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ORIGINAL ARTICLE

Physicochemical characterization of the fruits of the Unconventional Food Plants (UFP), snake gourd (*Trichosanthes cucumerina*)

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Abstract

Unconventional food plants emerge in a context where people increasingly care about living healthier. Among these plants, the snake gourd (*Trichosanthes cucumerina*) of Asian origin and belongs to the *Cucurbitaceae* family, produces fruits that can reach more than 1 m in length. This study aimed to physiochemically characterize the fruits in different lengths and harvest times. The fruits were harvested with the following lengths: between 0.2-0.35 m, 0.45-0.6 m, and 0.7-0.85 m; and at the following times: 115 and 135 days after planting. The attributes evaluated were soluble solids, titratable acidity, vitamin C, firmness, pH, dry matter, antioxidant activity, and polyphenols. The fruits of meter okra with 0.2-0.35 m and 0.45-0.6 m presented better color characteristics, greener, brighter, and with greater saturation. In addition, they presented higher values of soluble solids and lower firmness. At 115 days after planting, the fruits showed higher values of vitamin C, better color, lower acidity, and higher soluble solids content. Thus, we conclude that the fruits should be harvested with a maximum of 0.6 m and up to 115 days after planting.

Keywords: Quality; Post-harvest; Unconventional food plants; Vegetables; Titratable acidity; Vitamin C.

Highlights

- Snake gourd’s antioxidant capacity is not influenced by its size or harvest time
- Fruit harvested 115 days after planting had vitamin C content 4 times higher
- With up to 0.6 m the fruits showed better quality

1 Introduction

Currently, given the growing health concern, improving diet quality has become essential. Thus, it is necessary to increase the variety of foods available for a healthy and affordable diet, focusing on boosting the supply of fresh produce and reducing the consumption of ultra-processed foods (Queiroz et al., 2025; Silveira et al., 2023). In this context, unconventional food plants (UFPs) are of particular interest. By definition, UFPs are plants associated with traditional communities that, despite their nutritional potential, resilience, and ease of cultivation, remain underutilized and relatively unknown (Conceição et al., 2024; Brasil, 2010). The primary reason for their limited consumption is a lack of public awareness (Brack et al., 2020).

Efforts should be made to promote and explore UFPs to increase knowledge and awareness about them. These nutritionally rich, easy-to-grow, and economically viable plants have the potential to enhance dietary diversity and food security. Furthermore, UFPs can boost the income of farming families due to their high market value and unique appeal, as their exotic nature often piques consumer curiosity (Sartori et al., 2020).

Among UFPs, the snake gourd fruit—a common name for *Trichosanthes cucumerina* var. anguina—stands out as a versatile and nutritious option for consumers. It is particularly well-suited for implementation in family-based agricultural systems (Cervantes-Zapana et al., 2020; Shah et al., 2012). In Brazil, the snake gourd is sometimes referred to as “okra of meter” because its fruits can exceed 1 meter in length. When immature, its shape resembles okra (*Abelmoschus esculentus*), though it belongs to the *Cucurbitaceae* family, which includes pumpkins, cucumbers, melons, and watermelons. The plant exhibits indeterminate growth, tendrils, and a flexible stem. In this study, the name “snake gourd” is used, as it is more commonly recognized internationally.

Snake gourd is a plant of Asian origin and is widely consumed in countries across the region. In Brazil, its consumption is more prevalent in the Amazonas, Goiás, and Minas Gerais, though it has significant potential for broader adoption countrywide (Liu et al., 2024; Madeira et al., 2013).

Snake gourd is particularly notable for its health-promoting properties. It exhibits significant antioxidant activity, which may help prevent cardiovascular diseases and other chronic conditions (Liu et al., 2024; Ademosun, 2013). Additionally, its use in traditional medicine across different cultures highlights its versatility, with applications in treating fever, headaches, and abdominal pain (Ominowa et al., 2024; Shah et al., 2012).

