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## Biometric and physical-chemical analysis of pequis collected in the state of Mato Grosso.

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**Abstract.** Commonly found in Mato-grossense Cerrado, the pequi tree (*Caryocar brasiliense* Camb) produces a fruit called pequi, which is sold and consumed by the population where it is produced, in cream, candies, ice creams or *in natura*, as a typical regional side dish. It is a highly nutritious fruit and hence necessary to the population. The aim of this study was to proceed with the biometric and physical-chemical analysis of pequis collected in the north of the state of Mato Grosso, to contribute with a database to help identify good genotypes for commercial and industry usage, to build a germplasm bank. Whole fruits from seven different matrixes of *Caryocar brasiliense* Camb were randomly collected in União do Sul-MT, seasons 2017 and 2019. The mass, transverse diameter, longitudinal diameter, volume and sphericity of fruits and pyrenes have been determined, as well as the number of pyrenes per fruit and pulp mass. The pulp was analyzed for its moisture, pH, total titratable acidity and soluble solids contents. The physical evaluation for fruits and pyrenes show that the observed matrixes had statistically significant differences in all parameters tested, especially on mass, volume and pulp mass. The pequis from matrix 7 have the best results for whole fruit and pyrenes mass, and also for pulp mass and pulp mass/whole fruit ratio. The results for moisture and physical-chemical analysis show that the observed matrixes presented statistically significant differences. The findings are similar to the ones detected in studies with pequis in other regions. Based on the results obtained, the fruits that have been analyzed may be regarded as of interest for business and industry, therefore may be considered to build a germplasm bank.

**Keywords:** *Caryocar brasiliense* Camb, biometrics, physicochemical characteristic, cerrado

### Introduction

With an area of about 2 millions square meters, or 22% of national territory, Cerrado is one of the biggest Brazilian biomes, where 85% is located in Planalto Central (Brazilian Central Plateau) and the remaining area in the states of Alagoas, Amazonas, Bahia, Ceará, Maranhão, Pará, Paraíba, Piauí, Rio Grande do Norte, Roraima and Sergipe (Oliveira et al., 2009; Battle-Bayer et al.; 2010). This biome is known for its richness and diversity, and for being crossed by the three biggest water basins in South America (Gonçalves, 2007; Battle-Bayer et al., 2010).

Cerrado, source of renewable natural resources, has fruit-tree species with distinctive characteristics, and its fruits present national and international potential for exploitation, sparking the interest of industries (food, pharmaceutical and cosmetic ones) in developing innovations in their products, employing the available raw material from Cerrado. Consumers have also been displaying a growing interest in products from this biome

(Morzelle, 2015; Silva & Fonseca, 2016; De Almeida et al., 2019; Reis & Schmiele, 2019).

Fruits from Cerrado species are regularly consumed chiefly by the Midwest region population, whether *in natura* or after processing, as in juices, ice cream, bread, cakes, among others. The species on this ecosystem have applications not only in food industry but also in the pharmaceutical one, for its high biotechnological interest (Oliveira & Rocha, 2008; De Almeida et al., 2019; De Oliveira et al., 2020).

From the native Cerrado species, the pequi, also known as piqui, piquiá-bravo, grão-de-cavalo, amêndoa-do-espinho, pequiá, pequiá-pedra, pequerim, suari and piquiá (Lorenzi, 2002) stands out for its pulp which is rich in vitamins (it is the richest fruit in vitamin A contents, twenty times higher than in carrots), fats (oils extracted for several purposes) and proteins. Because it is a highly nutritious fruit, it is considered necessary for the population in Cerrado (Carvalho & Burguer, 1960; Vilela, 1998; De Oliveira et al., 2020). The locals explore the fruits of the pequi

tree (*Caryocar brasiliense*), especially for oil extraction, liquor manufacturing and for cooking.

Fruit species from Cerrado have considerable morphological and genetic variability, as among as inside populations of the same species. Studies carried with pequi from different regions in Cerrado, and in the same location, have been finding a wide variety on its chemical and physical characteristics, which influences the nutrients contents (Ribeiro & Rodrigues, 2006; Vera et al., 2007). Knowing physical and physicochemical properties of a fruit enables a better understanding of the different ways of commercial and industrial exploitation, the establishment of quality and yield parameters as well as aid in machine design, equipment and genetic improvement studies (Oliveira et al., 2009).

