Original article
Food Science and Technology

ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.5327/fst.514

Sweet, nutritious, and diverse fruits: the genetic heritage of Butia odorata palm groves in southern Brazil

Carlos Fellipe Meurer de LIMA[1*], Julia Goetten WAGNER[2], Bianca Rodeghiero VAHL[1], Nubia Marilin Lettnin FERRI[3], Ênio Egon SOSINSKI JÚNIOR[3], Claudete Clarice MISTURA[4], Márcia VIZZOTTO[3], Rosa Lía BARBIERI[3]

Abstract

The Butia genus comprises 22 palm species native to South America. These palms produce fruits popularly known as butiás, which have high levels of minerals, vitamin C, and carotenoids. These plants are underutilized and threatened with extinction due to human activities. Considering the need to promote local foods beneficial to health and develop conservation strategies for endangered species, it is essential to characterize the genetic resources of Butia spp. This study aimed to evaluate biometric, physicochemical, colorimetric characteristics, proximate composition, and bioactive compounds in fruits of Butia odorata (Barb.Rodr.) Noblick in southern Brazil. Mature fruits from 10 palms were collected in two in situ conservation areas. All analyses were performed in triplicate, and the data were subjected to analysis of variance and the Scott-Knott test ($p \leq 0.05$) for mean comparison using the RStudio statistical software. The analyses revealed significant statistical differences among the palms for the evaluated variables. Compared to other studies on the same species, the results show that the evaluated palms produce fruits rich in ascorbic acid, with high total soluble solids (TSS), high antioxidant activity, and carotenoid concentration, as well as lower fat content and reduced acidity. The genotypes also exhibited variability in colorimetric parameters, with a yellowish hue in the fruits. Higher consumer acceptance of fruits is associated with higher TSS content, which is related to the sugar content in the pulp, and lower acidity. The results demonstrate the high functional potential of these fruits and highlight genetic variability among the evaluated individuals regarding biometric, physicochemical, proximate composition, bioactive compounds, and colorimetric attributes. The results confirm the species' potential to contribute to both dietary health and biodiversity conservation. These findings support future efforts to value sustainable gathering through the promotion of functional food products while protecting remnant palm landscapes through integrated socioecological strategies.

Keywords: genetic resources; Arecaceae; in situ conservation.

Practical Application: This study assessed remnants of an endangered palm species from southern Brazil and characterized the nutritional and phytochemical properties of its fruits, supporting the development of functional food products while contributing to the conservation of remnant palm landscapes.

1 INTRODUCTION

Brazilian flora encompasses a vast diversity of species, and one of the richest botanical families is Arecaceae. This group of plants exhibits unique characteristics, plays a vital role in ecosystems, and holds significant economic value by providing valuable products for society. In Brazil, there are approximately 480 palm species, and this abundance led the indigenous Tupi-Guarani people to originally name the country "*Pindorama*," meaning Land of the Palms (Renuka & Sreekumar, 2012; Souza et al., 2020).

Among the members of the Arecaceae family, the genus *Butia* (Becc.) Becc. comprises 22 species native to South America, with recorded occurrences in Argentina, Brazil, Paraguay, and Uruguay (Heiden & Sant'anna-Santos, 2025). The fruits of these plants, popularly known as *butiás*, are consumed fresh or used as ingredients in juices, jams, ice creams, and other

Received: June 3, 2025.
Accepted: June 17, 2025
[1]*Universidade Federal de Pelotas – Pelotas (RS), Brazil.*
[2]*Universidade Federal de Santa Catarina – Florianópolis (SC), Brazil.*
[3]*Embrapa Temperate Agriculture – Pelotas (RS), Brazil.*
[4]*Edmundo Gastal Foundation for the Support of Agricultural Research and Development – Pelotas (RS), Brazil.*
**Corresponding author: meurer.cf@gmail.com*
Conflict of interest: nothing to declare.
Funding: This work is a result of the Rota dos Butiazais project, supported by the Brazilian Ministry of Science, Technology, and Innovations (MCTI), by the National Council for Scientific and Technological Development (CNPq) (processes 441493/2017-3, 315202/2018-1, and 140811/2020-6), by the Global Fund for the Environment (GEF) under the Strategies for Conservation, Restoration, and Management for Caatinga, Pampa, and Pantanal Biodiversity (GEF Terrestrial), which is coordinated by the Ministry of Environment and Climate Change (MMA) and has the Inter-American Development Bank (IDB) as the implementing agency and the Brazilian Biodiversity Fund (Funbio) as the executing agency. The Rota dos Butiazais project is also supported by the public policy of Mandatory Forest Repositioning of the State Secretariat for the Environment and Infrastructure of Rio Grande do Sul State (SEMA/RS), with resources from CPFL."

products. Despite providing an additional source of income for local communities and producing nutritious fruits, these palms remain underutilized, neglected, and threatened with extinction due to human activities (Barbieri et al., 2022; Dutra et al., 2021).

Bioactive compounds found in the pulp and seeds of *butiá* fruits show potential for applications in the pharmaceutical and food industries (Schneider et al., 2017; Zaccari et al., 2021). Studies demonstrating the beneficial effects of these compounds on human health have driven societal interest in healthy and nutritious foods, as they contribute to health promotion and disease prevention by reducing the risk of conditions such as cancer, Alzheimer's, Parkinson's, and cardiovascular diseases (Hoffmann et al., 2014; Morais et al., 2022; Patra et al., 2022).

Given the need to develop conservation strategies for endangered species while promoting local foods beneficial to health, it is essential to characterize plant genetic resources. Diversity within the genus *Butia* has been mainly characterized based on morphological attributes, although chemical properties are also relevant and should be further explored (Cidón et al., 2023; Wagner, 2022a).