From a nutritional perspective, snake gourd qualifies as a functional food due to its high dietary fiber content and low caloric value, making it an excellent component of a balanced diet (Raghunathan et al., 2024; Liyanage et al., 2016).

However, despite its potential, snake gourd remains underutilized, largely due to its poorly developed supply chain, which limits its wider adoption. This gap underscores the need for further research to address critical knowledge gaps regarding its cultivation, trade, and consumer use. Characterization studies are especially important to identify key traits of the fruit, such as determining the optimal harvesting stage. These insights could enhance its quality, extend its shelf life, and reduce post-harvest losses, thereby maximizing the species’ potential and contributing to sustainable agricultural practices (Kinupp, 2007; Nascimento et al., 2014; Kinupp & Lorenzi, 2021).

In light of the above, the objective of this study was to conduct a physicochemical characterization of snake gourd fruits of varying lengths and harvested at different times. This was achieved by evaluating attributes such as color, soluble solids content, titratable acidity, vitamin C content, firmness, pH, dry matter, antioxidant activity, and polyphenol content.

2 Materials and methods

2.1 Experimental design

Snake gourd fruits (*Trichosanthes cucumerina* var anguina) were obtained from plants grown from seeds and managed in a productive area located at the School of Agronomy and Food Engineering, the Federal University of Goiás, in Goiânia, Goiás, Brazil.

The seeds were planted in Nutriplan® trays with 50 cells each, with 2 seeds planted per cell. Carolina Soil® substrate was used, and after sowing, water was added until saturation. Subsequently, the trays were covered with a tarpaulin to keep the soil moist and create a dark environment to facilitate seed germination.

After the emergence of seedlings, on average 15 days, thinning was performed, and selected the most vigorous seedlings. The transplanting of seedlings to the beds (45x1m) of the garden was done in a double line with a spacing of 1m between plants and fertilization with 100g m^{-1} of fertilizer NPK formulation 4:14:8. The plants were tutored with phyllo throughout the period and cover fertilization was performed with 20g per hole of NPK fertilizer (13:3:25).

The snake gourds were harvested during the early hours of the day when they were at horticultural maturity, following consumption recommendations (Madeira et al., 2013; Kinupp & Lorenzi, 2021), at 115 and 135 days after planting (DAP). The lengths of the fruits were measured with a measuring tape, and they were separated into three categories: 0.2-0.35 m, 0.45-0.6 m, and 0.7-0.85 m (Figure 1).

Subsequently, the fruits were washed under running water and sanitized with a sodium hypochlorite solution (active chlorine 2.0 to 2.5% w/w) at 150 ppm for 15 minutes in the garden shed of the EA/UFG and then transported to the LTPC/UFG.

The characterization assay was conducted at the Postharvest Technology of Fruits and Vegetables Laboratory (LTPC) located in the Garden of the School of Agronomy and Food Engineering (EA) at the Federal University of Goiás (UFG) in Goiânia, Goiás, Brazil. Antioxidant and polyphenol analyses were carried out at the Postharvest Laboratory of the State University of Goiás (UEG) in Anápolis, Goiás, Brazil.

Figure 1. General appearance of snake gourd fruits (UFG/Goiânia – GO).

2.2 Physicochemical characterization of snake gourd

The samples were characterized for color (L* a* b*), soluble solids (SS), titratable acidity (TA), vitamin C content, firmness, pH, dry matter (DM), antioxidant activity, and polyphenols. The methodology of the analyses is described as follows:

a) Color – was determined using the portable colorimeter CR-400 Konica Minolta (Chiyoda, Tokyo, Japan), from which parameters were obtained: L* (luminosity), a* and b* (Minolta Corporation, 1994).

b) Soluble solids (SS) – were quantified by refractometric reading in °Brix, a 20 °C, drops were placed with the aid of gauze on the lens of the portable digital refractometer Brix/RI-Chek® (Reichert Technologies, Depew, New York, USA), according of the Association of Official Analytical Chemists (2012).

