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Original Research Article

Experimental hybrid cabotia pumpkin physical-chemical and technological quality

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ABSTRACT

The objective of the work was to evaluate and compare the physicochemical characteristics of an experimental cabotiá hybrid with the commercial hybrid Tetsukabuto. The genotypes were divided according to mass (kg), and were evaluated for quality. The color parameters evaluated showed no significant difference, although visually the hybrid was different from the commercial variety. It was possible to conclude that the size of the fruits does not influence the concentration of the compounds, and also, an inferiority of HC05 was observed with respect to the relevant quality characteristics in pumpkins, such as soluble solids content, carotenoids and vitamin C.

Keywords: Conventional Breeding; *Cucurbita Maxima*; *Cucurbita Moschata*; Tetsukabuto

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1. Introduction

Pumpkins are widely consumed as they are enjoyed by the Brazilian population and are therefore part as ingredients in large quantities of foods prepared in households and in dining rooms outside of homes in the country[1,2]. For this reason, the total cultivation area of the species of this fruit represents approximately 88,000 ha[3]. In Brazil, there is a great genetic variability of pumpkins (*Cucurbita moschata*) and strawberries (*Cucurbita maxima*), which are produced in several regions of the country, having some creole species with specific place of cultivation and commercialization[4].

With the emergence of new hybrid cultivars, with high productivity, good post-harvest resistance and consumer acceptance, producers began to use them in their production[5]. Over the years, local cultivars are being lost, and becoming rare, at risk of extinction caused by "erosion", a factor that directly influences the sustainability of national agriculture[6].

With the growth of studies in the area of genetics, seeking to improve the sensory characteristics and productivity of pumpkins, hybrids known as cabotiá or Japanese pumpkin were developed, coming from the cross between *C. maxima* and *C. moschata*. These hybrids are endowed with good agronomic and sensory characteristics, and this caused their production to spread in Brazil. Currently, the production depends on the importation of foreign seeds. In 2006, 9.2 tons of Tetsukabuto hybrid seeds were imported, corresponding to 70.5% of all imported pumpkin seeds, at a cost of 1.3 million dollars[7].

In order to counteract genetic erosion, there are several germplasm banks in Brazil with a great variety of pumpkin species. The three most expressive banks for breeding programs and ex-situ conservation are located at the Federal University of Viçosa (FUV), Embrapa Semi-Arid and Embrapa Hortaliças, which keep more than 4,000 accessions of *C. maxima* and *C. moschata*. Although the genetic improvement studies have grown, there is a lack of continuity of research in the food area to identify desirable characteristics for consumers and thus achieve effective results[5].

Thus, regardless of the species used in the genetic improvement study, its continuity is important for the advance in the performance of cultivars associated with a product with culinary and/or technological characteristics desired by consumers[8]. The production of pumpkin genotypes with superior quality, high nutritional value and with technological properties has been stimulated[9] and is of economic interest[10].

The state of Goiás is a large producer of pumpkins, and for this reason researchers seek to obtain local cultivars adapted to the conditions of the region, thus contributing to regional and national reduction of dependence on imported seeds.

Thus, the objective of the present work was to evaluate and compare the physicochemical characteristics of an experimental cabotiá hybrid with the commercial Tetsukabuto hybrid.

2. Material and methods

The seeds of Tetsukabuto F1 (TET) were purchased in local commerce, while the seeds of the experimental hybrid (HC05) were from the hybridization of strawberry and pumpkin from the Active Germplasm Bank (AGB) of the Federal Institute Goiano. The hybrids were grown as described by Alves *et al*.[11] using direct transplanting (DSP) in the municipality of Iporá, Goiás (16°22'26" S 51°09'21" W).

The treatments were divided in a 2 × 2 factorial design with five repetitions in each treatment. As the fruits obtained were heterogeneous, it was decided to evaluate the fruits according to their mass, which is a parameter used for commercialization. The first factor was the mass of commercial fruits (1.00–1.50 kg) and non-commercial fruits (<0.50 to 0.99 kg), according to the standard established by CEASA-GO[12]. The genotypes were divided into experimental hybrid (HC05) and commercial hybrid (TET) and this was the second factor studied. Each experimental unit was composed of one fruit in its respective category and repetition. The fruits were harvested on 03/04/2016 after 120 days of cultivation, received and analyzed in the laboratories of the Instituto Federal Goiano Campus Rio Verde, were washed with neutral detergent and running water, sanitized by immersion in commercial sodium hypochlorite solution (15 mL/L) for 15 minutes and peeled manually. The parts of the fruit were weighed separately on digital scales: Whole fruit (MT), skin (MC), pulp (MP), residue (MR), and seeds (MS). The yield was calculated using the formula (MC/MP/MR/MS * 100)/MT.

