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RESEARCH ARTICLE

Quality of sweet-grape tomatoes grown under different nitrogen rates and sources

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ABSTRACT

Most sweet-grape tomatoes are marketed fresh; thus, sensorial characteristics are important for this vegetable. In this context, the objective of this work was to evaluate the technological quality based on the physical, chemical, and sensorial characteristics of sweet-grape tomatoes, the cultivar Carolina, grown under different nitrogen (N) sources (urea and organo-mineral) and N rates (50%, 75%, 100%, and 125%). The experiment was conducted in a greenhouse with controlled environment; the plants were grown in pots, using a drip irrigation system. A completely randomized experimental design was used, in a 2×4 factorial arrangement. The N soil fertilizer application was divided into three times: at 10, 17, and 24 days after the emergence of the plants. The fruits were harvested when presenting reddish color in the whole surface. The parameters evaluated were: weight, volume, specific volume, density, color, texture, total soluble solids, and sensorial characteristics. The physical characteristics of the sweet-grape tomatoes showed better results when using the organo-mineral treatment. The sensorial analysis showed better results when using the treatment with organo-mineral nitrogen fertilizer, which resulted in better marketable fruits higher than 70%. The treatment with urea resulted in marketable fruits higher than 50%. The N rate of 50% (urea or organo-mineral) resulted in greater acceptance by consumers, when considering the parameters appearance and firmness.

Keywords: Nitrogen fertilizer application; Sensorial analysis; *Solanum lycopersicum* var *cerasiforme*

INTRODUCTION

Cherry- or mini-tomatoes have been stood out among tomato types that have been showing high demand for fresh consumption (Guilherme et al., 2014), mainly those from special hybrids, such as the sweet-grape tomato. The main characteristics of sweet-grape tomatoes is low acidity index, high contents of sugar and soluble solids (Junqueira et al., 2011), small size, elongated shape, and intense red color, which ensure a good acceptability by consumers (Oltman et al., 2014) and results in a high consumption, making the crop economically viable (Sandri et al., 2015). Fruits from this hybrid represents up to 10% of the total horticulture sales, despite being 20% to 40% more expensive than those from common tomato types (Junqueira et al., 2011).

Despite the investments on the spreading of technologies, such as protected environment crops, combined with efficient uses of irrigation and soil fertilizers to improve fruit quality, scientific researches still should contribute to maximize production processes. Increase in yield and decreases of production risks have making this activity more profitable; however, nitrogen fertilizer application is one of the factors that directly affect the fruit yield and quality (Mehmood et al., 2012; Trani, 2015).

Nitrogen (N) is one of the most required nutrients by tomato plants (Li et al., 2017) and can affect the quantity of vitamin C and the main phenolic compounds in these fruits (Hernández et al., 2020). Different N sources, such as ammonium (NH_4^+) and amide (urea), are commonly used in tomato crops (Lu et al., 2016; Ochoa-Velasco et al., 2016); however, it is necessary to define the best N source according to the species and variety to be grown and the effect of N supply from this source on technological and sensorial characteristics of the fruits.

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Tomato growers have focused mainly on yield, adaptation to specific growth conditions, resistances to diseases, and fruit shelf-life time, but not specifically on fruit quality (Casals et al., 2019). However, despite the commonly used varieties had been approved in crop tests, evaluating the physical-chemical and acceptability of sweet-grape tomatoes before making them available to consumers is important (Guilherme et al., 2014). Sensorial tests and evaluations of potential markets are essential to improve the product (Jürkenbeck and Spiller, 2021).

Most tomato fruits are marketed fresh; thus, sensorial characteristics are important (Weingerl and Unuk, 2015; Ylahy et al., 2018) to predict the quality and indicate consumption preferences (Guilherme et al., 2014; Casals et al., 2019). Preference test is one of the methods of sensorial analyses to assess the preference and satisfaction level of consumers for a specific product (Anzaldúa-Morales, 1994).

In this context, the objective of this work was to evaluate the technological quality of physical, chemical, and sensorial characteristics of fruits of sweet-grape tomatoes of the cultivar Carolina grown under different nitrogen sources and rates in a Cerrado Red Latosol under a protected environment, in the Cerrado biome, Brazil.