Despite the fruit trees relevance, regarding its socio-economic potential, the awareness on the great majority of species is rather incipient. Little is known about genotype characterization, whether it is on genetic improvement area, aiming profiling material for commercial crops or for industry interest, mainly food and/or considering its nutrients contents.

Therefore, the characterization of individuals from a native population is necessary, to identify and quantify parameters of interest. This characterization must be carried in fruits of previously identified individuals, in order to evince the current variability and take these genotypes as references to other studies.

In view of the considerations above, this study aimed to characterize pequi fruits from species of *Caryocar brasiliense* native from Mato Grosso, through biometric and physicochemical analysis to contribute to a database which would help identify suitable genotypes for commercial and industrial applications, in order to build a germplasm bank.

## Methods

The fruits from pequi trees were collected during the harvest period, between October 2017 and January 2018, in União do Sul-MT (latitude: 11°31'59" S, longitude: 54°21'10" W and altitude: 350 m). Twenty (20) whole fruits were randomly collected from seven (7) matrixes of *Caryocar brasiliense*. The fruits were taken to Interdisciplinary Chemical Research Laboratory (Laboratório Interdisciplinar em Pesquisas Químicas UFMT-CUS), washed under running water to remove dirt and disinfected immersed in a 0.5% sodium hypochlorite solution for 15 minutes.

For the physical characterization of fruits, the mass (g) of whole fruits was determined in a semi-analytical scale, Digimed KN 500, and so were longitudinal, transversal and diagonal diameters measured with a digital caliper MARBERG 150 mm 6", and results expressed in millimeters (mm). The measurements followed a three-dimensional model used by Goneli et al. (2011), for volume determination (Formula 1) and sphericity percentage (Formula 2) of whole fruits.

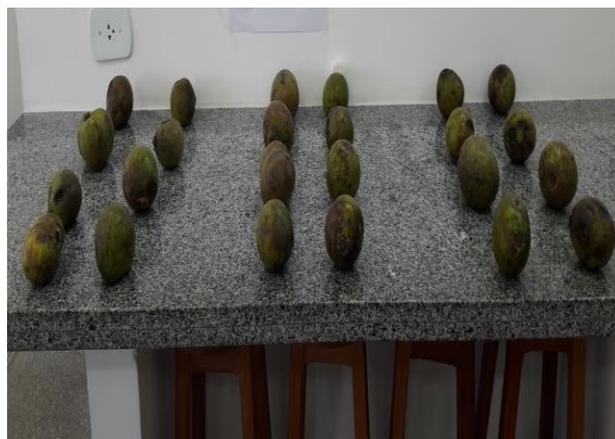


Fig. 1 Pequi fruits, washed and sanitized.

$$V = \pi(abc)/6 \quad \text{Formula 1}$$

$$E = [(abc)^{1/3}/a] 100 \quad \text{Formula 2}$$

In which:

a = longitudinal diameter, b = transversal diameter and c = diagonal diameter

The fruits were opened with a stainless steel knife previously immersed in a vitamin C solution to avoid pulp oxidation. The number of pyrenes in each fruit was registered. The pyrenes mass (g) from each fruit was determined, as well as the longitudinal, transverse and diagonal diameters, expressed in millimeters (mm). The volume and sphericity percentage of pyrenes were calculated using Formulas 1 and 2, respectively.

For pulp mass determination (g), 10 pyrenes have been randomly picked, from each matrix. Those pyrenes were individually weighed and placed in a 250 mL becker, and 100 mL of distilled water was added for cooking during 30 minutes, in hot plate. After cooking, pulp was removed and the endocarp dried until constant mass results. By the difference between pyrene and endocarp mass, the pulp mass was determined.

Moisture content measurement was carried, in triplicate, in a kiln at 105 degrees Celsius, until constant mass (IAL, 2008).

In physicochemical analysis three parameters have been tested, also in triplicate. The pH, through potentiometric method in a digital pH meter (INSTRUTHERM PH-2000), standardized with buffer solutions (pH 4.0 and pH 7.0). Soluble solids content (SS) determined via direct reading in a digital Abbe refractometer (POLAX), expressed in °Brix and Titratable acidity (TA), measured with the volumetric method by titration with standard NaOH 0.1 M solution and phenolphthalein, and results expressed in citric acid percentage (IAL, 2008).

## Statistical analysis

The results for physical, humidity content, and physicochemical analyses of pequi tree fruit have been subjected to Analysis of Variance (ANOVA) and

Tukey's average comparison test, at 5%. Statistics calculations made with software BioEstat 5.3.