The external longitudinal and transverse diameters, the internal cavity of the fruit and the thickness of the pulp were determined by measuring using a digital caliper. The total soluble solids (TSS) content was performed using a KRUSS DR301-95 portable digital refractometer directly from the juice released by kneading the pumpkin pulp. The total titratable acidity (TTA) and the hydrogen potential (PH) were determined according to the official method. For the pH measurement a digital pH meter LUCA-210P (LUCADEMA, SÃO PAULO, BRAZIL) was used, duly calibrated and the TTA was expressed in mL of solution per percent (v/m)[13].

The instrumental color was determined according to the CIELAB system, evaluating the parameters L* (luminosity), a* (-a: Green, +a: Red) and b* (-b: Blue, +b: Yellow) in a Color Flex EZ spectrophotometer (HUNTER LAB, Reston, USA). The analysis was performed by three measurements in different areas on the internal (pulp) and external (epidermis) parts of the fruits in natura. For texture analysis, the pulp was cut into cubes of 2 cm in length, width and depth, the compression test was performed using a CT3 texturometer (BROOKFIELD, MA, USA), with an acrylic probe tip (TA4/100) and rectangular base (TA-BT-KI), with a penetration depth of 2.0 mm and speed of 0.5 $mm \cdot s^{-1}$. The results for the hardness parameter were defined as the peak force reached during the first compression in grams.

Total carotenoid content was performed according to the methodology of Gross[14], with modifications, where 1 g of pumpkin pulp sample was weighed and added to 12.5 mL of acetone: Ethanol (PA, 1:1, v/v) solution and 250 µL of BHT (2,6-dithert-butyl-4-methyl phenol, 20 mg/mL). The mixture was homogenized and filtered on filter paper (Whatman 150 mm) and the procedure was repeated until total discoloration of the pulp residue was obtained (4 extractions). The volume of the extract obtained was completed with the extracting solution up to 50 mL, the reading performed in SP 2000 UV spectrophotometer (BEL PHOTONICS, PIRACICABA, BRAZIL) at 470 nm and the content of total carotenoids expressed in µg/g.

The ascorbic acid (vitamin C) content was determined according to AOAC No. 43.065[15], modified by Benassi and Antunes[16]. 5 g of each sample were weighed, added to 50 g of 2% oxalic acid and homogenized. From this extract, 20 g were weighed and the volume completed with the 2% oxalic acid solution to 50 mL and subsequently filtered with filter paper. A 10 mL aliquot of the filtrate was titrated with a 0.01% 2,6 dichlorophenolindophenol (DCFI) solution. The ascorbic acid concentration was calculated using Equation 1.

$$\frac{m\ g}{100\ g} = \frac{DCFI\ sample\ (mL)}{DCFI\ pattern\ (mL)} \times \frac{100\ g}{m\ sample\ (g)} \times \frac{m\ solvent + m\ sample}{m\ rate\ (g)} \times \frac{V\ (50\ mL)}{V\ rate\ (mL)} \tag{1}$$

The data obtained were submitted to the Bartlett test for analysis of homogeneity of variance and Shapiro-Wilk for analysis of normality of residuals. Finally, the analysis of variance was performed and evaluated the effects of mass, genotype and by the F test, with application of the Tukey test of means at the 5% and 1% probability level, using the Assistat 7.7 statistical software[17].

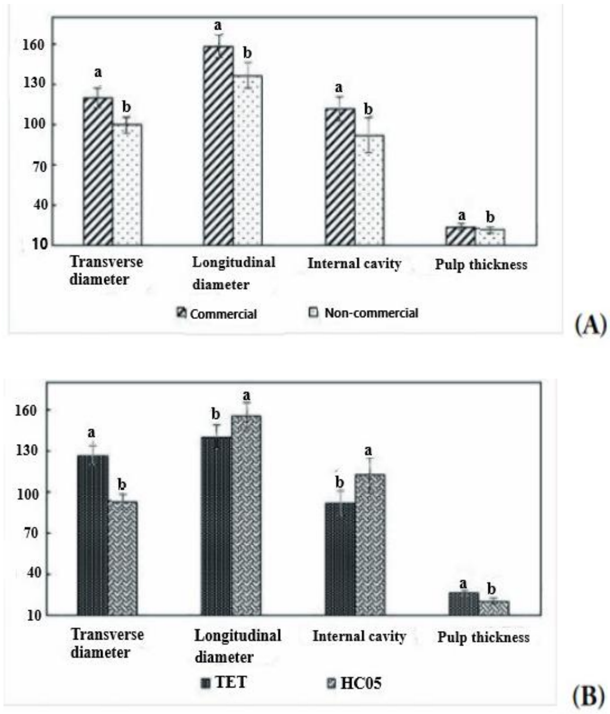

Figure 1. Sizing results: transverse diameter mm; longitudinal mm; internal cavity mm and pulp thickness mm for pumpkin fruits.

