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EFFECTS OF SOIL PHYSICAL AND CHEMICAL PROPERTIES ON THE MINERAL COMPOSITION OF PEQUI FRUITS (*Caryocar brasiliense* Camb.)[1]

EFEITOS DAS PROPRIEDADES FÍSICAS E QUÍMICAS DO SOLO NA COMPOSIÇÃO MINERAL DE FRUTOS DE PEQUIZEIRO (*Caryocar brasiliense* Camb.)[1]

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ABSTRACT - To enable the rational economic exploitation of native fruit species from the Cerrado biome, it is essential to understand their chemical characteristics and their interactions with the environments in which they thrive better. This study aimed to determine the effects of physical and chemical parameters of three soil types (Ferritic Ferralsol, Dystric Arenosol, and Plinthosol) from the municipality of Jataí (GO) on the chemical composition of the pulp of pequi fruits (*Caryocar brasiliense*). Fruit collection was carried out from pequi trees in areas selected based on the criteria of minimal anthropogenic interference, typical cerrado vegetation, and high occurrence of the studied fruit species. In each selected area, four trees (Plinthosol) and eight trees (Ferritic Ferralsoil and Dystric Arenosols) were chosen, distributed within an imaginary square of 30,000 m², and five fruits were collected from each tree, based on the cardinal points and the center. Soil samples were taken from the area beneath the tree canopy. Despite the differences among the various soil types, the collected fruits differed only in lipid, copper and manganese levels, with no statistically significant correlation established between soil type and the chemical composition of pequi fruits. This stability is likely due to the species adaptive and metabolic strategies, which enable the plants to maintain a relatively constant fruit composition even under varying edaphic conditions.

Keywords: Cerrado fruits; Genetic variability; Plant-soil relationship.

RESUMO - Para que se possa iniciar o aproveitamento econômico racional das frutíferas nativas do Cerrado é necessário conhecer melhor suas características químicas bem como as interações com os ambientes nos quais vivem. O presente trabalho teve como objetivo determinar os efeitos de parâmetros físicos e químicos de três tipos de solo (Latossolo Vermelho, Neossolo Quartzarênico e Plintossolo) oriundos do município de Jataí (GO) na composição química da polpa de frutos de pequizeiro (*Caryocar brasiliense*). A coleta dos frutos foi realizada em pequizeiros em áreas selecionadas principalmente segundo os critérios menor ação antrópica possível, área com formação típica do cerrado e maior ocorrência da espécie frutífera estudada. Em cada uma das áreas escolhidas foram selecionadas quatro (Plintossolo) e oito (Latossolo e Neossolo) árvores, dispostas dentro de um quadrado imaginário com 30.000 m^2, e coletados cinco frutos de cada árvore, de acordo com os pontos cardeais e o centro. As amostras de solo foram retiradas na área coberta pela copa das árvores. Apesar das diferenças entre os diferentes tipos de solo, os frutos coletados nos diferentes solos diferiram somente quanto aos níveis de lipídios, cobre e manganês, não sendo possível estabelecer correlação estatística entre os diferentes tipos de solo e a composição química dos frutos de pequizeiro. Provavelmente, devido a suas estratégias adaptativas e metabólicas, as plantas podem manter uma composição relativamente estável dos frutos, mesmo em diferentes condições edáficas.

Palavras-chave: Frutas do cerrado; Variabilidade genética; relação solo-planta.

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1 INTRODUCTION

Several species of the Caryocar genus are popularly known by names such as "pequi," "piqui," "piquiá," and "piquivinagreiro," reflecting the fact that Brazil is the center of dispersion for this genus (Oliveira et al. 2008). Of the sixteen species belonging to the Caryocar genus, twelve are found in Brazil. The pequi tree (*Caryocar brasiliense* Cambess) is a typical and native species of the Brazilian Cerrado, thriving in all physiognomies of the region: dense cerrado (cerradão), typical cerrado (cerrado sensu stricto), and shrubby grassland (campo sujo) (Chaves et al. 2017).

The pequi tree is an arboreal species, reaching heights of 8 to 12 meters, with variations depending on environmental conditions (Oliveira, 2008). This species has opposite, trifoliate leaves and terminal raceme inflorescences with 10 to 30 cream-yellow, hermaphroditic flowers, featuring five sepals, five petals, and over 200 stamens. Flowering typically occurs from June to September, with fruiting from November to December in the central regions of the Cerrado (Oliveira et al. 2008, Oliveira e Scariot 2010).