c) Titratable acidity (TA) – was determined using the volumetric method with an indicator according to method 310/IV (Instituto Adolfo Lutz, 2008) with adaptations. Ten grams of homogenized pulp were weighed on an analytical balance, then diluted in $5x10^{-3}$ L of distilled water, and 4 drops of phenolphthalein solution were added. After that, titration was performed using a 0.1 mol L^{-1} sodium hydroxide solution until a pink color was obtained. The acidity was calculated using the Formula 1:

$$Acidity = \frac{V*M*Eq}{P} \tag{1}$$

where: V is the volume of sodium hydroxide solution used in titration in milliliters (mL), M is the concentration of the sodium hydroxide solution, Eq is the equivalent weight of the predominant acid (citric acid = 64.02), and P is the mass of the sample in grams (g). The result was expressed as grams of citric acid per 100 grams of fruit.

d) Vitamin C – performed according to the adapted 364/IV method (Instituto Adolfo Lutz, 2008) in which 10g of pulp were placed homogenized with $5x10^{-3}$ of distilled water in the Erlenmeyer, $1x10^{-3}$ L of 20% sulfuric acid, $1x10^{-3}$ L of 1% starch solution and 1 ml of 1% potassium iodide were added. Titration with potassium iodate was performed until blue staining was obtained in the sample. The following Formula 2 was used to quantify vitamin C:

$$Vitamin\ C = \frac{100*V*F}{P} \tag{2}$$

where: V is volume of iodate spent on titration in mL, F is the correction factor of iodate and P is the mass of the sample in grams (g).

e) Firmness – was checked using an Instrutherm (São Paulo, SP, Brazil) model PTR-300 digital penetrometer, with the result expressed in Newtons (N). The tip used was $9x10^{-3}$ m long and 2.98 x 10^{-3} m thick.

f) Hydrogen potential (pH) – was checked with a TEC-7 digital bench pH meter (Tecnal Equipamentos Científicos, Piracicaba, SP, Brazil), 10g of pulp diluted in $5x10^{-2}$ L of distilled water was then placed in a beaker.

g) Dry matter (DM) – carried out using the Infrared Moisture Analyzer IV2500 (Gehaka®, São Paulo, SP, Brazil) and the result obtained by difference

h) Antioxidant activity and polyphenols – The snake gourd fruits were sliced thinly, packed in aluminum foil, frozen, lyophilized using a L108 Lyophilizer (Liobras®, São Carlos, SP, Brazil), and then crushed to obtain extracts. This procedure was carried out according to the method proposed by Larrauri et al. (1997) and Rufino et al. (2007), with adaptations. 0.75g of lyophilized sample and $1x10^{-2}$ L of methanol were used. After letting it sit for 1 hour, it was centrifuged at 4,000 rpm for 30 minutes. Then, $1x10^{-2}$ L of acetone was added, and the mixture was left at rest for 1 hour before being centrifuged again.

The antioxidant capacity was assessed using two spectrophotometric methods. By the method of DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging, 100 µL of the extract obtained from dilutions of 30,000 ppm, 15,000 ppm, and 7,500 ppm were used, along with 3.9×10^{-3} L of a 0.06 µmol DPPH solution. The absorbance readings were taken on a digital UV/VIS spectrophotometer, model UV-5100 (Metash, Shanghai, China), at 515 ηm. The DPPH radical standard curve was obtained from a solution of DPPH (60 µM), in which the concentration was varied from 10 µM to 50 µM. The result found refers to the sample required to reduce the initial DPPH concentration by 50% (EC_{50}) expressed in g of freeze-dried fruit g^{-1} of DPPH (Brand-Williams et al., 1995; Sánchez-Moreno et al., 1998; Rufino et al., 2007)