## Results and discussion

The tested parameters displayed significant variations among the matrixes considered, except for soluble solids.

Knowing the physical characteristics of a fruit cooperates with a better understanding of the various commercial exploitation forms, allows quality definition and performance parameters besides aiding in machine sizing, equipment and species genetic improvement studies (Oliveira et al., 2009). Fruit size is one of the most important variables regarding the price determination of pequis, since a wide fruit is a desirable characteristic on its sales. Table 1 displays the results for physical characterization of pequis from União do Sul – MT. For whole fruit mass, the most substantial mean was in matrix 7 (297.84 g), while matrix 4 had the lowest mean on its matter (116.96 g). All means calculated in all matrixes are within the expected average values for pequi fruits, from 79.10 g until 496.13 g (Vera et al., 2005). Pequis from other states, as Tocantins (TO), Goiás (GO) and Minas Gerais (MG) have an average fruit mass of 138.7 g, 120.9 g and 191.4 g, respectively (ALVES et al., 2014). In western Bahia, fruits have a 114.41g mean for mass (Nascimento & Coccozza, 2015); 132.04 g in fruits found in Lagoa Santa-MG (Plácido et al., 2015); 187.51 g in Sete Lagoas - MG (Garcia et al., 2017); and 165.07 g and 138.8 g, respectively, in pequis from Curvelo-MG and Rio Preto-MG (Soares et al. 2017). Cordeiro (2012) observed the following mean mass results of whole fruits from four cities in Mato Grosso: 77.91 g (Acorizal); 137.29 g (Várzea Grande); 139.63 g (Cuiabá); and 187.10 g, (Santo Antônio do Leverger). These average results are lower than in fruits from matrix 7.

Transversal and longitudinal diameters are physical measurements related to fruit shape, an important trait for industry and storage. For transversal diameter, the mean found in matrix 5 (70.31 mm) was the highest, and the mean of pequis

from matrix 1 (57.90 mm), the lowest. About longitudinal diameter, matrix 7 (89.49 mm) had a superior mean value, and the fruits from matrix 4, the lowest one (60.38 mm), the same for whole fruit (Table 1). The means for transversal and longitudinal diameters, in all arrays, are within the values observed in the literature (De Oliveira et al., 2020). For transversal diameter, the mean obtained in matrix 5 is higher than what was observed in pequis from TO (56.4 mm), GO (55.2 mm), MG (63.7 mm), western Bahia (61.29 mm) and Lagoa Santa-MG (61.42 mm). The longitudinal diameter mean in fruits from TO (72.4 mm), GO (64.3 mm), MG (74.3 mm), western Bahia (63.49 mm) and Lagoa Santa-MG (63.17 mm) are lower than matrix 7's mean (Alves et al., 2014; Nascimento & Coccozza, 2015; Plácido et al., 2015).

Volume and fruit sphericity are important physical parameters for industry and commerce, because fruits with a lower volume and high sphericity contribute to a better suitability of some industrial processes and storage. Fruits from matrix 4 showed the lowest mean for volume and the highest one for sphericity percentage, and in pequis from matrix 7 there was the highest mean for volume and the lowest for sphericity (Table 1). Fruits from Sete Lagoas-MG had volume mean (178.3 mL) superior than matrix 4, and mean sphericity percentage close to what was found in the observed matrix (Garcia et al., 2017).

The mean for pyrenes number in pequis from the assessed individuals are shown in Table 1. Matrix 1 had the lowest mean (1.1) and matrix 3, the highest (3.3). Fruits from TO, GO and MG (Alves et al., 2014), in Curvelo-MG and Rio Preto-MG (Soares et al., 2017), and pequis from Ponto Chique-MG and Jequitai-MG (Nascimento-Silva et al., 2020), had similar pyrene number to matrix 1 and lower to the average observed in matrix 3. The pyrenes number mean in pequis from Sete Lagoas-MG was 2.3, higher than matrix 1 fruits but lower than array 3's (Garcia et al., 2017). The kernels are commonly used in the manufacture of flour, oil, and others, then having more pyrenes per fruit is interesting.