The fruit is a drupe, weighing an average of 104.4 grams, and, when ripe, has an epicarp that ranges from light green to slightly yellow. The endocarp is rigid and spiny, while the pulp covering the seeds is usually yellow (most common), but can also be orange, pink, or whitish. The pulp is pasty, starchy, and oily. In most cases, each fruit contains only one developed seed, although up to four seeds can occasionally be found. The mature fruit's peel accounts for approximately 84% of its weight, the pulp represents 10%, and the seed constitutes 6% (Oliveira et al. 2008, Oliveira e Scariot 2010, Chaves et al. 2017).

The physical and chemical characteristics of *Caryocar brasiliense* fruits vary according to their region of origin and the climatic conditions in which they are cultivated (Alves et al. 2014, Costa e Costa 2023). The pulp is rich in carotenoids and phenolic compounds (Nascimento et al. 2017), containing approximately 30% edible oil, 10% total dietary fiber, and 3% protein (Lima et al. 2007, Paz et al. 2014 and Lopes et al. 2017). Additionally, it can be considered a source of iron, zinc, magnesium, and calcium (Mariano-da-Silva et al. 2009, Ramos e Souza 2011, Alves et al. 2014).

The pequi fruit is widely consumed by populations living in its natural distribution regions, providing significant energy and nutritional contributions, especially for low-income families during the harvest season (Oliveira et al. 2008). The most consumed part of the fruit is the kernel, usually cooked and served with rice or chicken. The pulp is used to produce preserves, milk-based drinks, jams, sweets, popsicles, animal feed, oil, and even liqueurs. The almond is used as an ingredient in farofas and sweets, or salted and consumed as a snack (Chaves et al. 2017).

As an oilseed, oil extracted from the pulp is not only used in cooking but also in the lubricant and cosmetic industries (e.g., soap, shampoos, and creams). It is also valued for medicinal purposes, such as treating bronchitis, colds, and flu, among other ailments (Oliveira et al. 2008, Oliveira e Scariot 2010, Lopes et al. 2017).

To enable the rational economic exploitation of native fruits from the Cerrado, it is essential to gain a deeper understanding of their chemical composition and the interactions between these fruits and the environments in which they grow. Studying the influence of soil on the composition of *Caryocar brasiliense* fruits is crucial for understanding the nutritional and functional variations of this native species. Soil nutrient availability can directly impact the physicochemical properties of the fruits, influencing the levels of bioactive compounds such as carotenoids and phenolics, as well as the concentration of essential minerals. A better understanding of these interactions can contribute to the development of optimized management and conservation strategies, while also enhancing the nutritional and economic value of the fruits. This, in turn, promotes their potential for human consumption and various industrial applications.

This study aims to characterize certain chemical parameters of pequi fruits from different soil types in the municipality of Jataí (GO), as well as to explore possible interrelations between the fruit composition and the soil's physical-chemical properties.

2 MATERIALS AND METHODS

Selection of the Study Area - The fruit collection was conducted in the municipality of Jataí (GO) from pequi trees (*Caryocar brasiliense*) originating from three different soil types: Ferritic Ferralsol, Dystric Arenosol, and Plinthosol. The areas were selected based on the following criteria: minimal anthropogenic influence, typical cerrado vegetation, and high occurrence of the fruit species under study. Once the trees were selected, their locations were marked using GPS (Global

Positioning System). A brief soil classification in the study areas was performed following the methodology described by Resende et al. (2002) e Embrapa (2006).

Fruit Collection - The fruits were collected between November and December, using mature pequi fruits (*Caryocar brasiliense*) for the study. In each of the selected areas, 4 to 8 trees were chosen within an imaginary square of 30,000 m². Five fruits were collected from each tree, based on the cardinal points and the center. After collecting, the fruits were immediately placed in paper bags and transported to the laboratory.

Soil Collection - Soil samples were collected using a soil probe, digger, and heavy auger from the area under the canopy of the trees. Each sample consisted of 10 spatially well-distributed subsamples, taken at a depth of 0 to 20 cm from points beneath the canopy of each tree (Chitolina et al. 2009). After collection, the subsamples were thoroughly mixed to obtain a composite sample, which was then placed in a specific plastic bag, labeled, and kept in the shade until transportation to the laboratory.

Preparation of Solutions - To minimize potential contamination, all solutions were prepared using deionized water and all reagents used for the analyses were of analytical grade ("P.A.").

Preparation of Laboratory Materials - All reusable laboratory materials were pre-soaked for 4 hours in a washing solution (HNO_3:HCl:water in a 1:2:9 ratio) and subsequently rinsed with deionized water (McDaniel 1992).

Figure 1. Localization of the study area (Jataí, Goiás State-Brazil). Source: Jataí, 2025.

Figura 1. Localização da área do estudo (Jataí, Goiás, Brasil). Fonte: Jataí, 2025.