MATERIAL AND METHODS

Site description

The experiment was conducted at the Goiano Federal Institute, Rio Verde campus, in the southwest of the state of Goias, Brazil (17°47'53"S, 51°55'53"W), in a greenhouse with controlled environment (air temperature of 27±3 °C, relative air humidity of 60±3%). A surface drip irrigation system was used, consisting of one emitter (Irritec) per pot, at flow rate of 2.0 L h^{-1} and maximum pressure of 196 kPa, and low-density polyethylene hoses of 16 mm diameter.

Experimental design

The experiment was conducted in a completely randomized design with a 2×4 factorial arrangement and six replications. The factors consisted of two nitrogen (N) sources (urea and organo-mineral) and four N rates [50, 75, 100, and 125% of the commercially recommended rate for the crop (120 kg ha^{-1})] (Soil Fertility Commission - RS/SC, 1995). The organomineral N is named according to its composition being a mixture of organic and mineral N. This source of nutrients has the following characteristics in its raw material: 51.72% organic matter, 17% moisture, 8 degrees of hydrogenic potential and a c/n ratio of 12:1. In addition, this source of organomineral has 02% in nitrogen content.

Variety and management

Sweet grape tomatoes (*Solanum lycopersicum*), which has indeterminate growth habit and harvest time at 60 days after planting, was used to evaluate the responses to the treatments. The tomato seedlings were produced in plastic trays and later transplanted to 8-liter pots at 20 days after sowing.

The soil of the experiment was classified as a dystrophic Typic Hapludox and presented the following composition: P total = 1.15 mg dm^{-3}; K = 72.0 mg dm^{-3}; Ca = 2.31 cmolc dm^{-3}; Mg = 1.43 cmolc dm^{-3}; Al = 0.02 cmolc dm^{-3}; sum of exchangeable bases = 3.92 cmolc dm^{-3}; cation exchange capacity = 6.52 cmolc dm^{-3}; base saturation = 60.1%; organic matter content = 46.2 g dm^{-3}.

The nitrogen soil fertilizer application was divided into three times, at 10, 17, and 24 days after the emergence of the plants. The fruits were harvested as they presented reddish color in the whole surface; thus, they were daily monitored.

Technological quality evaluation

The physical analyses of tomatoes were carried out using fruit samples randomly divided into three subsamples of 20 replications (fruits), totalizing 60 fruits, which were identified and measured for weight, volume, specific volume, and density. The weight was measured individually in an analytical digital balance (Shimadzu, BL320H, Japan) (Ferreira, Ferreria & Fontes, 2010). The volume was measured by the water displacement in a 100 mL graduated cylinder. The specific volume was calculated by the fruit volume to weight ratio, and the density was calculated by the fruit weight to volume ratio (Ferreira et al., 2010).

The fruits were washed, sanitized, and crushed, and their pulps were frozen for the physical-chemical analyses. The total soluble solid contents were evaluated in a portable digital refractometer (Reichert, Brix/RI-Chek, Japan). The total titratable acidity was measured using 5 g samples diluted into approximately 100 mL of distilled water and 0.3 mL of a phenolphthalein solution was added per 100 mL of the solution to be titrated. The titration was carried out with a 0.1M sodium hydroxide solution under constant shaking until the pink color was persistent for 30 seconds. The hydrogen potential (pH) was measured using a digital pH-meter (Hanna, HI 2221, Brazil) (Association of Official Analytical Chemists, 1995).

The fruit color and texture were also evaluated. The instrumental color of the external part of fresh fruits was determined using the parameters, according to the CIELab system (CIE, 1986), using a spectrophotometer (Color Flex EZ, Reston, USA): light or bright (L*), which varies from black (0) to white (100); a*, which varies from green (-a*) to red (+a*); and b*, which varies from blue (-b*) to yellow (+b*).

The texture was determined using the maximum force parameter. The fruits were transversally cut in their largest diameter for positioning them, without moving on the base of the texturometer (Brookfield, CT3, EUA) and the compression test was performed using test tips (TA4/100) and a rectangular base (TA-BT-KI), with a penetration depth of 5.0 mm, speed of 1.0 mm s^{-1}, and trigger load of 0.10 N following the methodology adapted from Bugaud et al. (2013).

