with the yellow color⁽²⁴⁾, indicating less orange and/or reddish-orange pigments (β -carotene, β -cryptoxanthin and flavonoids), and/or a higher content of yellow pigments (lutein and flavonoids)⁽²²⁾⁽⁵⁴⁾. At the same time, the lutein in the pulp



which colors yellow vegetables⁽²²⁾⁽⁵⁴⁾, had a high correlation with the color of the pulp ($r = 0.9367$). A lower correlation between the hue and the CI with the previously mentioned carotenoids (Table 4), and also a high correlation with the content of β -cryptoxanthin ($r = -0.9068$) and zeaxanthin (0.7886), were found in the peel (Table 4). On the other hand, in the biosynthesis of carotenoids in fruit and vegetables, α -carotene is a precursor of lutein, β -carotene is a precursor of zeaxanthin, and this, in turn, is a precursor of β -cryptoxanthin⁽²²⁾⁽⁵⁴⁾. The carotenoid amount and profile obtained in the peel and pulp of butia could be evidence of different metabolism rates of these compounds depending on the fruit compartment (peel or pulp). Furthermore, pigments

that confer color to fruits and vegetables, such as chlorophylls, carotenoids and flavonoids, are involved in reducing oxidative stress in vegetables due to their antioxidant properties, and in some cases, such as α and β -carotene and β -cryptoxanthin, they are precursors of vitamin A⁽²²⁾⁽⁵⁵⁾. Xanthophylls such as lutein, although less present than carotenes, are of special importance for the protection of sight, bones, the nervous and cardiovascular systems, and have antioxidant, anti-arthritis, anti-diabetic, anti-inflammatory activities, among other functions⁽⁵⁶⁾. The intake of 100 g of butia fruits *in natura* with peel would provide 8% to 16% of β -carotenes and 0.5 to 1% of lutein required daily by a child⁽⁴⁰⁾⁽⁵⁷⁾⁽⁵⁸⁾.

Figure 2. Content of α -carotene, β -carotene, lutein, zeaxanthin and β -cryptoxanthin per 100 g of fresh weight of peel or pulp of yellow, orange and red fruits



Mean \pm SE (n = 3). In the peel or pulp, different lowercase letters indicate statistical differences between different colored fruits (Tukey $p \leq 0.05$). For the same fruit color, different capital letters indicate statistical differences between the peel and the pulp (Student's test, $p \leq 0.05$).



3.5 Vitamin C

The content of vitamin C quantified in the pulp was 3.6% to 47.7% higher than in the peel. However, only the vitamin C was statistically different between the peel and the pulp of the yellow fruits. The peel of the orange fruits and the pulp of the red fruits had the lowest vitamin C content (Table 3). The amount of vitamin C in 100 g of whole fruits was 34.8 mg, 40.4 mg and 42.4 mg for the red, orange and yellow butia fruits, respectively. A wide range of vitamin C content is reported for butia fruits (17.61 to 70.44 mg AA 100 g⁻¹ fresh), depending on the species, variety and environmental conditions in which the crop is developed, and also on the quantification method used⁽⁴⁰⁾⁽⁵³⁾⁽⁵⁹⁾⁽⁶⁰⁾. Vitamin C is essential in the human diet and is a powerful antioxidant that must be obtained from fruits and vegetables. L-ascorbic acid (AA) is the most active and abundant form of vitamin C, followed by dehydroascorbic acid⁽³⁸⁾. The evaluated fruits (Table 3) had 1.5 to 2.4 times less vitamin C content (\approx 39.2 mg) compared to some fruits considered rich in this vitamin, such as oranges, 83.2; lemons, 74.3; apples, 60.0; strawberries, 65, and kiwis, 92 mg every 100 g⁻¹ fresh⁽⁶⁰⁾⁽⁶¹⁾. Intake of 100 g of butia *in natura* would provide 39% to 57% of the daily vitamin C requirements of an adult⁽⁴⁹⁾.

3.6 Total polyphenols

The content of total polyphenols (TP) in 100 g of fresh weight of peel and pulp is presented in Table 3. The fruit peels had a higher content of TP (\approx 647.7 mg GAE) than the pulp (\approx 297.0 mg GAE) in the three colors of fruits evaluated. The TP content in

the pulp was similar between the three types of fruits.