Note: Equal letters do not differ p005 by Tukey's test when commercial × non-commercial A and TET × HC05 B were evaluated.

3. Results and discussion

The results obtained for transversal and longitudinal diameters, internal cavity and pulp thickness for the two pumpkin genotypes can be seen in **Figure 1**.

It was possible to observe that the TET treatment presented close diameters, being the longitudinal 145.80 mm and the transverse 140.64 mm (**Figure 1**), indicating the rounded shape that the commercial cabotiá presents. Amaro *et al.*[18] reported the similarity between the length and width of pumpkin fruits (17.44 × 16.28 cm, respectively)by evaluating the agronomic performance of experimental Tetsukaboto pumpkin hybrids. Meanwhile, the experimental commercial hybrid HC05 showed longitudinal diameter (171.60 mm) larger than transverse diameter (99.53 mm) due to its flatter shape, which resembles the shape of some strawberries. The transverse and longitudinal diameters showed significant interaction (5%), and for the longitudinal (**Table 1**) there was no difference between the masses for the TET genotype

(145.80 and 134.58 mm) and also between the non-commercial genotypes (134.58 and 139.13 mm).

Table 1. Abstract of the interaction between fruit mass for the attributes longitudinal and transverse diameters, hardness and shell brightness

Treatments	TET	HC05
Longitudinal diameter		
Commercial	145.80 aB	171.60 aA
Non-commercial	134.58 aA	139.13 bA
Transverse diameter		
Commercial	140.64 aA	99.53 aB
Non-commercial	112.7 bA	86.80 bB
Hardness		
Commercial	7,479.07 bA	4,056.67 aA
Non-commercial	15,966.53 aA	3,053.60 aB
Shell brightness		
Commercial	38.98 aB	50.21 bA
Non-commercial	37.61 aB	55.95 aA

Note: Means followed by lower case letters in the column and upper case letters in the row differ statistically by Tukey's test at 5% probability level.

The flesh thickness was greater for TET samples (25.88 mm), while the internal cavity was greater for HC05 (112.50 mm), which explains the fact that the flesh is reduced in thickness in these genotypes. Values found in this study, corroborate previous studies regarding flesh thickness (17.00–28.86 mm) and internal cavity (91.69–215.16 mm) for pumpkin accessions from Piauí and Maranhão[19]; and, flesh thickness (26.39–29.76 mm)[20] in Japanese pumpkin hybrids grown in the organic system. Smaller internal cavities and greater pulp thicknesses are characteristics that indicate greater resistance to transport and packaging, so these characteristics are important for pumpkins.

The pulp yield did not show significant interaction in any of the factors, but when only the genotype was evaluated, TET obtained a higher yield than HC05, the total amount of residue, including peels and seeds, corresponded to 19–25% of the total mass of the pumpkins, for both mass groups and genotypes, as can be seen in **Figure 2**. Corrêa *et al.*[21], analyzing yield of F1 hybrid pumpkins of *C. moschata* and *C. maxima*, obtained 19.64% of residue, representing similarity with the results of the present work. All percentages in seed, regardless of whether evaluated by genotype or fruit mass, were higher than those reported by Nascimento *et al.*[22] (0.8–1.17%) for *C. maxima* accessions.