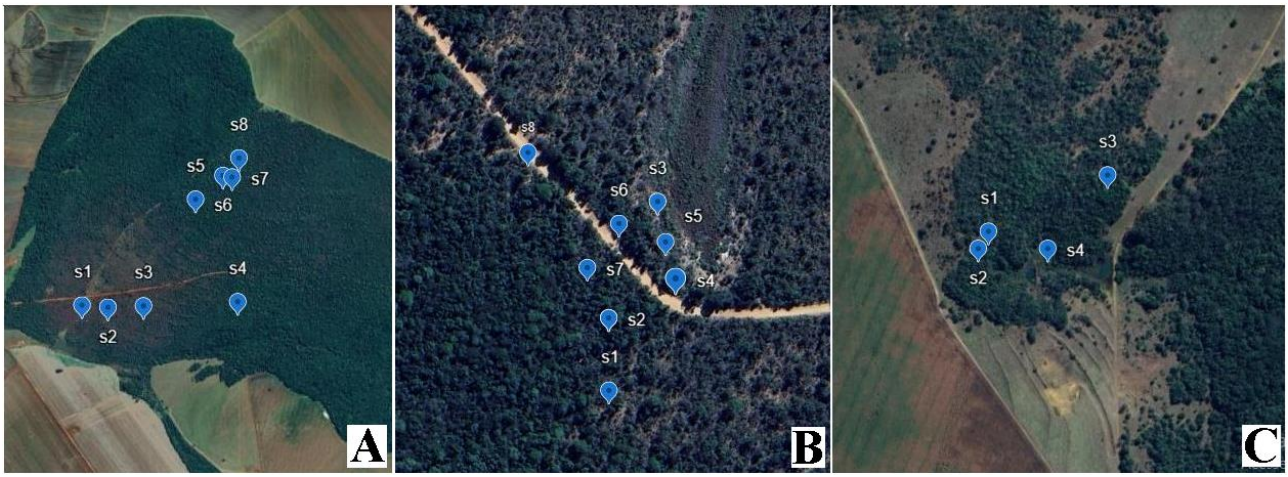

Figure 1. Aerial photos of each sampling areas: A) Ferritic Ferralsol (s1 17º46'57''S 51º35'49''W, s2 17º46'58''S 51º35'44''W, s3 17º46'57''S 51º35'36''W, s4 17º46'36''S 51º35'17''W, s5 17º46'31''S 51º35'26''W, s6 17º46'32''S 51º35'20''W, s7 17º46'30''S 51º35'18''W and s8 17º46'28''S 51º35'17''W), B) Dystric Arenosol (s1 17º43'09''S 51º28'22''W, s2 17º43'07''S 51º28'22''W, s3 17º43'04''S 51º28'21''W, s4 17º43'06''S 51º28'21''W, s5 17º43'05''S 51º28'21''W., s6 17º43'04''S 51º28'22''W, s7 17º43'06''S 51º28'23''W and s8 17º43'02''S 51º28'25''W) and C) Plinthosol (s1 17º40'51''S 51º28'43''W, s2 17º40'52''S 51º28'43''W, s3 17º40'47''S 51º28'34''W and s4 17º40'52''S 51º28'38''W). Source: Google Earth, 2025.

Figura 1. Aerial photos of each sampling areas: A) Ferritic Ferralsol (s1 17º46'57''S 51º35'49''W, s2 17º46'58''S 51º35'44''W, s3 17º46'57''S 51º35'36''W, s4 17º46'36''S 51º35'17''W, s5 17º46'31''S 51º35'26''W, s6 17º46'32''S 51º35'20''W, s7 17º46'30''S 51º35'18''W and s8 17º46'28''S 51º35'17''W), B) Dystric Arenosol (s1 17º43'09''S 51º28'22''W, s2 17º43'07''S 51º28'22''W, s3 17º43'04''S 51º28'21''W, s4 17º43'06''S 51º28'21''W, s5 17º43'05''S 51º28'21''W., s6 17º43'04''S 51º28'22''W, s7 17º43'06''S 51º28'23''W and s8 17º43'02''S 51º28'25''W) and C) Plinthosol (s1 17º40'51''S 51º28'43''W, s2 17º40'52''S 51º28'43''W, s3 17º40'47''S 51º28'34''W and s4 17º40'52''S 51º28'38''W). Fonte: Google Earth, 2025.

Preparation of Soil Samples - Upon arrival at the laboratory, the soil samples were removed from the plastic bags, spread onto trays, and subjected to air-drying in the shade for 12 hours. They were then sieved through a 2.0 mm mesh to separate gravel and pebbles, as proposed by Resende et al. (2002). The sieved soil was further air-dried at room temperature (24 hours) and subsequently stored in polypropylene containers until analysis.