**Table 1** – Physical parameters of pequis (*Caryocar brasiliense*) in the city of União do Sul-MT.

Matrix	Mass (g) <sup>1</sup>	Transversal diameter (mm) <sup>1</sup>	Longitudinal diameter (mm) <sup>1</sup>	Volume (mL) <sup>1</sup>	Sphericity (%) <sup>1</sup>	Pyrenes number <sup>1</sup>
1	150,74±28,13c	57,90±5,43c	74,95±14,79b	168,89±65,77b	91,27±7,15c	1,1±0,34c
2	213,81±62,15b	69,34±4,79b	76,10±12,77b	217,61±75,6b	97,78±6,24b	1,3±0,49c
3	136,95±15,17c	64,43±1,57b	65,19±4,24c	148,50±18,62c	100,79±2,7a	3,1±0,30a
4	116,73±19,11c	60,79±3,40c	60,38±3,8c	119,90±20,66c	101,12±2,47a	2,9±0,32a
5	170,96±55,80b	70,31±6,45a	71,81±10,79b	198,45±68,08b	100,17±3,99a	2,7±0,67a
6	168,99±39,66b	61,75±4,98c	73,96±10,07b	171,39±47,23b	93,20±5,86c	1,3±0,47c
7	297,84±100,89a	70,01±7,07a	89,49±13,58a	291,26±104,79a	90,93±3,11c	2,1±1,00b

<sup>1</sup> Results of mean ± standard deviation of 20 fruits per matrix, respectively. Means followed by equal letters in a column do not differ, according to Tukey test (p<0.05).

The results for physical parameters in pyrenes are displayed in Table 2. For total pyrene mass, pequis from matrix 7 have the highest mean (65.58 g), and the lowest one (29.82 g) is from matrix 4. The same has been observed about whole fruit

mass. The means obtained for total pyrene mass agrees to results obtained by other authors. Fruits from TO, GO and MG had means of 28.2 g, 24.7 g and 43.1 g for total pyrene mass, respectively (Alves et al., 2014). Pequis from western Bahia had a 27.48

g total pyrene mass mean (Nascimento & Coccozza, 2015). In cities in Minas Gerais the total pyrene mass means found were 34.98 g (Curvelo), 32.57 g (Rio Preto) (Soares et al., 2017), 36.52 g (Ponto Chique) and 25.08 g (Jequitai) (Nascimento-Silva et al., 2020). Cordeiro (2012) observed the following total

pyrene mass mean in four cities in Mato Grosso: 12.40 g (Acorizal); 19.91 g (Várzea Grande); 16.63 g (Cuiabá); and 18.74 g, (Santo Antônio do Leverger). The means for total pyrene mass are inferior to what was found in matrix 7's pequis.

**Table 2** – Table 2 – Physical parameters of pequis pyrenes (*Caryocar brasiliense*) in the city of União do Sul-MT.

Matrix	Mass (g) <sup>1</sup>	Transversal diameter (mm) <sup>1</sup>	Longitudinal diameter (mm) <sup>1</sup>	Volume (mL) <sup>1</sup>	Sphericity (%) <sup>1</sup>
1	39,57±7,19bc	35,65±1,79b	48,41±2,67b	42,42±6,85b	89,21±1,42a
2	45,27±12,79b	38,33±3,93b	51,12±5,32b	50,75±13,86a	89,15±2,31a
3	32,30±3,40c	34,25±1,06b	46,54±1,42b	15,80±16,60c	80,89±8,44b
4	29,82±3,53c	33,36±1,31b	45,08±2,36b	13,98±14,87c	80,77±7,33b
5	61,16±9,95a	41,17±5,50a	58,80±3,76a	34,29±35,08b	88,89±3,78a
6	37,38±6,44c	35,28±2,18b	47,71±3,06b	40,80±7,32b	89,28±1,37a
7	65,58±22,12a	38,61±4,83ab	57,85±6,39a	66,74±19,72a	85,92±1,87a

<sup>1</sup> Results of mean ± standard deviation in pyrenes of 20 fruits per matrix, respectively. Means followed by equal letters in a column do not differ, according to Tukey test (p<0.05).

For pyrene transversal diameter the mean from matrix 5 (41.17 mm) was higher, and in pyrenes from matrix 4 (33.36 mm), the lowest. About longitudinal diameter, pyrenes from matrix 5 (58.80 mm) had higher results, and the ones from matrix 4, the lowest (45.08 mm) (Table 2). The average numbers for transversal and longitudinal diameters, respectively, for pyrenes found in TO are (27.2 mm) and (29.2 mm), and in GO (26.4 mm) and (27.0 mm), lower than the ones observed in this study (Alves et al., 2014).