Given the urgent need for conservation strategies for endangered native species and the increasing demand for functional foods, studies on the genetic, nutritional, and functional diversity of *Butia odorata* are especially relevant. The fruits of this species, rich in bioactive compounds, not only offer potential health benefits but also represent a sustainable resource for income generation in local communities. These fruits are traditionally gathered from remnant palm groves located in conserved public or private lands, reinforcing the socioecological value of their conservation. Though, comprehensive characterization of these fruits remains limited. Hence, this study aimed to evaluate biometric, physicochemical, nutritional, and bioactive attributes of *B. odorata* genotypes from natural palm groves in Encruzilhada do Sul, Rio Grande do Sul, Brazil, supporting both biodiversity conservation and value-added applications in the food industry.

1.1 Relevance of the work

Given the urgent need for conservation strategies for endangered native species and the increasing demand for healthy foods, studies on the genetic, nutritional, and functional diversity of *Butia odorata* are relevant. The fruits of this species are rich in bioactive compounds, offering health benefits and representing a sustainable resource for income generation in local communities. These fruits are traditionally gathered from remnant palm groves located in conserved public or private lands, reinforcing the socioecological value of their conservation. This study evaluates biometric, physicochemical, nutritional, and bioactive attributes of *B. odorata* genotypes from natural palm groves in Encruzilhada do Sul, Rio Grande do Sul, Brazil, supporting biodiversity conservation and value-added applications in the food industry.

2 MATERIALS AND METHODS

The fruits were collected in *Butia* palm groves located in Encruzilhada do Sul in April 2024. Mature fruit bunches from 10 individuals in two areas, 24 km apart, were collected (Figure 1), and the fruits were transported in plastic boxes to the Food Science and Technology Laboratory at Embrapa Clima Temperado (Pelotas, Rio Grande do Sul state), where the analyses were conducted.

Figure 1. Collection of *Butia odorata* fruits in Encruzilhada do Sul, Rio Grande do Sul, Brazil.

Thirty representative fruits from each bunch were randomly selected and measured for equatorial diameter (ED) and longitudinal diameter (LD) using a digital caliper. The mass of the fruits and endocarps was weighed using an analytical balance. The pulp yield was calculated as the difference between fruit and endocarp mass.

The evaluated physicochemical properties included pH, titratable acidity, total soluble solids (TSS), and vitamin C content. To perform the analyses, the fruit pulps from each genotype were homogenized and processed in a Philips Walita centrifuge to extract juice. The pH was determined using a calibrated pH meter, and the TSS content was measured with a refractometer. Titratable acidity was quantified using the potentiometric neutralization method with an alkaline solution (NaOH). Vitamin C content was determined by ascorbic acid quantification through titration using 2,6-dichlorophenol-indophenol.

To assess moisture content, the fruits were dried in a vacuum oven at 70°C for 6 h. Ash content was determined by incinerating the material in a muffle furnace at 600°C for 4 h. Protein content was determined by an elemental analyzer through combustion, using a factor of 6.25 to convert nitrogen into protein. Lipid content was measured using an Ankom extraction system with petroleum ether as the solvent. Crude fiber content was also analyzed using an Ankom system, involving acid and alkaline digestion of the dried sample. Lipid and crude fiber determinations were conducted using lyophilized samples.

Total phenolic compounds were determined following an adapted version of the Swain and Hillis (1959) method. A total of 20 mL of methanol was added to 5 g of homogenized pulp using a Turrax homogenizer. The mixture was centrifuged for 20 min at 4,000 RPM and 0°C. A defined aliquot of the supernatant was transferred to a 15 mL Falcon tube, where 4 mL of distilled water, 0.25 mL of Folin-Ciocalteu reagent, and 0.5 mL of Na_2CO_3 were added. The solution was kept in the dark for 2 h to stabilize the reaction, indicated by a color change to blue. Absorbance was then measured using a spectrophotometer at a wavelength of 725 nm.

To determine antioxidant activity, the extract preparation followed the same steps as for total phenolic compounds. An aliquot of the supernatant was transferred to a 15 mL Falcon tube protected from light with aluminum foil. The reaction was conducted by adding 1900 μL of 2,2-diphenyl-1-picrylhydrazyl (DPPH), following the method of Brand-Williams et al. (1995). The reaction was kept in the dark for 24 h, and absorbance was measured using a spectrophotometer at a wavelength of 515 nm.

Total carotenoid content was determined using an adaptation of the Talcott and Howard (1999) method. A total of 2 g of homogenized pulp was diluted in 15 mL of an acetone/ethanol solution containing 400 mg/L of butylated hydroxytoluene. The mixture was centrifuged for 20 min at 4000 RPM and 0°C. The supernatant was collected, and the process was repeated until the samples appeared whitish. Then, 50 mL of hexane and 50 mL of distilled water were added to separate the phases, with 30-min intervals between each step. Finally, absorbance was measured in the hexane-containing phase using a spectrophotometer at a wavelength of 470 nm.

The color of ten representative fruits from each genotype was evaluated using a Minolta CR 300 colorimeter, with two readings taken at the equatorial region of each fruit. The readings provided values for the three-dimensional parameters L*, a*, and b*, where L* represents brightness, a* indicates the color variation between green and red, and b* represents the variation between blue and yellow (Pinheiro, 2009). From these parameters, the CIELAB elements of hue, saturation, and brightness were calculated. Additionally, the parameters were inserted into the LAB Color Chart software for graphical color representation (Teixeira, 2024).

Only one fruit cluster per genotype was collected, which was considered as a treatment, totaling ten treatments. The experiment followed a completely randomized design. All analyses were performed in triplicate. The data were subjected to analysis of variance and the Scott-Knott means test using RStudio software.

RESULTS AND DISCUSSION

Based on the results presented in Table 1, the genotypes of *B. odorata* showed significant statistical differences in fruit longitudinal and ED, weight, and pulp yield. The LD ranged from 20.73 mm (P5) to 30.92 mm (F5), with an average of 25.99 mm, while the ED varied between 24.22 mm (P5) and 33.12 mm (P1), with an average of 27.86 mm. The mean LD and ED values found for this species in Encruzilhada do Sul were higher than

Table 1. Biometric analysis in fruits of *Butia odorata* palms from Encruzilhada do Sul, Rio Grande do Sul, southern Brazil.