Measurement of Soil pH (SMP) - From the stock sample, 10 mL of soil was weighed into an 80 mL polypropylene container. Following the methodology proposed by Silva et al. (2009), 25 mL of a 0.01 M $CaCl_2$ solution was added, and the mixture was manually stirred with a glass rod for 15 minutes to ensure complete wetting of the sample. After 30 minutes, 5 mL of SMP buffer solution was added, and the mixture was agitated at 220 RPM for 15 minutes. After resting for 1 hour, the pH was measured using direct potentiometry with a Digimed combined electrode potentiometer.

Determination of Soil pH - From the stock sample, 10 mL of soil was weighed into an 80 mL polypropylene cup. Following the methodology proposed by Silva (2009), 25 mL of a 0.01 M $CaCl_2$ solution was added, and manual stirring was performed with a glass rod for 15 minutes to ensure complete wetting of the sample. After 30 minutes, the pH was measured by direct potentiometry using a Digimed combined electrode potentiometer.

Determination of Calcium and Magnesium in Soil Samples - From the stock sample, 5 mL of soil was weighed. Following Silva et al. (2009) methodology, the sample was subjected to extraction with 1 N Potassium Chloride (KCl) and diluted 1 mL of the supernatant at a 1:20 ratio with a 2.5% Lanthanum solution (H_2O + Lanthanum Oxide + HCl) after resting for 16 hours. The resulting extract was analyzed by atomic absorption spectrophotometry with acetylene flame atomization using a Perkin Elmer Analyst 100 spectrophotometer.

Determination of Aluminum in Soil Samples - From the stock sample, 5 mL of soil was weighed and subjected to extraction with 1 N Potassium Chloride (KCl). After resting for 16 hours, 10 mL of the supernatant was separated, to which 10 mL of water and three drops of Bromothymol Blue indicator were added. The sample was then titrated with 0.01 N NaOH (Silva et al. 2009).

Determination of Phosphorus in Soil Samples - From the stock sample, 10 mL of soil was weighed. Following Silva et al. (2009) methodology, the sample was extracted using a Mehlich extractor (0.025 N H_2SO_4 + 0.05 N HCl solution). After resting for 16 hours, 5 mL of the supernatant was collected, to which 10 mL of Ammonium Molybdate solution (subcarbonate of bismuth + H_2O + H_2SO_4) and 0.08 g of ascorbic acid were added. The samples were shaken horizontally for 5 minutes at 220 RPM and then left to rest for 1 hour. The color intensity was measured in an ANALYSER brand colorimeter at 660 nm.

Determination of Potassium Levels in Soil Samples - From the stock sample, 10 mL of soil was weighed. Following the methodology proposed by Silva et al. (2009), the sample was subjected to extraction using a Mehlich extractor (0.025 N H_2SO_4 + 0.05 N HCl solution). After resting for 16 hours, 15 mL of the supernatant was collected and measured using flame photometry (LPG gas) in an ANALYSER brand flame spectrophotometer.

Determination of Copper, Iron, Manganese, and Zinc Levels in Soil Samples - From the stock sample, 10 mL of soil was weighed and subjected to extraction using a Mehlich extractor (0.025 N H_2SO_4 + 0.05 N HCl solution), following the methodology proposed by Silva et al. (2009). The sample was left to rest for 16 hours, after which 15 mL of the supernatant was collected and analyzed by atomic absorption spectrometry with acetylene flame atomization using a Perkin Elmer Analyst 100 atomic absorption spectrophotometer.

Determination of Organic Matter in Soil Samples - From the stock sample, 1 mL of soil was weighed. Then, 10 mL of a 1:1 solution of $Na_2Cr_2O_7$ 4N + H_2SO_4 10N was added, and the mixture was agitated at 180 RPM for 10 minutes. After resting for 1 hour, 50 mL of water was added, and the mixture was left to rest for an additional 14 hours (Raij et al. 2001). The color intensity was measured using an ANALYSER brand colorimeter at 650 nm.

Determination of Boron in Soil Samples - From the stock sample, 10 mL of soil was weighed into polypropylene bags. Following the methodology proposed by Silva et al. (2009), 20 mL of barium chloride extracting solution and 0.5 g of activated charcoal were added. The samples were then placed in a microwave oven and subjected to maximum power (700W) for 4 minutes, followed by medium-high power (490W) for 5 minutes. After resting for 30 minutes, the samples were filtered using filter paper. From the filtrate, 4 mL of aliquot was transferred to borosilicate test tubes, and 1 mL of buffer solution was added. Subsequently, 1 mL of Azomethine-H solution (ascorbic acid + H_2O) was added, manually agitated, and left to rest in the dark for 30 minutes. The color intensity was measured by spectrophotometry at 420 nm using a spectrophotometer.