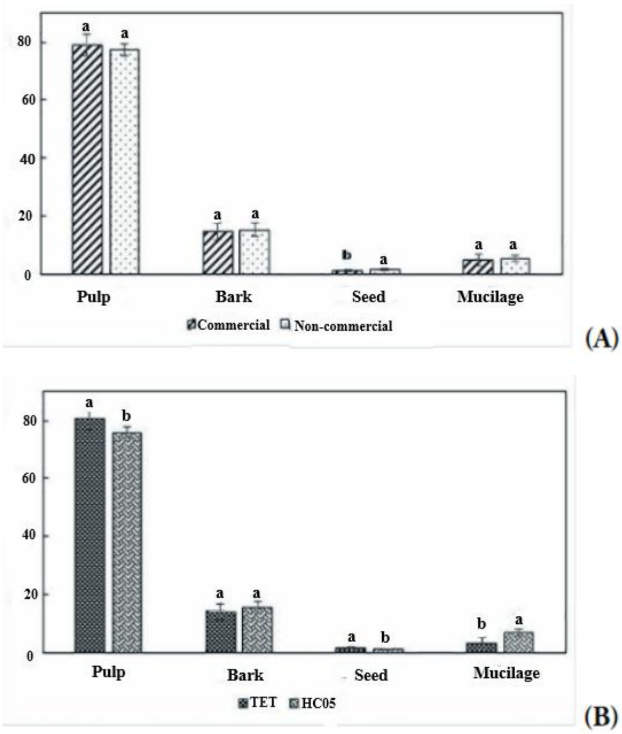

Figure 2. Results of yield in percentage of pulp and residues (peel, seed and mucilage) for pumpkin fruits.
Note: Equal letters do not differ ($p > 0.05$) when commercial × non-commercial (A) and TET × HC05 (B) were evaluated (Test F).

Table 2. Total titratable acidity (TTA), pH, total soluble solids (TSS), total carotenoids, ascorbic acid (vitamin C) and texture (hardness) for the factors mass and pumpkin genotype

	ATT (%)	pH	TSS (°Brix)*	Hardness (g)*	Carotenoids (μg/g)	Vit C (g/100g)**
Mass						
1.00 to 1.50 kg	6.00 a	5.86 a	4.92 b	5767.87 b	67. 00 a	20. 46a
0.50 to 0.99 kg	5.30 a	5.93 a	7.06 b	9510.07 a	61.14a	15.66 b
CV (%)	17.42	6.08	30.18	48.62	11.81	18.95
Genotype						
Tetsukabuto F1	7.03 a	5.64b	7.96a	11722.80 a	91.1l a	19.83 a
HC05	4.26 b	6.14a	4.03b	3555.14 b	37.03 b	16.30 b
CV(%)	17.42	6.08	30.18	48.62	11.8l	18.95

* Significant by "F" test (5%).
** Significant by "F" test (1%); means followed by the same letter in the column do not differ by Tukey test ($p \leqslant 0.05$).

According to Coelho and Wosiacki[23], the food industry is a large producer of vegetable waste, which has a high content of bioactive compounds, vitamins and mineral salts. This was also observed in the research developed by Costa *et al.*[24], in which the quality of pumpkin flour produced from its by-products (peels, seeds and mucilage) was evaluated, and 4.81 mg of β-carotene/100 g of pumpkin flour were found, in addition to several other types of carotenoids in smaller amounts.

The quality evaluations of a product are different according to its destination. When the commercialization is in natura, the main attributes to be evaluated are: appearance (size, shape and color), product condition and absence of defects, texture, flavor and odor "flavor"[25]. For this reason, when you have a fruit or vegetable product and you want to compare it with another already marketed, it is important to evaluate the nutritional value and other characteristics mentioned above.

Table 2 presents the results for total titratable acidity (TTA), PH (hydrogen potential), total soluble solids content (TSS), total carotenoids, ascorbic acid (vitamin C), and texture (hardness) for the mass and genotype factors.

In relation to the mass factor, there was no significant difference for acidity, pH and total carotenoids. For the content of soluble solids and hardness, the difference obtained is favorable, and it is possible to observe that fruits with mass <1.00 kg, considered unfit for commercialization, could be consumed, avoiding food waste and helping the issue of food and nutritional security, ensuring a greater amount of food available to the population (**Table 2**).

The soluble solids contents were close to those obtained by Paula *et al.*[26], (3.20–4.50 °Brix) for pumpkin and strawberry and by Martinez-Valdivieso *et al.*[10], (3.4–4.7 °Brix) for Cucurbita pepo cultivars. Amaro *et al.*[18] reported soluble solids contents twice as high as reported in this work (18.44 °Brix) in their work with variety Tetsukaboto. The higher the content of soluble solids in pumpkins, the higher the industrial yield[20] and thus, breeding should select genotypes that meet this characteristic. The PH and acidity values found in this work, regardless of mass or genotype evaluation, were close to those reported by Paula *et al.*[26] (6.40 and 0.11 %, respectively) and by Martínez-Valdivieso *et al.*[10] (6.5–6.9 and 0.10–0.17%, respectively).