Genotype	Longitudinal diameter (mm)	Equatorial diameter (mm)	Fruit weight (g)	Pulp yield (%)
P1	25.87 ± 0.48 c	33.12 ± 0.16 a	18.69 ± 0.55 a	85.44 a
P2	26.13 ± 0.55 c	30.33 ± 0.46 b	15.75 ± 0.42 b	81.52 b
P3	24.31 ± 0.71 d	29.60 ± 0.18 c	14.24 ± 0.08 c	82.50 b
P4	24.62 ± 0.04 d	27.01 ± 0.12 d	11.80 ± 0.27 e	81.29 b
P5	20.73 ± 0.67 e	24.22 ± 0.24 f	7.93 ± 0.26 g	82.69 b
F1	26.18 ± 0.75 c	29.61 ± 0.65 c	14.23 ± 0.15 c	80.45 c
F2	27.37 ± 0.41 b	26.73 ± 0.09 d	13.40 ± 0.29 d	78.61 d
F3	26.31 ± 0.11 c	25.54 ± 0.35 e	10.28 ± 0.23 f	77.87 d
F4	27.44 ± 0.60 b	26.84 ± 0.15 d	12.36 ± 0.40 e	73.01 e
F5	30.92 ± 0.14 a	25.59 ± 0.24 e	11.94 ± 0.27 e	71.50 e

Means followed by different letters indicate significant differences according to the Scott-Knott test at a 5% probability level.

those reported by Tonietto et al. (2019), who evaluated natural populations of *B. odorata* in Santa Vitória do Palmar (LD 21.40 mm and ED 26.30 mm), Tapes (LD 20.21 mm and ED 20.00 mm), Arambaré (LD 19.47 mm and ED 18.65 mm), and Barra do Ribeiro (LD 21.36 mm and ED 19.81 mm), all located in Rio Grande do Sul state. These results also differ from the variation range found in other studies on the same species (Wagner, 2024; Wagner et al., 2022a).

The average fruit weight across the different genotypes was 13.06 g, similar to the findings of Eloy et al. (2019), who evaluated *B. odorata* fruits in a cultivated collection in the municipality of Capão do Leão (Rio Grande do Sul state) and reported an average of 13.00 g. However, this value was higher than those recorded in other regions, such as the studies by Tonietto et al. (2019) in Santa Vitória do Palmar (9.60 g), Tapes (5.68 g), Arambaré (6.21 g), and Barra do Ribeiro (5.54 g). It was also higher than the results found by Wagner et al. (2022a), who analyzed fruits from genotypes collected in Pelotas and Capão do Leão (10.81 g).

Pulp yield ranged from 71.5 (F5) to 85.44% (P1), with an average of 79.49%. The yield observed for genotype P1 was higher than previously reported for the same species (Eloy et al., 2019; Pizzanelli & Xavier, 2013; Sganzerla, 2010; Tonietto et al., 2019; Wagner, 2024; Wagner et al., 2022a). Additionally, genotype P1 stood out in terms of LD and fruit weight. However, the high variability among the evaluated genotypes is evident. *Butia* palms undergo cross-pollination, and high genetic variability in morphological traits is a characteristic of the genus (Beskow et al., 2015).

The physicochemical analyses revealed significant statistical differences among the genotypes for pH, TSS, titratable acidity, and vitamin C content (Table 2). The pH of *B. odorata* pulp was influenced by the genotypes and ranged from 3.15 (P3) to 3.55 (P5), forming different statistical classes.

The pH values ranged from 3.15 to 3.55, higher than those reported by Schwartz et al. (2010) for different *B. odorata* populations in Santa Vitória do Palmar. Additionally, they exceeded the values found by Tonietto et al. (2019), who evaluated populations from various municipalities along the "Costa Doce" region in east Rio Grande do Sul state, and by Crosa et al. (2011), who studied *B. odorata* fruits in Uruguay. The values observed in this study are similar to those reported by Wagner (2024), who analyzed *Butia* palm fruits from Encruzilhada do Sul, which may indicate that the genotypes from this region have less acidic pulp.

According to Eloy et al. (2019), lower acidity levels contribute to higher fruit acceptability. In this study, significant differences in fruit titratable acidity were observed, ranging from 1.224 (P5) to 3.552% (F5), with an average of 2%. The high variability among the evaluated genotypes showed a wider range compared to other studies on the same species, such as Schwartz et al. (2010), who reported a variation between 1.96 and 2.87% among the evaluated populations; Crosa et al. (2011), with a range of 1.3–1.6% among different fruit samples from a single *Butia* palm grove; Eloy et al. (2019), with values between 2.63 and 3.00% in fruits treated with plant growth regulators; Tonietto et al. (2019), with a variation from 1.36 to 1.76% among different populations; Wagner et al. (2022a), with values ranging from 1.07 to 2.23%; and Wagner (2024), with a range of 1.51–1.96% among different genotypes. Nonetheless, higher acidity levels also contribute to longer pulp preservation by reducing microbial contamination (Pereira et al., 2013).

The TSS content is directly related to sugar concentration in the pulp (Nunes et al., 2024). According to the analysis, the genotypes from Encruzilhada do Sul had an average TSS of 17.17 °Brix, a higher result than Wagner (2024), who analyzed a population from the same municipality and found an average of 13.52 °Brix. These values also exceeded those recorded by Ferrão et al. (2013) in the municipality of Santa Maria, located in the middle of Rio Grande do Sul state (12.39 °Brix), and Crosa et al. (2011) in Castillos, east Uruguay (14 °Brix). Additionally, they were higher than the values reported by Tonietto et al. (2019) in Santa Vitória do Palmar (12.30 °Brix), Arambaré (12.41 °Brix), Tapes (13.16 °Brix), and Barra do Ribeiro (13.18 °Brix). According to Eloy et al. (2019), *B. odorata* has a higher TSS content than other *Butia* species in Rio Grande do Sul. Furthermore, the results demonstrate that *Butia* palm fruits from Encruzilhada do Sul exhibit superior TSS levels compared to those from the same species in other regions.