Determination of Sulfur in Soil Samples - From the stock sample, 10 mL of soil was weighed. Following the methodology proposed by Silva et al. (2009), 25 mL of an extracting solution was added, and the mixture was agitated for 30 minutes. Then, 0.25 g of activated charcoal was mixed in, followed by agitation for 3 minutes. After filtering the mixture, another 0.25 g of activated charcoal was added to obtain a clear supernatant free of impurities and suspended particles. Subsequently, 10 mL of the supernatant was placed into test tubes, and 1 mL of 6.0 M HCl solution containing 20 mg of sulfur and 500 mg of barium chloride was added. After resting for 1 minute, the samples were agitated for 30 seconds to ensure complete dissolution of the barium chloride crystals. The color intensity was measured using an ANALYSER brand colorimeter at 420 nm.

Determination of Soil Texture (Clay, Silt, and Sand) - The soil texture was determined by granulometric analysis following the methodology proposed by Kiehl (1979).

Determination of Cation Exchange Capacity (CEC) in Soil Samples - The cation exchange capacity was determined using the methodology proposed by Kiehl (1979), which employs buffered saline solutions.

Determination of Organic Matter in Soil Samples - Organic matter was determined according to the methodology proposed by Raij et al. (2001), which is based on the oxidation of organic matter by dichromate ions in a strongly acidic medium.

Determination of Protein Content in Pequi Samples - From the stock sample, 0.50 g was subjected to peroxide-perchloric digestion (H_2O_2:$HClO_4$ at a 2:1 ratio) following the methodology proposed by Miyazawa (2009). The samples were placed in borosilicate tubes (20x250 mm) and heated at 220°C for 3 hours until complete discoloration, indicating that the material was fully mineralized. The sample was then diluted 1:100 with distilled water. Once mineralized, the sample underwent distillation with 45% NaOH, and the distillate was collected in a solution of H_3BO_3 containing a mixed indicator (methyl red and bromocresol green). The distillate was subsequently titrated with standardized H_2SO_4.

Determination of Ether Extract in Pequi Samples - From the stock sample, 1.0 g was placed in a cotton extraction cartridge and subjected to extraction with nonpolar solvents, followed by evaporation of the solvent used (Pregnolattoe and Pregnolato 2008).

Determination of Phosphorus in Pequi Samples - From the stock sample, 0.50 g was subjected to peroxide-perchloric digestion (H_2O_2:$HClO_4$ at a 2:1 ratio) following the methodology proposed by Miyazawa et al. (2009). The samples were placed in borosilicate tubes (20x250 mm) and heated at 220°C for 3 hours until complete discoloration, indicating that the material was mineralized. The sample was then diluted 1:100 with distilled water, followed by the addition of 2 mL of Ammonium Metavanadate (0.25%) and 2 mL of Ammonium Molybdate (5%). After a 15-minute resting period, the color intensity was measured using an ANALYSER brand colorimeter at 660 nm.

Determination of Potassium in Pequi Samples - Following the methodology proposed by Miyazawa et al. (2009), 0.50 g of a previously mineralized sample (digestion with H_2O_2:$HClO_4$ at a 2:1 ratio at 220°C for 3 hours) was diluted 1:100 with distilled water. The potassium content was determined using flame photometry (LPG gas) in an Analyst 100 flame spectrophotometer.

Determination of Calcium, Magnesium, and Sulfur in Pequi Samples - Following the methodology proposed by Miyazawa et al. (2009), 0.50 g of a previously mineralized sample (digestion with H_2O_2:$HClO_4$ at a 2:1 ratio at 220°C for 3 hours) was diluted 1:100 with distilled water and then further diluted 1:50 with a 2.5% Lanthanum solution. The metal contents were analyzed using atomic absorption spectrophotometry with acetylene flame atomization in a Perkin Elmer Analyst 100 atomic absorption spectrophotometer.

Determination of Copper, Iron, Manganese, and Zinc in Pequi Samples: Following the methodology proposed by Miyazawa et al. (2009), 0.50 g of a previously mineralized sample (digestion with H_2O_2:$HClO_4$ at a 2:1 ratio at 220°C for 3 hours) was diluted 1:100 with distilled water. The metal concentrations were analyzed using atomic absorption spectrophotometry with acetylene flame atomization in a Perkin Elmer Analyst 100 atomic absorption spectrophotometer.

Statistical Analysis - Analysis of variance (F-test) was used to evaluate the treatment factors, followed by an analysis under a fractional factorial scheme with crossed classification. Comparisons among the means of the main effect levels were performed using Tukey's multiple comparison test (Pimentel-Gomes 2000), while the interaction effects were analyzed through linear regression analysis and determination of the coefficient of determination (Souza 1998).