By the ferric reducing antioxidant power (FRAP) method, the extracts were also diluted to concentrations of 30,000 ppm, 15,000 ppm, and 7,500 ppm. Subsequently, an aliquot of 90 µL was mixed with 270 µL of distilled water and 2.7×10^{-3} L of the FRAP reagent. After resting for 30 minutes, readings were taken on the spectrophotometer at 595 nm. The standard curve was obtained using a standard solution of ferrous sulfate (2,000 µM), varying concentrations from 500 µM to 1,500 µM. The result was expressed in µM ferrous sulfate per gram of lyophilized fruit (Pulido et al., 2000; Rufino et al., 2006).

For the determination of total extractable polyphenols, an aliquot of 1 mL of the sample extract, 1×10^{-3} L of the Folin-Ciocalteu solution, 2×10^{-3} L of sodium carbonate solution, and 2×10^{-3} L of distilled water were used. After resting for 30 minutes, the spectrophotometric reading was performed at 700 nm. The standard curve was constructed using gallic acid with concentrations ranging from 0 to 50 µg. The results were expressed in mg of gallic acid per 100 g^{-1} of lyophilized fruit (Larrauri et al., 1997; Obanda et al., 1997).

2.3 Statistical analysis

The experiment was carried out in a completely randomized design, with 3 replications with 4 fruits each, in a double factorial scheme: fruit size (0.2-0.35 m, 0.45-0.6 m, and 0.7-0.85 m) x harvest time (115 dap and 135 dap).

After carrying out the analyses, the means found were submitted to the Scott-Knott test at 5% probability using the Sisvar 5.8 program (Ferreira, 2014).

3 Results and discussion

The results showed that there was no interaction between fruit size and harvest time in any of the characteristics studied, so all the variables were analyzed separately for each of these sources of variation

Concerning fruit color, for fruit size there was a statistical difference between okra with 0.2-0.35 m and the others for the coordinates a*, b* and Chroma (Figure 2A, 2C and 2E), as the 0.2-0.35 m length showed the lowest value (-13.34) for the a* coordinate, the highest value for the b* coordinate (24.61) and also for Chroma (28.01). The a* and b* color parameters ranged from negative to positive, with the more negative a* being greener and the more positive redder, while for b*, the negative indicates blue and the positive, yellow. Chroma, on the other hand, represents the saturation of the color, with higher values denoting brighter colors (Ferreira, 2017). Thus, the results show that the 0.2-0.35 m fruits have a color with greener and yellower pigments and greater saturation than the larger fruits.

Statistical differences were also observed for the time of harvest for the coordinates a*, b*, and Chroma (Figure 2B, D and F). Fruit harvested at 115 dap had a lower a* value (-12.86) and higher b* and chroma values (18.57 and 25.99, respectively) than fruit harvested at 135 dap. These results showed that the fruit harvested at 115 dap had a greener color. The greener color on the skin of metro okra is important for harvesting, considering that the fruits are consumed immature.