The hardness parameter showed significant interaction (**Table 2**) between the two analyzed factors, with no difference between the genotypes with mass of 1.00 to 1.50 kg (7,479.07 and 4,056.67 g) and between the masses of genotype HC05 (4,056.67 and 3,053.60 g). **Table 2** shows a significant difference between the genotypes, showing that the experimental hybrids have lower hardness and this characteristic is directly related to shorter cooking time and easier chewing than TET. According to Carmo[27], the pulp hardness is influenced by the amount of starch and soluble solids present in the fruit, and it was possible to observe that the genotypes with higher soluble solids content also present higher hardness. Grangeiro *et al.*[28] found values of 40.50 N (4,129.79 g), analyzing the texture of melon hybrids, which are close to those obtained for the HC05 pumpkin fruits.

Physics defines hardness as a force necessary to establish deformation, as for sensory definitions it represents the force necessary to deform the sample when chewing, and which is exerted by compressing the food between the molar teeth[29]. On the other hand, considering postharvest handling, hardness is essential, since firmer fruits suffer less mechanical injuries, which they are subject to during transportation and commercialization[30].

The total carotenoid content was not influenced by the difference in fruit size, but there was a significant difference between the genotypes, the fruits of TET showed carotenoid content twice as high as that obtained in HC05, a result that, although not interesting from the point of view of the food industry, is a characteristic to be improved in the hybridization process.

In a study conducted by Lima Neto[31], to identify pumpkin accessions promising for carotenoid biofortification, quite variable values were found, from 8.6–506.6 μg/g, with 8.6 μg/g being obtained from a Tetsukabuto hybrid, so there are genotype on the market with carotenoid contents below the experimental one. Faustino[32], ,reported higher values of total carotenoids (106.50 to 437.53 μg⁄g), higher than those reported in this work by studying the genetic parameters of pumpkin (*C. moschata* Duch.). This distinction in carotenoid concentrations is due to the high genetic variability that pumpkins possess. Factors such as cutting, grinding and freeze-drying of the fruit can also influence the quantification of carotenoids, because there is a release of enzymes that accelerate the oxidation of these compounds[33,34].

Gajewski *et al*.[35] reported the existence of a correlation between high content of soluble solids and total carotenoids by studying quality characteristics in different species of pumpkins. This relationship was also observed in this work, since the variety TET showed higher soluble solids content and higher total carotenoid content.

There was a significant difference in vitamin C content among the hybrids evaluated by mass and by genotype, with non-commercial hybrids and HC05 showing the lowest contents. In a study by Alves *et al*.[36], the vitamin C values ranged from 34.0–25.7 mg⁄100 g, higher than those obtained in this study. According to Chitarra and Chitarra[25], the vitamin C content tends to decrease with storage of many vegetables, due to the direct action of the ascorbic acid oxidase enzyme (ascorbinase), or by the action of oxidizing enzymes such as peroxidase.

Table 3. Instrumental color results for skin and flesh evaluating factors Mass and Genotype

Bark	**Pulp**					
Mass	**L***	**a***	**b***	**L***	**a***	**b***
1.00 a 1.50 Kg	44.59 a	7.42 a	20.29 b	55.82 b	17.63 b	42.20 b
0.50 a 0.99 Kg	46.78 a	9.32 a	29.30 a	58.80 a	20.41 a	50.86 a
Genotype	**L***	**a***	**b***	**L***	**a***	**b***
Tetsukabuto FI	38.30 b	8.24 a	23.51 a	56.00 b	22.57 a	50.77 a
HC05	53.08 a	8.53 a	26.77 a	58.61 a	15.47 b	42.29 b
CV(%)	6.99	33.63	16.09	3.10	8.30	5.84

Note: Means followed by the same letter in the column do not differ by Tukey test ($p \leqslant 0.05$) when comparing the mass and genotype factors separately.

Color is an extremely important attribute when it comes to marketing fresh products and is considered the first characteristic observed by the consumer directly influencing the purchase intention[37]. **Table 3** shows the results of the chromaticity analysis, showing the parameters L* (brightness), a* (negative-green, positive-red) and b* (negative-blue, positive-yellow), for peel and pulp. For the peel, in the luminosity parameter there was a significant interaction (5%) between the commercial x non-commercial and TET × HC05 factors (**Table 3**). There was a difference in brightness among the genotypes, with the experimental hybrid showing the highest value, due to its lighter rind. In the a* chromaticity parameter, low values were obtained with a tendency towards green, with no significant difference in any of the factors. In the b* chromaticity parameter, it is possible to observe high values tending to yellow coloration, with no difference between the genotypes (**Figure 3**). The values found for the b* parameter in this study were higher than those reported by Martínez-Valdivieso *et al*.[10] for the mesocarp (pulp) of 22 cultivars of C. pepo (14–40).