3 RESULTS AND DISCUSSION

The fruits exhibited variation in the number of putamens, ranging from 1 to 3, although the majority contained a single putamen (88.75%). These putamens housed only one seed each. The predominance of one putamen per fruit and a single seed per putamen is consistent with findings reported by other authors (Vera et al. 2005, Carvalho 2008, Luz et al. 2011).

In Table 1, the mineral content of the pulp (mesocarp) of different pequi samples is presented, highlighting the richness of this fruit in various mineral elements. This is evident when comparing these data with values previously reported for

economically cultivated fruits (IBGE 2011), as previously noted by Mariano-da-Silva et al. (2009).

When comparing the values in Table 1 with those in Table 2, which shows the daily mineral intake recommendations by Franco (2001), Padovani et al. (2006), WHO (2006) and NRD (2023), pequi fruit contains significant levels of potassium, magnesium, copper, and manganese. Desta maneira, estudos adicionais are recommended to explore the use of pequi fruit as an alternative complementary source of these minerals.

The lipid concentrations found in this study align with those reported in the literature, while the protein concentrations were higher (Rodrigues et al. 2004, Lima et al. 2007, Mariano-da-Silva et al. 2009, Santos et al. 2010, Cardoso 2011, Ribeiro 2012, Cordeiro et al. 2013, Paula-de-Almeida et al. 2022, TBCA 2023). Although pequi pulp is considered rich in fatty acids, Jesus (2014) had already noted the heterogeneity in centesimal composition reported in studies.

Lipid concentrations in fruits from different soil types differed statistically in the present study, with the highest concentrations observed in fruits collected from areas with Plinthosol (43.07%) and Ferritic Ferrasol (43.07%), and the lowest in areas with Dystric Arenosol (36.68%). Vera et al. (2007), despite not characterizing the soils of the studied regions, also reported differences in lipid content in fruits obtained from the municipalities of Araguapaz and Mambaí, in the state of Goiás. The authors attributed these differences to varying edaphoclimatic conditions and genetic variability among plants. In general, nutrient-poor and dry soils may lead to lower lipid content due to oxidative stress, whereas more fertile and moist soils, such as those with medium to clayey texture, may promote fruits with higher lipid levels due to greater availability of essential nutrients.

However, as demonstrated by Bertolino et al. (2019), pequi oil exhibits lower unsaturation compared to other edible oils, offering greater oxidative rancidity stability. Lorenzo et al. (2020) determined that the most abundant fatty acids are palmitic, oleic, and linoleic acids, which have low atherogenic potential, enhancing the functional quality index of pequi oil.

The calcium and phosphorus contents did not significantly differ among fruits collected from the three soil types, although calcium levels tended to be lower in fruits from Plinthosols. While Angeloni et al. (2004) and Ramos and Souza (2011) reported calcium levels similar to those found in this study, Jesus (2014) reported much lower levels. Phosphorus levels align with those reported by Angeloni et al. (2004) and Mariano-da-Silva et al. (2009) but are higher than those reported by Ramos and Souza (2011). No significant differences were detected in the iron content of fruits from different soil types. The iron levels found in this study are consistent with those reported in the literature (Brait 2003, Angeloni et al. 2004, Mariano-da-Silva 2009, Ramos and Souza 2011). Angeloni (2004) and Mariano-da-Silva et al. (2009) reported potassium, magnesium, and sulfur levels like those found here, but Ramos and Souza (2011) reported much lower magnesium concentrations. Brait (2003), Angeloni et al. (2004) and Mariano-da-Silva et al. (2009) observed copper, manganese, and zinc levels similar to those in this study. However, Ramos and Souza (2011) found higher averages of zinc and manganese.

Table 3 presents the mineral content of the different soils analyzed, along with organic matter content (OMC), clay, silt, and sand levels, cation exchange capacity (CEC), base saturation, aluminum saturation, calcium in CEC (Ca/CEC), magnesium in CEC (Mg/CEC), potassium in CEC (K/CEC), hydrogen + aluminum (H + Al), hydrogen + aluminum in CEC (H + Al in CEC), and soil pH.

Table 1. Protein content (PB), ether extract (EE), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) in dry matter (DM) from different pequi fruits samples, collected from trees located in three soil types in the municipality of Jataí (GO).

Tabela 1. Médias dos teores de proteína (PB), estrato etéreo (EE), fósforo (P), potássio (K), cálcio (Ca), magnésio (Mg), enxofre (S), cobre (Cu), ferro (Fe), manganês (Mn) e zinco (Zn) na matéria seca (MS) nas diferentes amostras de pequi, coletadas em arvores localizadas em três tipos de solos no município de Jataí (GO).