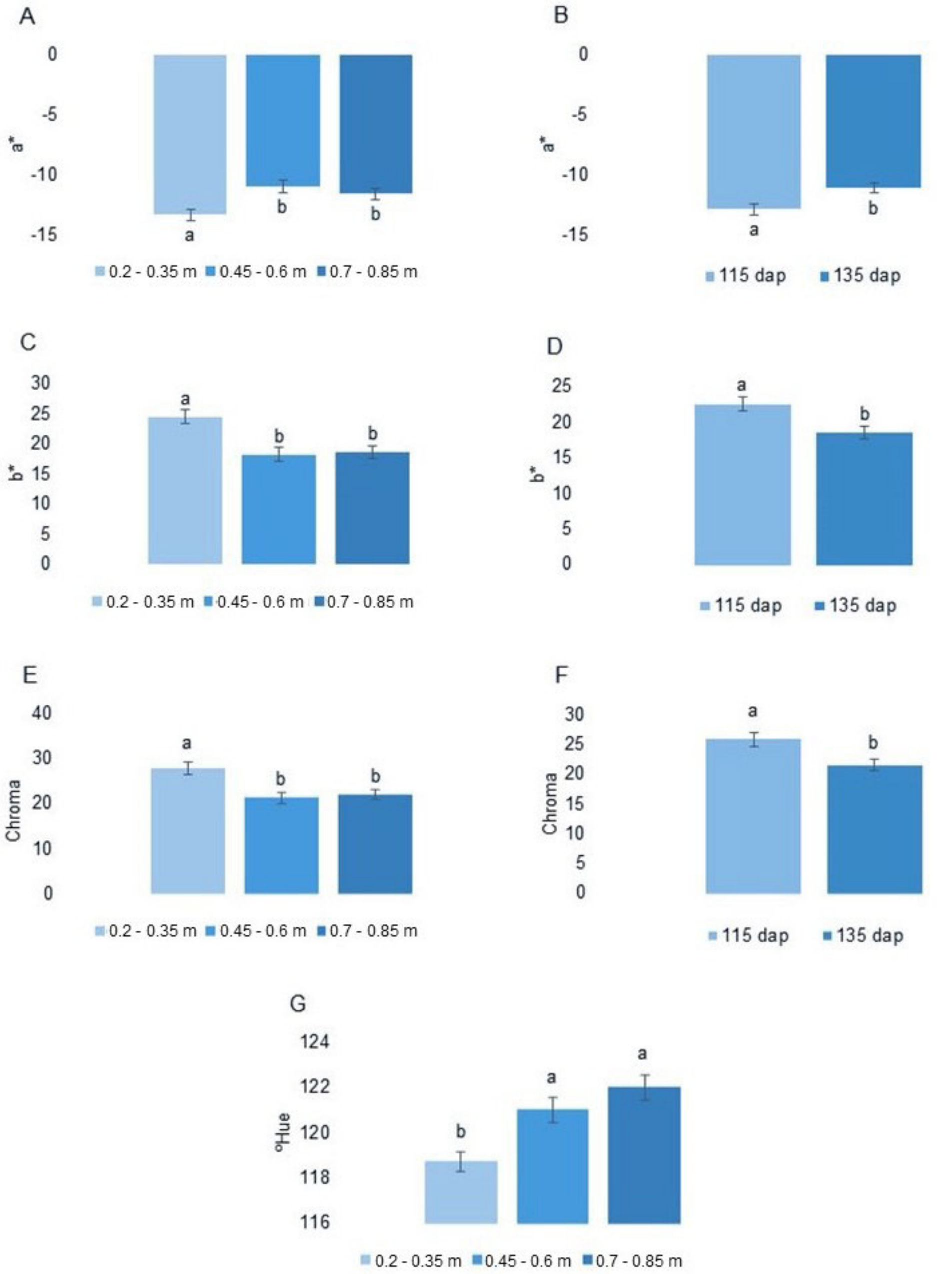

Figure 2. Color parameters of snake gourd fruits: a*, b*, chroma, and hue in different fruit sizes (A, C, E, G); a*, b*, and chroma in different harvest times (B, D, F). The values presented are means ± standard deviation. Equal letters within columns did not differ significantly according to the Scott-Knott test ($p > 0.05$).

For the a* and b* coordinates, a study conducted with snake gourd cultivars found values ranging from -2 to -9 for a* and between 20 and 22 for b* (Dabesor et al., 2022), differing from the results obtained in the present study. The current study reported more favorable values, with a* values lower than -9 and b* values greater than 22, likely due to differences in the assessed harvest point.

For luminosity, which ranges from black (0) to white (100), the fruits did not show statistical differences between fruit sizes or harvest times, with an average L* value of 46.44. In a study involving various metro okra varieties, mean L* values between 40 and 51 were found, similar to the results obtained in the present study (Dabesor et al., 2022).