Sensorial evaluation

The study of sensorial analysis was approved by the Research Ethics Committee of the Goiano Federal Institute, Brazil (CAAE 98181118.5.0000.0036); the consent of each participant was previously obtained. The panel of tasters was composed by non-trained tasters of both sexes and different ages; they were students, employees, and professors of the Goiano Federal Institute, Rio Verde campus. A preference test of ideal scale was conducted to evaluate appearance, flavor, and texture attributes, using a scale from +3 to -3, in which +3 was very above the ideal and –3 was very below the ideal (Table 1) (Dutcosky, 2013). The intention of purchase test was carried out using a scale of 5 points, in which 1 was equal to surely would buy and 5 was equal to never would buy (Table 2) (Dutcosky, 2013). The samples were monadically served, together with water and a salty cracker for palate cleaning between evaluations. The analyses were carried out at the Laboratory of Sensorial Analyses of the Goiano Federal Institute, Rio Verde campus, in individual cabins under white light, in two sessions with four samples each to avoid the fatigue of the tasters. The results were expressed as percentage of tasters, which attributed each value for each attribute evaluated for each sample.

Table 1: Ideal scale for appearance, flavor, and firmness of fruits of sweet-grape tomato (*Solanum lycopersicum* var. *cerasiforme*)

Parameters	Appearance, flavor, and firmness
+3	Very above the ideal
+2	Moderately above the ideal
+1	Slightly above the ideal
0	Ideal
-1	Slightly below the ideal
-2	Moderately below the ideal
-3	Very below the ideal

Table 2: Ideal scale for intention of purchase of fruits of sweet-grape tomato (*Solanum lycopersicum* var. *cerasiforme*)

Parameters	Intention of purchase
1	Surely would buy
2	Probably would buy
3	Not sure whether would buy
4	Probably would not buy
5	Never would buy

The effect of fruit size on the intention of purchase by possible consumers was evaluated using whole fruits grouped into three sizes (small, medium, and large) placed in transparent plastic bags at environment temperature for visual analysis. This test was carried out after the sensorial analysis; the tasters were asked to classify, in an increasing order of preference, samples from treatments with N sources (urea and organo-mineral).

Statistical analysis

The data of all analyzed variables were subjected to analysis of variance by the F test at 1% and 5% probability. Significant means were compared by the Tukey's test at 5% probability level to evaluate the effects of N sources and rates, using the Assistat 7.7 statistical program (Silva and Azevedo, 2016).

RESULTS AND DISCUSSION

Technological quality evaluation

The specific volume of fruits from plants grown in soils fertilized with organo-mineral N was 3.08% greater than that of fruits from plants grown in soils fertilized with urea. The fruit density was 8.33% greater when using urea as N fertilizer, compared to the organo-mineral N (Table 3). Contrastingly, Ferreira et al. (2010) found that tomatoes grown under inorganic fertilizer applications present greater specific volume than those grown under organic fertilizer applications.

The pH values found were within the ideal range for sweet-grape tomatoes, higher than 3.7 and lower than 4.5 (Giordano et al., 2000; De Paula Vieira et al., 2014). The analysis of variance for the pH of tomato fruits did not differ significantly between the fertilized sources (urea and organo-mineral) (Table 3). These results are consistent with those of Ferreira et al. (2006), who evaluated tomatoes (*Lycopersicon esculentum* Mill. cv Santa Clara) fertilized with different N rates, with or without organic fertilizer, and found no changes in pH. However, other studies must be carried out to evaluating pH of tomato fruits using different fertilizer sources found fruits with lower acidity when using organic fertilizers (Ferreira et al., 2010; Paixão et al., 2020).

The mean total titratable acidity found in tomato fruits in the organo-mineral fertilizer treatment was 5.97%, which means 8.21% higher than that found in those in the treatments with urea, which had total titratable acidity of 5.48% (Table 3). A total titratable acidity higher than

0.35% is ideal for fruits grown for industrial processing, since it contributes to the flavor and food safety, inhibiting microorganism proliferations (Ilahy et al., 2018). In addition, acidity, as well as sugar, is related to the perception of sweetness and aroma of tomato fruits (Adhikari et al., 2018; Casals et al., 2019), which affect their acceptability by consumers.

The fertilizer sources and rates had no effect on the total soluble solid contents of tomato fruits (Tables 3 and 4), denoting that nitrogen has no effect on this parameter, as found in the cultivar Santa Clara by Ferreira et al. (2006). However, other studies found significant differences in total soluble solid contents of tomato fruits grown in organic production systems using cattle and bird manure and seaweed as soil fertilizers (Barrett et al., 2007; Pieper and Barrett, 2009; Bilalis et al., 2018). The absence of significant difference between treatments for total soluble solid contents may be related to environmental and cropping conditions in which the plants were grown (Ferreira et al., 2006).