SOIL	PB (% MS)	EE (%MS)	P (g/kg)	K (g/kg)	Ca (g/kg)	Mg (g/kg)	S (g/kg)	Cu (g/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
FERRITIC FERRALSOL	6,29*	43,07a	1.73*	12.03*	1.23*	1.14*	0.63*	7,50b	0.033*	0. 021b	0.028
DYSTRIC ARENOSOL	5,75*	36,68ab	1.63*	12.17*	1.14*	1.19*	0.65*	12,12a	0.027*	0.059a	0.020*
PLINTHOSOL	4,93*	58,87a	1.36*	6.58*	0.71*	0.91*	0.37*	7,75b	0.030*	0. 011b	0.014*
Standard derivation (%)	17,757	20,695	17,779	24,062	17,197	21,844	20,815	18,176	19,962	19,866	16.638

Means followed by the same letters in the same row do not differ according to Tukey's test at 95% confidence.
* Not significant at 95% confidence.

Médias seguidas de letras iguais, em uma mesma linha, não diferem entre si de acordo com o teste de Tukey à 95% de confiança.
* Não significativo a 95% de confiança.

Table 2. Daily Human Requirements for Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Barium (Ba), Copper (Cu), Iron (Fe), Manganese (Mn), and Zinc (Zn).

Tabela 2. Necessidades humanas diárias de fósforo (P), potássio (K), cálcio (Ca), magnésio (Mg), bário (Ba), cobre (Cu), ferro (Fe), manganês (Mn) e zinco (Zn).

	P mg	K mg	Ca mg	Mg mg	Ba mg	Cu mg	Fe mg	Mn mg	Zn mg
WHO	-	-	400–500	300	-	-	10–20	2–3	10– 5
Franco	1200	3750	1200	280–350	2–7	2–3	5–28	–	12–15
NRD	-	2000	800–1200	280	-	-	10–15	2–5	12–15
Padovani	580–1055	–	1200–1300	350-420	-	0,6-0,9	5–8,0	1,3-2,9	9,4

Source: WHO 2006, NRD 2023, Franco 2001, Padovani et al. 2006

Fonte: WHO 2006, NRD 2023, Franco 2001, Padovani et al. 2006

Table 3. Clay content, silt, sand, cation exchange capacity (CEC), base saturation, aluminum saturation, calcium at CEC (Ca/CEC), magnesium at CEC (Mg/CEC), potassium in CEC (K/CEC), hydrogen + aluminum (H+Al), hydrogen + aluminum at CEC (H + Al at CEC), ionic hydrogen potential (pH), organic matter (OMS), phosphorus, potassium, magnesium (Mg), sulfur (S), cooper (Cu), iron (Fe), manganese (Mn) and zinc in dry matter in soil samples collected beneath the canopy of *Caryocar brasiliense* trees located in three different soil types in the municipality of Jataí (GO).

Tabela 3. Teores de argila, silte, areia, capacidade de troca de cátions (CTC), saturação de bases, saturação de alumínio, cálcio na CTC (Ca/CTC), magnésio na CTC (Mg/CTC), potássio na CTC (K/CTC), hidrogênio + alumínio (H + Al), hidrogênio + alumínio na CTC (H + Al na CTC), potencial hidrogênio iônico (pH), matéria orgânica (OMS), fósforo (P), potássio (K), magnésio (Mg), enxofre (S), cobre (Cu), ferro (Fe), manganês (Mn) e zinco (Zn) na matéria seca (MS) nas amostras de solo coletadas sobre a copa de pequizeiros localizados em três tipos de solo no município de Jataí (GO).

SOIL	Clay (g/kg)	Silt (g/kg)	Sand (g/kg)	CEC (cmol/kg)	Base saturation (%)	Aluminum saturation (%)	Ca/ CEC (%)	Mg/ CEC (%)
FERRITIC FERRALSOL	567,50a	70,00a	362,50c	9,29a	7,51*	49,30*	3,81*	2,58*
DYSTRIC ARENOSOL	201,25c	41,25b	757,50a	4,70b	8,16*	56,85*	4,48*	2,54*
PLINTHOSOL	340,00b	50,00bc	610,00b	8,70a	8,03*	52,60*	4,05*	2,88*
Standard derivation (%)	16,897	18,452	10,923	12,124	20,488	12,791	14,473	16,185

SOIL	K/ CTC (%)	pH $CaCL_2$	H + Al	H+Al / CTC	OMS (%)	P (mmol/Kg)	K (mmol/Kg)
FERRITIC FERRALSOL	1,15*	4,01*	8,61a	92,48*	3,85*	0,02*	1,05a
DYSTRIC ARENOSOL	1,18*	3,99*	4,32b	91,83*	2,18*	0,02*	0,54b
PLINTHOSOL	1,10*	3,91*	8,00a	92,49*	3,83*	0,02*	0,98a
Standard derivation (%)	20,393	2,624	13,311	1,725	12,323	19,489	14,825