Vitamin C, or ascorbic acid, is an essential nutrient with disease-preventing potential (Grosso et al., 2013). According to Zaccari et al. (2021), vitamin content in fruits may vary depending on the species, variety, edaphoclimatic conditions, and analysis

Table 2. Physicochemical analysis in fruits of *Butia odorata* palms from Encruzilhada do Sul, Rio Grande do Sul, southern Brazil.

Genotype	pH	TSS	Tit. acidity (%)[1]	Vit. C[2]
P1	3.20 ± 0.00 f	16.1 ± 0.2 e	1.683 ± 0.060 c	60.12 ± 2.13 d
P2	3.24 ± 0.00 e	17.7 ± 0.1 c	1.791 ± 0.071 c	39.26 ± 2.13 g
P3	3.15 ± 0.00 g	20.3 ± 0.4 a	1.797 ± 0.054 c	38.04 ± 2.13 g
P4	3.28 ± 0.00 d	16.0 ± 0.2 e	2.144 ± 0.036 b	34.36 ± 2.13 h
P5	3.55 ± 0.00 a	19.0 ± 0.4 b	1.224 ± 0.032 d	50.31 ± 2.13 e
F1	3.34 ± 0.01 c	15.1 ± 0.2 g	2.017 ± 0.084 b	30.62 ± 1.06 i
F2	3.46 ± 0.00 b	16.2 ± 0.3 e	2.041 ± 0.072 b	91.24 ± 1.06 b
F3	3.46 ± 0.01 b	15.6 ± 0.2 f	1.840 ± 0.029 c	46.54 ± 1.06 f
F4	3.30 ± 0.01 d	19.0 ± 0.3 b	1.915 ± 0.003 c	63.07 ± 1.06 c
F5	3.21 ± 0.03 f	16.7 ± 0.3 d	3.552 ± 0.172 a	165.33 ± 0.00 a

TSS: Expressed in °Brix; [1]Expressed as % citric acid; [2]Expressed in mg of ascorbic acid per 100 mL of juice. Means followed by different letters indicate significant differences according to the Scott-Knott test at a 5% probability level.

method. In this study, *B. odorata* vitamin C levels ranged from 30.62 to 165.33 mg of ascorbic acid per 100 mL of juice, exhibiting high variability with an average of 61.89 mg per 100 mL. These values are significantly higher when compared to previous studies on the same species and other *Butia* species. Zaccari et al. (2021) reported an average of 55.43 mg of ascorbic acid per 100 mL of juice in *B. odorata* fruits, while Wagner (2024) found an average of 46.72 mg per 100 mL for *B. odorata*, 45.12 mg for *Butia catarinensis*, and 26.32 mg for *B. eriospatha*. The Brazilian Health Regulatory Agency (ANVISA) recommends a daily intake of 45 mg of vitamin C (Brasil, 2003). In this study, genotypes P1, P5, F2, F3, F4, and F5 recorded vitamin C levels above the recommended daily intake in just 100 mL of juice.

Significant statistical differences were observed among the genotypes of *B. odorata* regarding dry matter, ash, crude fiber, lipids, and protein content (Table 3). Dry matter ranged from 20.26 (P1) to 26.15% (P4) among genotypes, with an average of 22.63%, exceeding the results found by Wagner et al. (2022a) in Pelotas and Capão do Leão, by Zaccari et al. (2021) in Castillos, and by Ferrão et al. (2013) in Santa Maria and Santa Rosa (Rio Grande do Sul state). According to Freitas et al. (2021), the dry matter content of fruits correlates positively with soluble solids content, reinforcing that *B. odorata* fruits from Encruzilhada do Sul have sweeter pulp than other genotypes of the same species.

Ash content represents the mineral composition of the samples, ranging from 0.46 (P1) to 1.06% (F5). These values are similar to those reported by Wagner (2024), who analyzed fruits from a natural population of *B. odorata* in the same municipality as the present study, and by Martins et al. (2019), who recorded an ash content of 0.7% in *Butia yatay* (Mart.) Becc. However, the average of 0.73% was lower than that found by Wagner et al. (2022b), who reported an average of 1.08% in fruits of *Butia eriospatha* (Mart. ex Drude) Becc.

Fiber content varied from 1.27 to 2.78% among the genotypes analyzed. These values were lower than those reported by Trevisan et al. (2021), who observed an average of 2.87%, and by Zaccari et al. (2021), who recorded 3.73% of fiber per 100 g of pulp, both evaluating *B. odorata* fruits. Dietary fiber is essential for proper digestive function and disease prevention, with a recommended daily intake of 38 g for adults (Institute of Medicine, 2005). Thus, 100 g of *butiá* pulp can provide between 5 and 10% of the recommended daily fiber intake.

Protein content ranged from 0.59 (P1) to 1.23% (F5), with an average of 0.81%. These values are similar to those found for the same species by Morais et al. (2022), Wagner (2024), and Wagner et al. (2022a). Lipid content varied from 0.33 (P2) to 0.78% (F1), with an average of 0.54%. This average was lower than those reported by Ferrão et al. (2013) and Wagner et al. (2022a), who analyzed *B. odorata* fruits from other regions of Rio Grande do Sul. Additionally, it was also lower than values found for other species of the *Butia* genus (Barbosa et al., 2021; Martins et al., 2019; Rockett et al., 2020; Wagner, 2024).

Significant statistical differences were observed in the analysis of bioactive compounds (Table 4). Phenolic compounds ranged from 201.55 mg (P1) to 598.06 mg of chlorogenic acid equivalents per 100 g of sample (F5). Similar results for this species were reported by Beskow et al. (2015) and Wagner (2024), who found mean total phenolic compound levels of 401.32 and 345.00 mg of chlorogenic acid equivalents per 100 g of sample, respectively. However, higher concentrations were observed by Hoffmann et al. (2017) and Pereira et al. (2013), who reported 1,250.30 and 636.95 mg of chlorogenic acid equivalents per 100 g of sample, respectively.