The fertilizer rates had no effect on the, specific volume, and density of tomato fruits (Table 4). The rates of 50% and 125% resulted in the lowest and highest pH values, respectively, with a difference of 2.74% (Table 4). The doses of N promoted diferença estatística for pH, denoting a codependence between the N source and N rate for fruit acidity (Table 4). The fruit firmness was affected only by the N rates where 50% of N rate was better than 100 and 125% (Table 4). Total soluble solid contents, fruit specific volume, fruit density and firmness are importance aspects related to resistance of fruits to post-harvest handling, and maintenance of physical quality during transport and distribution, that affect the acceptability of the product by the consumer (Oltman et al., 2014).

Some external factors such as temperature and light incidence can affect the fruit color by inhibiting lycopene synthesis (Benard et al., 2009; Ilahy et al., 2018). All plants were grown in the greenhouse with controlled environment; therefore, no significant differences were

Table 3: Test of means for pH, total titratable acidity (TTA), total soluble solid contents (TSS), firmness, specific volume, and density of sweet-grape tomatoes (*Solanum lycopersicum* var. *cerasiforme* -cv. Carolina) grown in soils fertilized with urea and organo-mineral nitrogen fertilizer

Source of N	pH	TTA (%)*	TSS (°Brix)	Firmness (N)	Specific volume (m^3 Kg^{-1})**	Density (Kg m^{-3})**
Urea	4.34^a	5.48^b	7.24^a	4.87^a	0.84^b	1.20^a
Organomineral	4.31^a	5.97^a	7.47^a	4.72^a	0.91^a	1.10^b
CV (%)	2.07	14.31	11.19	24.18	8.65	8.21

Means followed by same letter in the columns are not significantly different from each other by the Tukey's test (p>0.05). **and *significant at 1 and 5% probability, respectively.

Table 4: Test of means for pH, total titratable acidity (TTA), total soluble solid contents (TSS), firmness, specific volume, and density of sweet-grape tomatoes (*Solanum lycopersicum* cv. Carolina) grown in soils fertilized with four different rates of nitrogen

N rates (%)	pH*	TTA (%)**	TSS (°Brix)	Firmness (N)**	Specific volume (m^3 Kg^{-1})	Density (Kg m^{-3})
50	4.26^b	6.13^a	7.57^a	5.78^a	0.89^a	1.13^a
75	4.33^{ab}	5.39^{ab}	7.60^a	4.82^{ab}	0.88^a	1.14^a
100	4.33^{ab}	5.14^b	7.39^a	4.16^b	0.88^a	1.12^a
125	4.38^a	6.24^a	6.87^a	4.42^b	0.85^a	1.19^a
CV (%)	2.07	14.31	11.19	24.18	8.65	8.21

Means followed by same letter in the columns are not significantly different from each other by the Tukey's test (p>0.05). **and *significant at 1 and 5% probability, respectively

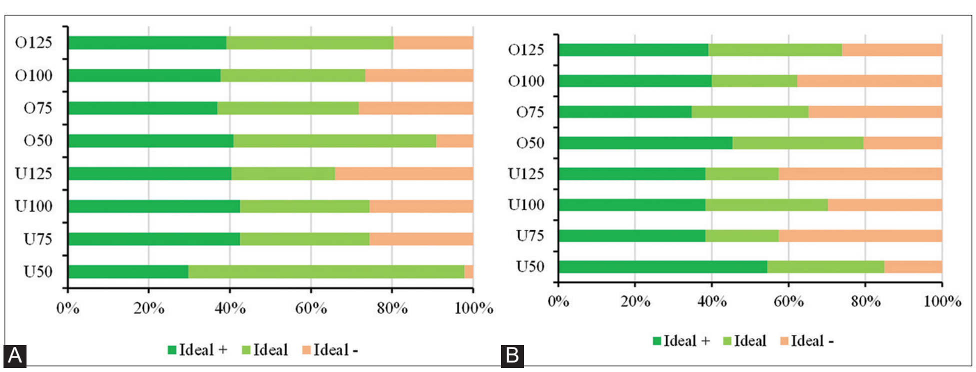

Fig 1. Classes of ideal scale for the attribute appearance (A) and flavor (B) of sweet-grape tomatoes in the treatments U50 (Urea 50%), U75 (Urea 75%), U100 (Urea 100%), U125 (Urea 125%), O50 (Organo-mineral 50%), O75 (Organo-mineral 75%), O100 (Organo-mineral 100%), and O125 (Organo-mineral 125%). Percentage of tasters that attributed each grade in the ideal scale test in the sensorial analysis