SOIL	Ca (mmol/Kg)	Mg (mmol/Kg)	S (mmol/Kg)	Cu (mmol/Kg)	Fe (mmol/Kg)	Mn (mmol/Kg)	Zn (mmol/Kg)	B (mmol/Kg)
FERRITIC FERRALSOL	3,38a	2,38a	0,29*	0,04a	3,13b	0,28*	0,01a	0,14*
DYSTRIC ARENOSOL	2,00b	1,13b	0,30*	0,01b	3,83b	0,10*	0,00b	0,08*
PLINTHOSOL	3,50a	2,50a	0,30*	0,02ab	7,87a	0,18*	0,01a	0,14*
Standard derivation (%)	14,429	14,719	8,325	11,295	19,608	19,427	19,938	12,369

Means followed by the same letters in the same row do not differ according to Tukey's test at 95% confidence.
* Not significant at 95% confidence.

Médias seguidas de letras iguais, em uma mesma coluna, não diferem entre si de acordo com o teste de Tukey à 95% de confiança
* Não significativo a 95% de confiança.

Although the results show clear differences among the three soil types analyzed (Ferritic Ferralsol, Dystric Arenosol, and Plinthosol), particularly in patterns reflecting soil fertility (CEC, macro- and micronutrient concentrations), no statistical relationship could be established between the mineral content of the fruits and that of the soils (Table 4). Linear regression analyses showed a determination coefficient below 0.75.

These results appear to corroborate the conclusions of the study conducted by Ramos e Souza (2011), who assessed the variability in the chemical and nutritional characteristics of fruits from six populations of *Caryocar brasiliense* occurring in the states of Maranhão and Piauí (Mid-North and Northern regions of Brazil). The authors highlight that their findings demonstrated the inability to establish a clear relationship between the observed variability among populations and the location and climate data of their occurrence sites.

Although different soil types may influence the chemical composition of *Caryocar brasiliense* fruits (Alves et al., 2014), in some cases, this influence may not be as evident or significant due to various factors, such as the plant's adaptation to environmental conditions and the species' metabolic strategies.

Table 4. Coefficient of determination (R^2) obtained from the relationship of statistically significant sub-levels (F-test) within the sources of variation at each level.

Tabela 4. Coeficiente de determinação (R^2) obtidos a partir da relação dos sub-níveis estatisticamente significativos (teste de F) dentro das causas de variação de cada nível.

parameters	R^2 value	parameters	R^2 value	parameters	R^2 value
EE x clay	0.0193	Cu x clay	0.4355	Mn x clay	0.2417
EE x silt	0.0051	Cu x silt	0.3402	Mn x silt	0.1885
EE x sand	0.0188	Cu x sand	0.4597	Mn x sand	0.2551
EE x CEC	0.0702	Cu x CTC	0.5552	Mn x CTC	0.3019
EE x H + Al	0.0656	Cu x H + Al	0.5423	Mn x H + Al	0.2915
EE x OMS	0.1259	Cu x OMS	0.5618	Mn x OMS	0.3892
EE x K	0.1102	Cu x K	0.6292	Mn x K	0.3398
EE x Ca	0.1630	Cu x Ca	0.5415	Mn x Ca	0.3984
EE x Mg	0.1353	Cu x Mg	0.5194	Mn x Mg	0.3837
EE x Cu	0.0034	Cu x Cu	0.1582	Mn x Cu	0.0983
EE x Fe	0.3309	Cu x Fe	0.0505	Mn x Fe	0.0844
EE x Zn	0.2257	Cu x Zn	0.4831	Mn x Zn	0.3089

The pequi tree is a species adapted to low-fertility soils, possessing a deep root system that allows it to explore layers richer in nutrients (Naves et al. 2010, Miranda et al. 2016, Gonçalves and Aquino 2021). The plant has low nutritional requirements (Carlos et al. 2014, Venturin et al. 2014), and, like other native species of the Brazilian savanna (cerrado), it may be capable of regulating the allocation of nutrients in the fruits, maintaining a balance even under different edaphic conditions. (Haridasan 2008). Furthermore, the pequi tree can form associations with arbuscular mycorrhizal fungi (Reis 1999), which enhance nutrient absorption, mitigating the direct effects of soil composition.

4 CONCLUSIONS

It was not possible to establish a statistical correlation between the different soil types and the chemical composition of pequi fruits. The pequi tree appears to possess adaptive strategies that minimize the effects of the physical and chemical differences of the studied soil types. Its ability to explore nutrients at greater depths, interact with beneficial microorganisms, and regulate its metabolism seemingly contributed to the relatively stable composition of the fruits, even in different soil types.

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