The concentration of phenolic compounds is directly related to antioxidant activity, and the abundance of these compounds in *Butia* palm fruits makes them an excellent source of natural antioxidants (Cidón et al., 2023; Morais et al., 2022). Evaluating the phenolic composition in *B. catarinensis* fruits, Danielski and Shahidi (2024) identified eight different compounds in the pulp, with gallic acid being the most abundant. Additionally, the authors identified nine components in the seeds, with phenolic concentrations similar to those found in the pulp. These findings highlight the functional potential of the seeds, suggesting that their benefits can be harnessed to promote healthy eating and sustainable cultivation of *Butia* palms.

Antioxidant activity inhibits lipid oxidation and protects cells from the action of free radicals (Morais et al., 2022). The genotypes analyzed showed variation in antioxidant activity from 586.29 (P2) to 1,494.85 μg Trolox/100 mg (F5). Wagner et al. (2022a) reported values for the same species ranging from 785.05 to 3,459.82 μg Trolox/100 mg. This variable is highly sensitive to external factors, such as fruit maturation stage and pest infestation (Chaves Neto et al., 2020; Silva, 2017). However, these results reflect the high variability characteristic of the species.

Table 3. Proximate composition analysis in fruits of *Butia odorata* palms from Encruzilhada do Sul, Rio Grande do Sul, southern Brazil.

Genotypes	Dry matter (%)	Ash (%)	Crude fiber (%)	Lipids (%)	Proteins (%)
P1	20.26 ± 0.11 e	0.46 ± 0.03 h	1.27 ± 0.01 h	0.44 ± 0.01 f	0.59 ± 0.01 f
P2	21.01 ± 0.18 d	0.72 ± 0.01 d	1.61 ± 0.01 f	0.33 ± 0.01 g	0.76 ± 0.01 d
P3	22.90 ± 0.22 b	0.51 ± 0.01 g	1.44 ± 0.05 g	0.61 ± 0.01 c	0.71 ± 0.02 e
P4	22.57 ± 0.07 c	0.75 ± 0.01 d	1.97 ± 0.03 d	0.35 ± 0.01 g	0.61 ± 0.01 f
P5	23.52 ± 0.83 b	0.61 ± 0.02 f	1.86 ± 0.05 e	0.48 ± 0.01 e	0.71 ± 0.02 e
F1	20.67 ± 0.08 e	0.69 ± 0.03 e	1.81 ± 0.06 e	0.78 ± 0.01 a	0.62 ± 0.06 f
F2	21.56 ± 0.15 d	0.72 ± 0.02 d	2.02 ± 0.03 d	0.60 ± 0.01 c	0.84 ± 0.02 c
F3	22.03 ± 0.63 c	0.89 ± 0.02 c	2.26 ± 0.01 c	0.52 ± 0.01 d	0.99 ± 0.02 b
F4	26.15 ± 0.39 a	0.93 ± 0.03 b	2.53 ± 0.02 b	0.65 ± 0.01 b	1.02 ± 0.01 b
F5	25.61 ± 0.47 a	1.06 ± 0.03 a	2.78 ± 0.06 a	0.61 ± 0.04 c	1.23 ± 0.01 a

Means followed by different letters indicate significant differences according to the Scott-Knott test at a 5% probability level.

Table 4. Analysis of bioactive compounds in fruits of *Butia odorata* palms from Encruzilhada do Sul, Rio Grande do Sul, southern Brazil.

Genotypes	Phenolic Compounds[1]	Antioxidant Activity[2]	Total carotenoids[3]
P1	372.61 ± 42.78 c	710.89 ± 28.99 b	26.47 ± 3.08 d
P2	163.28 ± 55.17 d	586.29 ± 169.96 b	67.86 ± 12.27 a
P3	308.57 ± 23.15 c	588.80 ± 258.32 b	34.56 ± 2.98 c
P4	340.19 ± 34.16 c	848.56 ± 141.76 b	18.83 ± 4.50 d
P5	344.35 ± 53.81 c	779.89 ± 130.98 b	63.95 ± 5.94 a
F1	292.40 ± 16.57 c	698.97 ± 188.07 b	16.37 ± 1.05 d
F2	442.75 ± 23.50 c	1057.55 ± 89.47 a	50.54 ± 4.07 b
F3	519.26 ± 51.99 b	1176.93 ± 333.57 a	39.74 ± 1.66 c
F4	578.50 ± 29.05 b	1359.81 ± 130.46 a	35.69 ± 4.28 c
F5	704.82 ± 61.00 a	1494.85 ± 303.47 a	73.84 ± 4.75 a

[1]Expressed in mg of chlorogenic acid/100 g of tissue; [2]Expressed in µg Trolox/g of tissue; [3]Expressed in mg β-carotene/100 g of tissue. Means followed by different letters indicate significant differences according to the Scott-Knott test at a 5% probability level.

Carotenoid concentrations ranged from 26.47 (P1) to 73.84 mg β-carotene/100 g of tissue (F5). The intake of these plant pigments provides health benefits, as they are precursors of vitamin A and possess antioxidant and anticancer properties (Antonini, 2023). The *B. odorata* genotypes evaluated in the *Butia* palms from Encruzilhada do Sul exhibited carotenoid levels far higher than those reported for the same species by other authors. For example, Vinholes et al. (2017) found carotenoid concentrations ranging from 1.71 to 2.86 mg β-carotene/100 g of tissue, while Wagner et al. (2022a) reported values between 2.28 and 20.15 mg β-carotene/100 g of tissue.

Fruit color is an important morphological attribute for germplasm characterization and directly influences consumer choice (Li et al., 2023; Mistura, 2015). Therefore, colorimetric analyses are valuable tools for determining variability and assessing market acceptability (McGuire, 1992). The analysis revealed significant statistical differences for all CIELAB parameters (Table 5) among fruits from different *B. odorata* genotypes from Encruzilhada do Sul.