Table 2 displays results for volume and sphericity percentage of pequis. Fruits from matrix 7 had the highest volume mean (66.74 mL) and matrix 4, the lowest one (13.98 mL), the same found in whole fruits. About sphericity percentage, the lowest mean is from matrix 4 (80.77%), and the highest one, in matrix 1 (89.21%).

The pulp has the most prominent popular use and commercial value, then some analyses in this part of the fruit were carried. Table 3 presents the results obtained from the individuals studied. For pulp mass, pequis from matrix 4 had the lowest mean (16.38 g, 14.03% of whole fruit mass), and the ones from

matrix 7, the highest (74.36 g, 24.97% of whole fruit mass). Those results follow other studies that observed whole fruit mass. Pequis from TO, GO and MG had average pulp mass results of 6.9 g, 8.4 g and 14.3 g, respectively (Alves et al., 2014). In Curvelo-MG and Rio Preto-MG means for pulp mass were 15.75 g and 13.77 g, respectively (Soares et al., 2017), and in Ponto Chique-MG it was 13.33 g (8.08% of whole fruit mass) and in Jequitai-MG, 9.26 g (11.02% of whole fruit mass) (Nascimento-Silva et al., 2020). Pequis from four cities in MT had means of 5.52 g (Acorizal); 9.51 g (Várzea Grande); 6.61 g (Cuiabá); and 7.00 g, (Santo Antônio do Leverger) (Cordeiro et al., 2012). Those findings are lower than the results obtained in this study. According to Nascimento-Silva and Naves (2019) the average yield for pulp in pequis is from 4 to 7% of total fruit weight (Nascimento-Silva & Naves, 2019). The average pulp mass of pequis from west Bahia was 11.17% of whole fruit mass (Nascimento & Coccozza, 2015), lower than the results for the matrixes observed in this study, and the same happened to the findings from Ponto Chique-MG and Jequitai-MG (Nascimento-Silva et al., 2020).

**Table 3** - Mass, Mass/fruit pulp ratio percentage, moisture and physicochemical parameters of pequis pulp (*Caryocar brasiliense*) in the city of União do Sul-MT.

Matrix	Mass (g) <sup>1</sup>	Mass/fruit pulp ratio (%)	Moisture content (%) <sup>1</sup>	pH <sup>1</sup>	Total titratable acidity (% citric acid) <sup>1</sup>	Soluble solids (°Brix)
1	26,09±6,43b	17,31	34,70±0,66b	6,20±0,17b	0,215±0,037c	2,30±0,36a
2	30,80±9,60b	14,40	48,77±2,59a	6,40±0,00b	0,322±0,097a	2,23±0,15a
3	18,46±2,20c	13,48	39,56±2,25b	5,13±0,06c	0,407±0,064ba	2,27±0,29a
4	16,38±1,89c	14,03	42,13±1,66a	5,17±0,06c	0,247±0,067c	2,97±0,84a
5	32,76±10,20b	19,16	46,01±2,47a	5,97±0,15c	0,226±0,033c	2,40±0,10a
6	25,17±4,59b	14,89	34,50±3,67b	6,27±0,06b	0,268±0,018b	2,43±0,06a
7	74,36±15,30a	24,97	49,80±1,89a	7,23±0,12a	0,161±0,00d	2,70±0,28a

<sup>1</sup> Results of mean ± standard deviation, respectively. Means followed by equal letters in a column do not differ, according to Tukey test (p<0.05).

The physicochemical analysis, as well as physical characterization, provide important data which contribute to selecting promising species for genetic improvement and industry. Moisture content,

pH, acidity and soluble solids are interesting characteristics for industry, being possible predictors of alterations in fruit, along with its processing or storage.

Moisture content represents available water which works as a solvent, enabling microorganism growth and chemical and enzymatic reactions, being then associated to food preserving. The means found in pequis for moisture content vary from 34.50% (matrix 6) to 49.80% (matrix 7) (Table 3). Most of the results obtained are close to what was found in the cities of Acorizal (47.28%); Cuiabá (46.80%), Santo Antônio do Leverger (45.73%) and Várzea Grande (50.62%), in MT (Cordeiro et al., 2012); also from GO (56.21%) and MG (54.78%) (Alves et al., 2014); Lagoa Santa-MG (54.40%) (Plácido et al., 2015); and Rio Verde-GO (45.10%) (De Almeida et al., 2019), Ponto Chique-MG (50.46%) and Jequitai-MG (52.14%) (Nascimento-Silva et al., 2020). The means obtained for pulp in this study are lower than the results from TO (72.17%) (Alves et al., 2014). High water levels may lead to short shelf life and compromise quality in products (Pereira et al., 2003).