However, 20% and 33% were quantified in orange and red fruit peel, respectively, more TP than in yellow fruit peel. Similar TP contents were found in pulp of *B. capitata* with 260.4 mg GAE⁽⁵³⁾; 493.6 mg GAE⁽⁶⁰⁾; 280.5 to 380.5 mg GAE⁽¹²⁾, and in *B. eriosthata* 278.4 mg GAE⁽⁴⁴⁾. Gallic acid has been reported as the main polyphenol in butia pulp followed by hydroxybenzoic acid⁽¹²⁾. However, some authors have found other flavonoids and phenolic compounds (epicatechin and chlorogenic acid) as predominant in exhaustive studies on *Butia* Becc. genotypes, where the species and the number of polyphenols in the fruits depend on the species and the geographical location⁽²³⁾. The pulp of other fruits such as banana, oranges and peaches, with 90.4; 33.7 and 84.6 mg GAE, respectively, contains less TP than butia fruits⁽⁴³⁾. Polyphenols are strong antioxidants, reducing oxidative stress during fruit growth, in the postharvest and in the subsequent handling⁽⁶²⁾⁽⁶³⁾. In turn, phenolic compounds color the peel and pulp of fruits, in shades of orange, red, blue, violet, and purple, and are responsible for other sensory characteristics such as astringency and bitter taste⁽⁶³⁾. From the nutritional point of view, the study of phenolic compounds has gained relevance due to their effect on human health both for the antioxidant (beneficial) properties⁽²³⁾⁽⁶⁴⁾ and for being antinutrients, reducing the digestibility of proteins and the absorption of Fe and Cu, also highlighting that the excesses of phenolic compounds can trigger some types of cancer⁽⁴²⁾⁽⁶²⁾⁽⁶³⁾.

Table 3. Content of dry matter, crude protein, dietary fiber, ash, vitamin C, total polyphenols (TP) and total antioxidant capacity (TAC) per 100 g in fresh weight of pulp or peel of three colors of butia fruits

	Peel			Pulp		
	Yellow	Orange	Red	Yellow	Orange	Red
Dry matter (g)	22,20 \pm 0,51 ^{aA}	24,07 \pm 0,18 ^{aA}	24,30 \pm 0,82 ^{aA}	14,20 \pm 0,15 ^{cB}	17,80 \pm 0,25 ^{aB}	15,77 \pm 0,32 ^{bB}
Ash (g)	0,80 \pm 0,07 ^{aA}	0,85 \pm 0,07 ^{aA}	0,82 \pm 0,01 ^{aA}	0,68 \pm 0,04 ^{aA}	0,70 \pm 0,03 ^{aA}	0,64 \pm 0,05 ^{aB}
Protein (g)	1,07 \pm 0,02 ^{aA}	1,09 \pm 0,09 ^{aA}	1,02 \pm 0,02 ^{aA}	0,81 \pm 0,01 ^{aB}	0,76 \pm 0,05 ^{aB}	0,70 \pm 0,02 ^{aB}
Dietary Fiber (g)	6,95 \pm 0,05 ^{aA}	7,60 \pm 0,10 ^{aA}	6,70 \pm 0,30 ^{aA}	3,80 \pm 0,30 ^{aB}	3,75 \pm 0,25 ^{aB}	3,65 \pm 0,05 ^{aB}
Vitamin C (mg)	49,07 \pm 3,68 ^{aB}	31,20 \pm 5,55 ^{bA}	45,83 \pm 1,85 ^{abA}	59,17 \pm 2,00 ^{aA}	59,60 \pm 2,76 ^{aA}	47,53 \pm 0,66 ^{bA}
TP (mg GAE)	519,8 \pm 0,78 ^{bA}	645,9 \pm 0,23 ^{abA}	777,5 \pm 0,36 ^{aA}	244,8 \pm 0,30 ^{aB}	303,0 \pm 0,10 ^{aB}	343,3 \pm 0,39 ^{aB}
TAC (% DPPH inhibition)	62,6 \pm 2,9 ^{bA}	82,7 \pm 3,9 ^{aA}	66,9 \pm 3,6 ^{bA}	55,3 \pm 2,6 ^{aA}	39,6 \pm 1,9 ^{bB}	25,7 \pm 0,6 ^{cB}

Mean \pm SE (n = 3) In the peel or pulp, different lowercase letters indicate statistical differences between different colored fruits (Tukey p \leq 0.05). For the same fruit color, different capital letters in the row indicate statistical differences between peel and pulp (Student's test, p \leq 0.05).