In the CIELAB system, lightness (L) represents the perceived intensity of light in a color, ranging from black (minimum value – 0) to white (maximum value – 100). The lightness values ranged from 77.89 (P5) to 88.46 (P4). Chroma, which represents color intensity, varied between 63.03 and 73.79. The genotypes evaluated in this study exhibited higher lightness and saturation compared to *B. odorata* populations in the Rio Grande do Sul municipalities of Santa Vitória do Palmar, Arambaré, Tapes, and Barra do Ribeiro (Tonietto et al., 2019), as well as Castillos, Uruguay (Zaccari et al., 2021).

There is high genetic variability in the color of mature *Butia* palm fruits, which can be greenish, yellowish, orange, pink, red, brown, cream, or purple (Barbieri et al., 2022). According to Autran and Gonçalez (2006), hue angle (°Hue) is expressed through primary colors and can range from 0 to 360°. The quadrant between 0 and 90° corresponds to yellow hues. Thus, the *B. odorata* fruits from Encruzilhada do Sul exhibit a yellowish coloration (Figure 2).

Table 5. CIELAB parameters from the colorimetric analysis of fruits of *Butia odorata* palms from Encruzilhada do Sul, Rio Grande do Sul, southern Brazil.

Genotypes	Hue angle (°Hue)	Chroma	Lightness
P1	80.52 d	57.12 b	66.21 c
P2	75.23 f	52.11 d	59.84 e
P3	80.24 d	61.87 a	69.64 b
P4	88.46 a	54.10 c	73.79 a
P5	77.89 e	58.44 b	61.12 e
F1	87.57 b	51.68 d	70.60 b
F2	80.70 d	61.60 a	63.03 d
F3	82.78 c	52.36 d	66.58 c
F4	86.86 b	60.23 a	65.37 c
F5	78.50 e	62.09 a	64.08 c

Means followed by different letters indicate significant differences according to the Scott-Knott test at a 5% probability level.

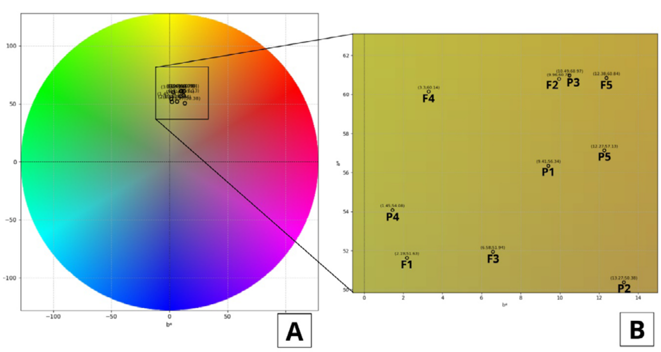

Figure 2. Fruit coloration of *Butia odorata* palms from Encruzilhada do Sul, Rio Grande do Sul, southern Brazil, according to the CIELAB color space.

The characterization of *B. odorata* fruits from *in situ* conserved palm groves in southern Brazil reveals a wide genetic variability with significant implications for food science, nutrition, and conservation. Genotypes with higher pulp yield, sweetness (TSS), vitamin C, fiber, and antioxidant content demonstrate potential for use in functional food products aimed at health promotion. These traits are especially relevant for the development of minimally processed juices, jams, or nutritional supplements. Furthermore, the high nutritional quality observed in fruits collected through traditional gathering reinforces the value of conserving remnant palm groves on public and private lands. By supporting biodiversity conservation with sustainable use and local income generation, these results support strategic actions for enhancing food security and valorizing Brazilian native sociobiodiversity.

4 CONCLUSION

This study provides valuable insights into the physicochemical, nutritional, and functional diversity of *B. odorata* fruits from *in situ* conserved palm groves in southern Brazil. The results confirm the species' potential as a source of bioactive-rich native fruits, contributing to both dietary health and biodiversity conservation. These findings support future efforts to value sustainable gathering through the promotion of functional food products while protecting remnant palm landscapes through integrated socioecological strategies.

REFERENCES

Antonini, L. M. (2023). Compostos bioativos em alimentos funcionais e seus benefícios à saúde: uma revisão. In I. K. N. M. Moraes, D. T. C. Silva & P. G. Freitas (Eds.), *Ciências da saúde: inovação, pesquisa e demandas populares* (pp. 156–172). Publicar.

Autran, C. S., & Gonçalez, J. C. (2006). Caracterização colorimétrica das madeiras de Muirapiranga (*Brosimum rubescens* Taub.) e de Seringueira (*Hevea brasiliensis*, clone Tjir 16 Mull Arg.) visando a utilização em interiores. *Ciência Florestal*, *16*(4), 445–451. https://doi.org/10.5902/198050981926

Barbieri, R. L., Marchi, M. M., & Sosinski Júnior, E. E. (2022). *Butia odorata*: a palmeira dos butiazais em Tapes e na Fazenda São Miguel. In A. M. Tozetti, R. K. Farina & M. Raguse-Quadros (Eds.), *Patrimônio natural dos butiazais da Fazenda São Miguel* (pp. 38–48). Fi.

Barbosa, M. C., Rosa, Q. S., Cardoso, L. M., Gomides, A. F. F., Barbosa, L. C. A., Sant'anna, H. M. P., Pinheiro, S. S., Peluzio, M. C. G., Teixeira, R. D. B. L., & Valente, M. A. S. (2021). Composition proximate, bioactive compounds and antioxidant capacity of *Butia capitata*. *Food Science and Technology*, *41*(Suppl. 2), 763–768. https://doi.org/10.1590/fst.26720

Beskow, G. T., Hoffmann, J. F., Teixeira, A. M., Fachinello, J. C., Chaves, F. C., & Rombaldi, C. V. (2015). Bioactive and yield potential of jelly palms (*Butia odorata* Barb. Rodr.). *Food Chemistry*, *172*, 699–704. https://doi.org/10.1016/j.foodchem.2014.09.111

Brand-Williams, W., Cuvelier, M. E., & Berset, C. (1995). Use of a free radical method to evaluate antioxidant activity. *Lebensmittel-Wissenschaft + Technologie*, *28*(1), 25–30. https://doi.org/10.1016/S0023-6438(95)80008-5

Brasil (2003). Ministério da Saúde. Agência Nacional de Vigilância Sanitária. Resolução RDC nº 360, de 23 de dezembro de 2003. *Diário Oficial da República Federativa do Brasil*.