PH is an important parameter for food processing industry since it is related to volatile compounds retention in processed goods, directly affecting olfactory characteristics (Lima et al., 2015). As opposed to most tropical fruits, pequi has its pH value above 4.5, being then rated as a low acidity fruit, proper for pathogenic microorganism growth and rotting. PH means found in the observed matrixes vary from 5.13 to 7.23 (Table 3), similar to other studies. In pulps from Chapada do Araripe-Ceará (CE) (Oliveira et al., 2010) and Lagoa Santa-MG (Plácido et al., 2015) pH mean was 6.9; 7.0 in Uberlândia-MG (Da Paz et al., 2014), 5.32 in western Bahia (Nascimento & Coccozza, 2015); 5.70 and 6.75, respectively, in Ponto Chique and Jequitai-MG (Nascimento-Silva et al., 2020; De Oliveira et al., 2020), and in western Mato Grosso do Sul, mean pH was 5.10.

Titrateable acidity (TA) is applied to measure organic acids contents in fruit pulps. In industry, fruit acidity has its importance since it tends to reduce microorganisms manifestation, resulting in better lifetime. In addition to organic acids being responsible for the acidic character and flavor of foods, they are necessary for preservation in anti-oxidant foods (Garcia et al., 2017). Fruits containing from 0.08 to 1.95% of citric acids levels are well accepted for consumption (Sacramento et al., 2007). In pulps of the studied pequis, average contents of TA ranged from 0.161 to 0.407% of citric acid (Table 3). These are similar to what observed in pequis from Sete Lagoas - MG, 0.33% of citric acid (Garcia et al., 2017), western Mato Grosso do Sul, with 0.40% (De Oliveira et al., 2020), and Jequitai-MG, with 0.11% of citric acid (Nascimento-Silva et al., 2020). Obtained TA contents are lower than the results for fruits in Uberlândia - MG, 0.7% of citric acid (Da Paz et al., 2014); West Bahia, 1.76% (Nascimento & Coccozza, 2015); Lagoa Santa-MG, 1.52% (Plácido et al., 2015) and Ponto Chique-MG, 0.55% of citric acid (Nascimento-Silva et al., 2020).

Soluble solids contents (SS) is used as an indirect measurement of sugar content, although its results do not represent the exact sugar content,

because in addition to these, other substances are also dissolved in the vacuolar sap (Lima et al., 2015). However, sugars levels are majority, reaching from 85 to 90% soluble solids (Chitarra & Chitarra, 2005). There were no significant differences among the studied pulps, the means range from 2.23 to 2.97 °Brix (Table 3). These results are similar to those by De Oliveira et al. (2020) in pulps from western Mato Grosso do Sul (4.4 °Brix). Nevertheless, the average SS contents obtained in this study are lower than results from Chapada do Araripe-CE (Oliveira et al., 2010); Uberlândia-MG, 15.2 °Brix (Da Paz et al., 2014); western Bahia, 11.95 °Brix (Nascimento & Coccozza, 2015); Lagoa Santa-MG, 7.33 °Brix (Plácido et al., 2015) and Sete Lagoas-MG 9.2 °Brix (Garcia et al., 2017).

The differences observed in moisture content, physical and physicochemical parameters in this study, as well as in the other ones, can be explained due to variants as soil, weather, season and genetic variability, which may influence in the results (Schiassi et al., 2018).

## Conclusion

The physical appraisal for fruits and pyrenes shows that the studied matrixes had statistically significant differences in all parameters assessed, especially regarding mass, volume and pulp mass. Pequis from matrix 7 have the best results for whole fruit and pyrenes mass, and also for pulp mass and pulp mass percentage/whole fruit mass ratio, important features for fruit sales. Regarding its shape, an interesting parameter for industry and storage, pequis from matrix 4 had the best results due to the low volume and high sphericity levels in fruits, opposed to what was observed in fruits from matrix 7 showing that there is not necessarily a connection with volume, fruit mass and pulp yield.

Moisture content and physicochemical results, except from soluble solids, show that the matrixes have statistically significant differences. Those findings are similar to studies with pequis carried in other regions.

Based on the results obtained, the fruits that have been analyzed display important agro-industrial characteristics, therefore may be regarded in order to build a germplasm bank.

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