The °Hue, which expresses the shade of color whose values range from 0 to 360°, with yellow-green tones between 90 and 180°, showed statistically significant results only for the size of the fruit, in which okra measuring 0.2-0.35 m showed the lowest value (118.74), i.e. these fruits have a greener skin, which is desirable for immature fruit (Figure 2G).

Color is one of the main visual aspects observed by consumers when buying food, so it is of the utmost importance to evaluate it and it is also an essential parameter in post-harvest studies since it is a non-destructive analysis that allows inferences to be made about vegetables (Chitarra & Chitarra, 2005; Silva et al., 2009a, 2009b; Ferreira, 2017). The snake gourd is consumed when it reaches horticultural maturity, i.e., the definition is cultural and does not depend on the fruit's complete physiological maturity, so it is harvested while still immature and with green skin (Madeira et al., 2013).

Therefore, taking into account the importance of color for the final consumer of vegetables, it is essential to evaluate the color parameters a*, b*, and L*, with a view to a more greenish or yellowish coloration that can infer the ripeness of the snake gourd, as well as the luminosity that reveals the quality and tenderness of the fruit, together with the Chroma and °Hue parameters, which allow us to infer the hue more directly and the saturation of the color that also relates to the quality of the fruit.

As for soluble solids (SS), the averages found, expressed in °Brix, differed statistically from each other for both fruit sizes and harvest times (Figure 3). For the fruit sizes, the highest values were found for 0.2-0.35 m and 0.45-0.6 m (3.15 and 3.23 °Brix, respectively), which did not differ from each other (Figure 3A). For harvest times, the highest value found was 3.40 °Brix at 115 dap (Figure 3B).