Chaves Neto, J. R., Silva, S. M., & Dantas, R. L. (2020). Atributos de qualidade, compostos bioativos e atividade antioxidante de frutos de uvaieira durante a maturação. *Agrarian*, *13*(49), 296–308. https://doi.org/10.30612/agrarian.v13i49.8684

Cidón, C. F., Turchetto-Zolet, A. C., Bajay, M. M., Zucchi, M. I., & Konzen, E. R. (2023). Phenotypic and molecular basis for genetic variation in jelly palms (*Butia* sp.): where are we now and where are we headed to? *Genetics and Molecular Biology*, *46*(3 Suppl. 1), e20230145. https://doi.org/10.1590/1678-4685-gmb-2023-0145

Crosa, M. J., Burzaco, P., Pastorino, N., Isisity, M., Gioscia, D., & Ayres, C. (2011). Caracterización fisicoquímica y nutricional del fruto *Butia capitata* y de su pulpa tamizada. *Revista del Laboratorio Tecnológico del Uruguay*, (6), 3–6. https://doi.org/10.26461/06.01

Danielski, R., & Shahidi, F. (2024). Nutraceutical potential of underutilized tropical fruits and their byproducts: phenolic profile, antioxidant capacity, and biological activity of Jerivá (*Syagrus romanzoffiana*) and Butiá (*Butia catarinensis*). *Journal of Agricultural and Food Chemistry*, *72*(8), 4035–4048. https://doi.org/10.1021/acs.jafc.3c06350

Dutra, J. P., Santos, A. A. M., Barbieri, R. L., & Marchi, M. M. (2021). *Butiá para todos os gostos*. Embrapa.

Eloy, J., Kirinus, M. B. M., Farias, P. C. M., & Malgarim, M. B. (2019). Produção e qualidade de *Butia odorata* sob a adição de fitorregulador. *Revista Agrarian*, *12*(44), 165–173. https://doi.org/10.30612/agrarian.v12i44.7393

Ferrão, T. S., Ferreira, D. F., Flores, D. W., Bernardi, G., Link, D., Barin, J. S., & Wagner, R. (2013). Evaluation of composition and quality parameters of jelly palm (*Butia odorata*) fruits from different regions of Southern Brazil. *Food Research International*, *54*(1), 57–62. https://doi.org/10.1016/j.foodres.2013.06.002

Freitas, S. T., Marques, A. T. B., & Rybka, A. C. P. (2021). *Definição do ponto ideal de colheita de mangas em função do teor de matéria seca do fruto, visando à alta qualidade de consumo* (Circular Técnica, 127). Embrapa Semiárido

Grosso, G., Bei, R., Mistretta, A., Marventano, S., Calabrese, G., Masualli, L., Giganti, M. G., Modesti, A., Galvano, F., & Gazzolo, D. (2013). Effects of vitamin C on health: a review of evidence. *Frontiers in Bioscience*, *18*(3), 1017–1029. https://doi.org/10.2741/4160

Heiden, G., & Sant'Anna-Santos, B. F. (2025). *Butia in Flora e Fungo do Brasil*. Jardim Botânico do Rio de Janeiro. Retrieved from: http://servicos.jbrj.gov.br/flora/search/Butia

Hoffmann, J. F., Barbieri, R. L., Rombaldi, C. V., & Chaves, F. C. (2014). *Butia* spp. (Arecaceae): An overview. *Scientia Horticulturae*, *179*, 122–131. https://doi.org/10.1016/j.scienta.2014.08.011

Hoffmann, J. F., Zandoná, G. P., Santos, P. S., Dallmann, C. M., Madruga, F. B., Rombaldi, C. V., & Chaves, F. C. (2017). Stability of bioactive compounds in butiá (*Butia odorata*) fruit pulp and nectar. *Food Chemistry*, *237*, 638–644. https://doi.org/10.1016/j.foodchem.2017.05.154

Institute of Medicine (2005). *Dietary Reference Intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids*. National Academies Press.

Li, B., Zhang, X., Han, C., Duan, R., Yang, J., & Xue, H. (2023). Effects of Methyl Jasmonate on fruit coloration and quality improvement in Pears (*Pyrus bretschneideri*). *Agronomy*, *13*(9), Article 2409. https://doi.org/10.3390/agronomy13092409

Martins, J. S., Melo, E. M., Fallavena, L. P., & Hertz, P. F. (2019). Avaliação nutricional de Butiá (*Butia yatay*) processado. *Segurança Alimentar Nutricional*, *26*(1), Article e019012. https://doi.org/10.20396/san.v26i0.8654389

McGuire, R. G. (1992). Reporting of objective color measurements. *HortScience*, *27*(12), 1254–1255. https://www.doi.org/10.21273/HORTSCI.27.12.1254

Mistura, C. C., Barbieri, R. L., Castro, C. M., Padulosi, S., & Alercia, A. (2015). *Descriptors for Butiá [Butia odorata (Barb.Rodr.) Noblick]*. Bioversity International.