Table 4. Pearson's linear correlation coefficient (r) between hue (°hue), color index, total polyphenol content and total antioxidant capacity with the content of α and β -carotene, lutein, β -cryptoxanthin and zeaxanthin and vitamin C from the pulp or peel of butia fruits of three colors

	α -carotene	β -carotene	lutein	β -crypt.	zeax.	vit C	TP	TAC
<i>Peel</i>								
Hue	-	-0,6705*	0,5163*	-0,9068**	0,7886**	-0,0188*	-0,7875**	0,0094*
CI	-	0,7863**	-0,3437*	0,6871*	-0,6237*	-0,1796*	0,7876**	0,2136*
TP	-	0,6259*	-0,3136*	0,7581*	-0,7585*	-0,0243*	-	0,2519*
TAC	-	0,5687*	0,3351*	0,2380*	0,0031*	0,8498**	0,2519*	-
<i>Pulp</i>								
Hue	-0,2794 ^{ns}	-0,9088**	0,9367**	-	0,1919*	0,4092*	-0,7202**	0,5250*
CI	-0,1451*	0,8308***	-0,7455**	-	-0,5774*	-0,8666*	0,6940*	-0,6544*
TP	-0,0442*	0,7049*	-0,7156*	-	-0,1851*	-0,4058*	-	0,7902*
TAC	-0,0446*	0,5867*	0,5868*	-	0,4814*	0,5325*	0,7902*	-

β -crypt.: β -cryptoxanthin; zeax.: zeaxanthin; vit C: vitamin C; TP: Total polyphenols; CI: Color Index; TAC: Antioxidant capacity. ns: not significant ($p \geq 0.05$); * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$.

3.7 Total antioxidant capacity

The red and orange fruits had 1.5 to 2.5 times more total antioxidant capacity (TAC) in the peel than in the pulp, while it was similar in the yellow fruits (Table 3). The peel of orange butias presented higher TAC than the peel of yellow and red fruits (Table 3). The pulp TAC was different between the three colors of fruits. The TAC was 1.4 and 2 times higher in the yellow pulp than in the orange and red pulp, respectively. The results obtained by comparing the TAC in the peel and in the pulp of orange or red fruits can be partly explained by the content of polyphenols, β -carotene and lutein (Table 3, Figure 2). Vitamin C is one of the main antioxidants in vegetables⁽⁴⁷⁾, however, its content was similar in the previously described cases. The total antioxidant capacity in pulp determined as a percentage of inhibition of the radical DPPH was within the range obtained for *B. capitata* in four localities in the north of Minas Gerais, Brazil, 17.20 to 58.39%⁽³⁸⁾. The total antioxidant capacity of a plant tissue depends on its chemical compounds and their concentration⁽⁵⁵⁾⁽⁶²⁾. The compounds measured in the butia fruits studied, showed a different contribution to the TAC in peel and pulp (Table 4). The TAC had a greater correlation with vitamin C in the peel than in the pulp, and, on the contrary, the correlation of the TAC with the TP and lutein was higher in the pulp than in the

peel (Table 4). At the same time, the correlation of β -carotene with TAC was similar for the peel and the pulp (Table 4). In fruits and vegetables, TAC is part of a complex system that includes fat-soluble compounds (α -tocopherol, β -carotenes), water-soluble compounds (ascorbic acid and glutathione), antioxidant enzymes (peroxidase, superoxide dismutase, catalase) and other compounds such as isoflavonoids, phenols, polyamines and amino acids, such as cysteine and methionine⁽⁵⁵⁾.

4. Conclusions

This study has allowed characterizing the peel and pulp of three colors of fruits of *Butia odorata* (Barb. Rodr.) Noblick by their physical attributes and chemical compounds of nutritional interest and by their antioxidant capacity. The butia peels studied had a higher content of provitamin A (β -carotene and β -cryptoxanthin), lutein, total polyphenols and dietary fiber than the pulp. This information can be useful, since it gives a differential value to the use of the peel as a by-product and, in particular, for its β -cryptoxanthin content; and the yellow fruits for their lutein content. Moreover, the three types of fruits would provide a similar amount of dietary fiber and vitamin C. In addition, intake of red and orange fruits whole would be an important source of



carotenoids and polyphenols due to their content in the peel. When eaten whole *in natura* (peel and pulp), butias are an interesting complement to the diet due to their contribution of vitamin C, dietary fiber, provitamin A, lutein and total polyphenols.

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Author contribution statement

All authors contributed equally in the elaboration of this article.

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