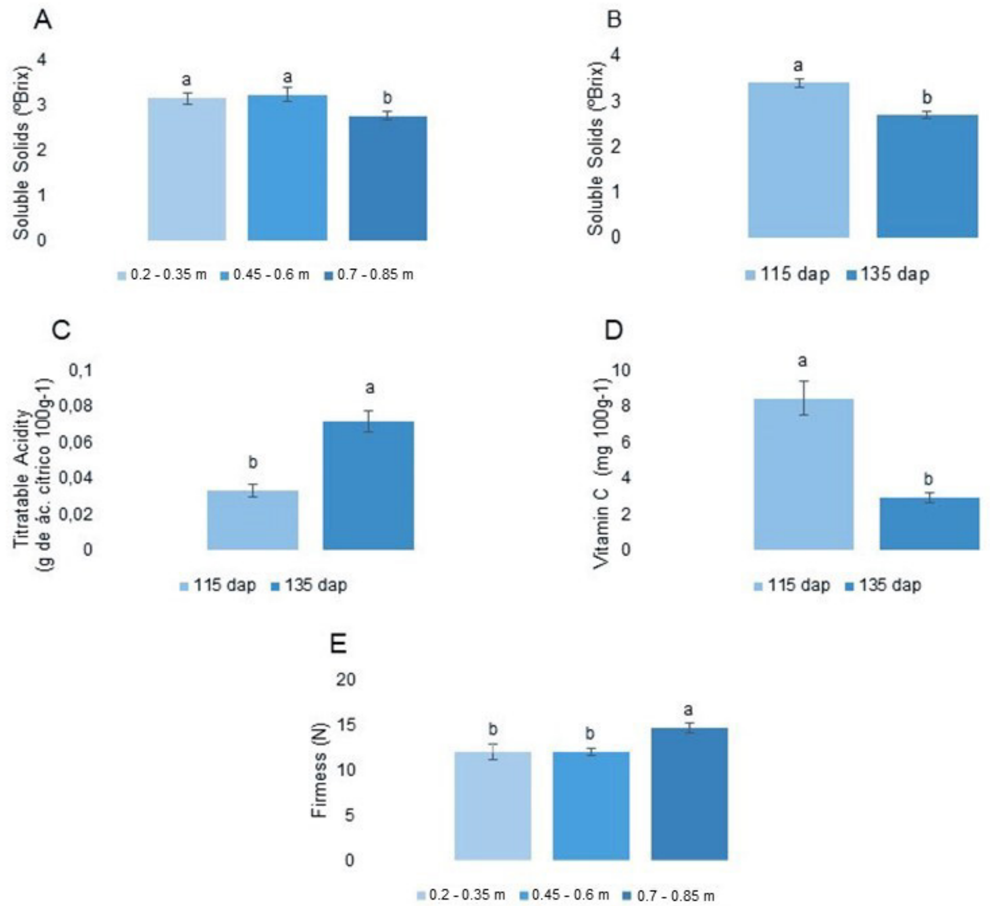

Figure 3. Soluble solids snake gourd fruit at different sizes (A) and harvest times (B); Titratable acidity (C) and Vitamin C (D) snake gourd fruit at different harvest times; Firmness (E) of snake gourd fruit at different sizes. The values shown are means ± standard deviation. Equal letters in the columns did not differ according to the Scott-Knott test ($p > 0.05$).

It is i noteworthy that the soluble solids content is an important characteristic in the composition of the fruit's flavor, as it is the variable that quantifies all the sugars and acids present, as well as indicating the yield of the fruit and the energy expenditure for concentrating the pulp by the food industry (Shirahige, 2010). In the literature, values between 1 and 3 °Brix of soluble solids are found in the fruit of some varieties of metro okra (Dabesor et al., 2022), which differs from the results found in the present study in which values above 3 °Brix were found in the best results, again possibly due to the different harvest point of the fruit.

The fruit of snake gourd has low soluble solids values as it is not sweet fruit, like zucchini (*Cucurbita pepo*) which has values between 2.3 and 4.6 °Brix (Martínez-Valdivieso et al., 2015), okra (*Abelmoschus esculentus*) between 5 and 6 °Brix (Santos et al., 2019), chayote (*Sechium edule*) is around 4 °Brix (Ramírez-Rodas et al., 2021). The differences in soluble solids found in this study at different sizes and harvest times can be attributed to the beginning of the use of fruit metabolites in respiration through the natural process of senescence, the larger the fruit and the longer it remains attached to the mother plant (Chitarra & Chitarra, 2005).

The titratable acidity was significantly different only between the harvest times, with the lowest value at 115 dap being 0.033 g citric acid 100 g^{-1} and the highest value at 135 dap being 0.072 g citric acid 100 g^{-1} (Figure 3C). There was no statistical difference between the fruit sizes and the average value was 0.053 g citric acid 100 g^{-1}.

Titratable acidity is another component of fructose flavor that is related to fruit astringency, associated with soluble solids conferring milder or more acidic flavor, so it is a variable always checked to assess the quality of food products (Giordano & Silva, 2000; Chitarra & Chitarra, 2005). A study found a titratable acidity value of 1.98±0.01% citric acid and a pH of 4.40±0.10. However, fully mature fruits were used for this study because, in the region, there is a custom of consuming mature vegetables as a more economically viable substitute for conventional tomatoes (Adebooye & Oloyede, 2007). This indicates that the fruit tends to increase in acidity as it matures, similar to other vegetables, and a lower acidity value suggests more immature fruits, which are more desirable as they are consumed at horticultural maturity in Brazil.

There are vegetables for which optimal acidity levels are well-defined, such as tomatoes, which should have around 0.35 g per 100 g. However, there are not yet studies parameterizing these values for snake gourds. Based on vegetables from the same family, low acidity is a characteristic that has been observed, such as in cucumber (*Cucumis Sativus* L. - 0.07% citric acid) (Moreno Velázquez et al., 2013), zucchini (*Curcubita moschata* - 0.48% citric acid) (De Paula Nascente et al., 2019), and squash (*Curcubita máxima Duchesne* - 0.52% malic acid) (Russo et al., 2012).