Morais, R. A., Teixeira, G. L., Ferreira, S. R. S., Cifuentes, A., & Block, J. M. (2022). Nutritional composition and bioactive compounds of native Brazilian fruits of the Arecaceae family and its potential applications for health promotion. *Nutrients*, *14*(19), Article 4009. https://doi.org/10.3390/nu14194009

Nunes, L. S., Negão, C. A., Soua, E. C., & Silva, A. S. (2024). Estudo de mel de abelha da espécie *Apis mellifera* do nordeste do Pará. *Revista Multidisciplinar do Nordeste Mineiro*, *4*, 1-8. Retrieved from https://remunom.ojsbr.com/multidisciplinar/article/view/2262/2441

Patra, A., Abdullah, S., & Pradhan, R. C. (2022). Review on the extraction of bioactive compound and characterization of fruit industry by-products. *Bioresources and Bioprocessing*, *9*, Article 14. https://doi.org/10.1186/s40643-022-00498-3

Pereira, M. C., Steffens, R. S., Jablonski, A., Hertz, P. F., Rios, A. O., Vizzotto, M., & Flôres, S. H. (2013). Characterization, bioactive compounds and antioxidant potential of three Brazilian fruits. *Journal of Food Composition and Analysis*, *29*(1), 19–24. https://doi.org/10.1016/j.jfca.2012.07.013

Pinheiro, J. M. S. (2009). *Tecnologia pós-colheita para conservação de bananas da cultivar tropical* (Master's Dissertation). Universidade Estadual de Montes Claros.

Pizzanelli, M., & Xavier, O. (2013). *Aportes para la elaboración de una guía de buenas prácticas de la cosecha extractiva del butiá: caracterización social y estimación del potencial productivo y reproductivo del palmar de* Butia odorata *(Barb. Rodr.) Noblick de Castillos (Rocha, Uruguay)* (Doctoral Thesis). Universidad de la República.

Renuka, C., & Sreekumar, B. B. (2012). *A field guide to the palms of India*. Kerala Forest Research Institute.

Rockett, F. C., Schmidt, H. O., Schmidt, L., Rodrigues, E., Tischer, B., Oliveira, V. R., Silva, V. L., Augusti, P. R., Flôres, S. H., & Rios, A. (2020). Phenolic compounds and antioxidant activity *in vitro* and *in vivo* of *Butia* and *Opuntia* fruits. *Food Research International*, *137*, Article 109740. https://doi.org/10.1016/j.foodres.2020.109740

Schneider, L. R., Santos, D. C., Campos, A. D., & Lund, R. G. (2017). The phytochemistry and pharmacology of *Butia* sp.: a systematic review and an overview of the technological monitoring process. *Phytotherapy Research*, *31*(10), 1495–1503. https://doi.org/10.1002/ptr.5883

Schwartz, E., Fachinello, J. C., Barbieri, R. L., & Silva, J. B. (2010). Avaliação de populações de *Butia capitata* de Santa Vitória do Palmar. *Revista Brasileira de Fruticultura*, *32*(3), 736–745. https://doi.org/10.1590/S0100-29452010005000089

Sganzerla, M. (2010). *Caracterização físico-química e capacidade antioxidante do butiá* (Master's Dissertation). Universidade Federal de Pelotas.

Silva, J. L. (2017). *Compostos bioativos e capacidade antioxidante em frutos de Juazeiro armazenados sob temperatura controlada* (Master's Dissertation). Universidade Federal de Campina Grande.

Souza, F. G., Araújo, F. F., Farias, D. P., Zanotto, A. W., Neri-Numa, I. A., & Pastore, G. M. (2020). Brazilian fruits of Arecaceae family: an overview of some representatives with promising food, therapeutic and industrial applications. *Food Research International*, *138*(Part A), Article 109690. https://doi.org/10.1016/j.foodres.2020.109690

Swain, T., & Hillis, W. E. (1959). The phenolic constituents of Prunus-domestica I – the quantitative analysis of phenolic constituents. *Journal of the Science of Food and Agriculture*, *10*(1), 63–68. https://doi.org/10.1002/jsfa.2740100110

Talcott, T. S., & Howard, R. L. (1999). Phenolic autoxidation is responsible for color degradation in processed carrot puree. *Journal of Agriculture and Food Chemistry*, *47*(5), 2109–2115. https://doi.org/10.1021/jf981134n

Teixeira, R. S. (2024). *LAB Color Chart [software]*. Version: 2.0. Universidade Federal de Pelotas.

Tonietto, A., Schlindwein, G., Tonietto, S. M., Montero, C. R. S., Bender, R. J., & Shwartz, E. (2019). Caracterização de frutos de butiazeiros em populações naturais do sul do Brasil. *Pesquisa Agropecuária Gaúcha*, *25*(3), 156–166. https://doi.org/10.36812/pag.2019253146-155

Trevisan, A. C. D., Da Silva, V. L., Martins, J. S., Coelho-De-Souza, G., Severo, S. A., & Ramos, M. O. (2021). Food composition data: edible plants in the Pampa. In M. C. M. Jacob & U. P. Albuquerque (Eds), *Local food plants of Brazil* (pp. 251–270). Springer.

Vinholes, J., Lemos, G., Barbieri, R. L., Franzon, R. C., & Vizzotto, M. (2017). *In vitro* assessment of the antihyperglycemic and antioxidant properties of araçá, butiá and pitanga. *Food Bioscience*, *19*, 92–100. https://doi.org/10.1016/j.fbio.2017.06.005

Wagner, J. G. (2024). *Caracterização e funcionalidades de recursos genéticos de butiá (Arecaceae)* (Doctoral Thesis). Universidade Federal de Pelotas, Pelotas.

Wagner, J. G., Cruz, J. G., Silveira, T., Ferri, N. M. L., Tichter, V. B., Lima, F. M., Figueira, K. U., Mistura, C. C., Vizzotto, M., & Barbieri, R. L. (2022a). Accessing the nutritional variability of *Butia odorata*: a food with identity. *Food Science and Technology*, *42*, Article e54822. https://doi.org/10.1590/fst.54822

Wagner, J. G., Ferri, N. M. L., Lucas, J. V., Heiden, G., Vizzotto, M., & Barbieri, R. L. (2022b). Herança alimentar: investigação do uso e da variabilidade físico-química do butiá-da-serra (*Butia eriospatha*, Arecaceae). *Revista Ambientes em Movimento*, *2*(1), 31–34.

Zaccari, F., Del Puerto, M., & Bacrera, M. C. (2021). Butiá: propiedades físicas, nutricionales y antioxidantes de frutos rojos, anaranjados y amarillos. *Agrociencia Uruguay*, *25*(2), Article e789. https://doi.org/10.31285/AGRO.25.789