A.

B.

Figure 3. External part of (**A**) Commercial cabotiá pumpkin Tetsukabuto F1 and (**B**) Experimental hybrid HC05.

Table 4. Abstract of fruit mass x genotype interaction for flesh color (L*, a* and b*)

Color parameters	Treatments	TET	HC05
L*	Commercial	56.87 aA	54.77 bA
	Non-commercial	55.14 aB	62.45 aA
a*	Commercial	22.48 aA	12.78 bB
	Non-commercial	22.66 aA	18.16 aB
b*	Commercial	49.25 aA	35.16 bB
	Non-commercial	52.30 aA	49.42 aA

Note: Means followed by lower case letters in the column and upper case letters in the row differ statistically by the Tukey test at the 1% probability level.

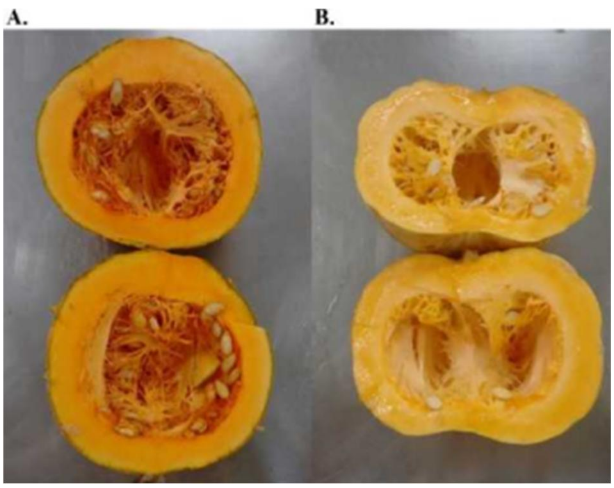

Figure 4. Internal part of (**A**) Commercial cabotiá pumpkin Tetsukabuto F1 and (**B**) Experimental hybrid HC05.

For the pulp, all parameters analyzed showed significant interaction (1%) (**Table 4**) between the factors. In the luminosity parameter, the smaller fruits (non-commercial) and the genotype HC05 obtained the highest value, presenting significant difference, the interaction shows that HC05 differed in relation to mass (54.77 and 62.45). In the chromaticity parameter a*, the values obtained were relatively high, with a greater tendency towards red, the interaction shows that there was no significant difference between the masses for TET (22.48 and 22.66) and there was a difference between the genotypes for the two mass groups. In the chromaticity parameter b* it was possible to observe higher values tending to yellow coloration, with smaller fruits presenting higher values and also the genotype TET, since its pulp has a more intense coloration than HC05 (**Figure 4**). The interaction shows that there was no significant difference between the masses for TET (49.25 and 52.30) and between the genotypes with mass lower than 1.00 kg (52.30 and 49.42).

In general, the average mass of the fruits does not alter the availability of compounds that disqualify them for consumption, but in general hybridization studies aim for smaller fruits[38]. Therefore, they are nutritionally suitable for consumption, and also for transportation. It is noted the inconsistency in discarding the fruits in the field and limiting the availability to the consumer market. The analyzed physicochemical characteristics show some similarities between the two genotypes, being that the evaluation parameters of the intrinsic quality of the fruits presented lower values for the experimental hybrid HC05.

Although inferior for some parameters, the experimental hybrid of cabotiá HC05 does not have physical-chemical attributes that disqualify it for commercial use. However, for future work, there is a need to continue the genetic improvement of this hybrid and to perform sensory evaluations in order to obtain gains in physical-chemical attributes in the fruits, thus generating a national product adapted to the edaphoclimatic conditions and that is able to nourish and please the consumer's palate.

4. Conclusion

It is concluded that both the mass of the pumpkin fruits and the genotype influence the physical (yield, longitudinal or transversal diameter and pulp thickness) and chemical (soluble solids content, total carotenoids, vitamin C and acidity) parameters of an experimental cabotiá hybrid compared to the commercial hybrid Tetsukabuto. In addition, pumpkin fruits that are not currently marketed for their size (mass) showed positive physicochemical characteristics, showing that they should not be disregarded based on this parameter.

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Conflict of interest

The authors declared no conflict of interest.

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