For vitamin C, there was a statistical difference only for harvest times in which fruits harvested at 115 Dap the value was higher, with 8.45 mg 100 g^{-1}, compared to fruits with 135 Dap (Figure 3D). There was no significant difference in the sizes, observing an overall average of 5.70 mg 100 g^{-1}.

Vitamin C content can vary widely in vegetables due to various factors. One of these is the harvest season, as has been observed in other vegetables like carrot (*Daucus carota*), radish (*Raphanus sativus*), pepper (*Capsicum spp*.), orange (*Citrus spp*.), and tangerine (*Citrus spp*.) (Wang et al., 2007; Couto & Canniatti-Brazaca, 2010; Ferreira et al., 2011; Neves et al., 2022). Additionally, changes in vitamin C content can occur due to oxidation reactions, such that levels tend to decrease as senescence progresses (Carnelossi et al., 2004).

The firmness was significantly different between the lengths, in which the fruits with 0.2-0.35 m and 0.45-0.6 m presented lower averages (12.05 N and 12.10 N), differing from the larger fruits (Figure 3E) results found in the literature for wild varieties that showed a peak of firmness when they are ripe greens that only decreases when the fruits are fully ripe (Dabesor et al., 2022). This indicates that the younger fruits have a softer texture There was no statistical difference between the harvest times and the average was 13.26.

The pH and dry matter of the fruits showed no statistically significant differences, neither between the lengths of the fruit nor between the harvest times separately, the average values observed were 5.85 for pH and 4.82%

for dry matter. In wild variety meter okra, the dry matter value found in the literature is 9.5 g 100 g^{-1} (Adebooye & Oloyede, 2007).

Regarding the antioxidant capacity, there was no statistical difference between the fruit sizes or between the harvest times, separately, by the free radical capture method DPPH in which the average observed was 43.12 g lyophilized fruit mg^{-1} DPPH. By the method of reduction of Iron (FRAP), the average value observed was 11.09 µM ferrous sulfate g^{-1} of lyophilized fruit. The polyphenols presented an average of 52.68 2.87 mg of gallic acid 100 g^{-1} of lyophilized fruit, which is an interesting value because polyphenols are also part of the compounds with antioxidant power and are superior to that found in zucchini pulp, which is around 25 mg of acid gallic 100 g^{-1} (Gomes et al., 2023).

As all fruits were harvested still immature, the visual changes observed may not have been sufficient to significantly increase the antioxidant activity of the fruits, which generally tends to increase with ripening since substances such as lycopene, carotenoids, and other compounds with antioxidant potential are synthesized (Meléndez-Martínez et al., 2010). The potential of fruits to combat reactive oxygen species that can cause chronic diseases has been demonstrated but, using ripe fruits, attributes much of the antioxidant response to lycopene. Thus suggested the inclusion of okra meter in the diet to replace or complement the tomato conventional (*Lycopersicon esculentum*) (Ademosun, 2013), there is also antioxidant activity attributed to flavonoids and phenolics; however, other parts of the plant, especially the leaves, exhibit even higher activity (Liyanage et al., 2016).

4 Conclusions

As the results have shown, snake gourd fruits measuring 0.2-0.35 m and 0.45 to 0.6 m in length possess better color characteristics, firmness, and higher soluble solids content. Additionally, fruits harvested at 115 DAP (Days After Planting) have higher levels of Vitamin C, lower acidity levels associated with higher soluble solids content, and better color characteristics. Therefore, the fruits should be harvested at lengths up to 0.6 m and at 115 DAP in order to make the most of their full potential, while also offering better flavor and texture.

With this information, it is possible to better guide farmers on the appropriate timing for harvesting the fruits for commercialization and consumption. Additionally, considerable values were found for antioxidant activity and polyphenols, which are independent of the fruit's size and harvest time. This underscores the importance of including meter-long okra in the population's diet.

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