found for the parameters L* (light), a* (-a green, +a red), and b* (-b blue, +b yellow) of tomato fruits, regardless of the fertilized source used. The a* means were 20.10 (urea) and 20.30 (organo-mineral). Bilalis et al. (2018) also found no significant differences in tomato (*Lycopersicon esculentum* cv Moinho. 'Heinz 3402 'F1), with a* value of 43.4 for fruits of plants grown in soils fertilized with organic compost. The tomato red color is attributed to the presence of lycopene non-vitamin carotenoid pigment group, which are powerful antioxidants and responsible for positive effects of the consumption of tomato on human health (Borguini et al., 2013; Ilahy et al., 2018). Most tomato fruits are marketed fresh; thus, color characteristics are important for the consumer market (Weingerl and Unuk, 2015; Ylahy et al., 2018).

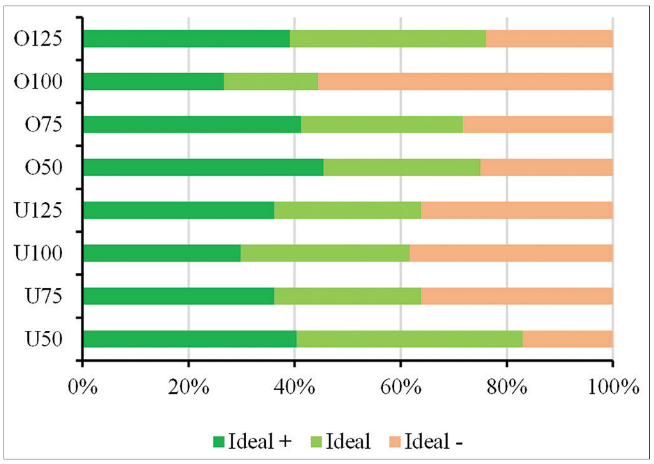

Fig 2. Classes of ideal scale for the attribute texture of sweet-grape tomatoes in the treatments U50 (Urea 50%), U75 (Urea 75%), U100 (Urea 100%), U125 (Urea 125%), O50 (Organo-mineral 50%), O75 (Organo-mineral 75%), O100 (Organo-mineral 100%), and O125 (Organo-mineral 125%). Percentage of tasters that attributed each grade in the ideal scale test in the sensorial analysis

Sensorial evaluation

The test of ideal scale of the sensorial analysis showed that more than 90% of tasters classified the tomato fruits as ideal, and 80% classified the fruits as above the ideal for the treatments urea and organo-mineral, when using 50% of the recommended rate for the attributes appearance (Fig. 1A) and flavor (Fig. 1B). The treatment with 50% of the recommended rate presented higher values of light, showing that the consumer considers bright-appearance fruits more attractive. The results confirm those of Oltman et al. (2014), who evaluated different types of fresh tomatoes and found that consumers consider color as the most important attribute. Nitrogen application is needed to achieve high lycopene contents, which is directly related to the fruit color (Simonne et al., 2007; Kuscu et al., 2014).

Regarding the texture, 42% of tasters classified the fruits from the treatment with urea and N rate of 50% as ideal (Fig. 2). Most tasters classified fruits from the treatment with the N rate of 100% as below the ideal for texture; this treatment presented the lowest value in the instrumental analysis (4.16 N; coefficient of variation of 24.18), denoting greater preference and acceptance by consumers for tomatoes with better texture. This was also found by Batu (2004) and Otman et al. (2014) when evaluating different tomatoes types.

The intention of purchase test showed that all treatments had satisfactory results (Costa et al., 2020). More than 50% of tasters answered that surely or probably would buy the tomato fruits (Fig. 3). Considering that the tasters answered that surely or probably would buy the tomato fruits, the intention of purchase found for the fruits, according to the treatments, in decreasing order were: U50 (91.49) > O50 (81.82) > O125 (71.74) > O75 (67.39) > U75 = U125 (59.57) > O100 (55.56) > U100 (53.06).

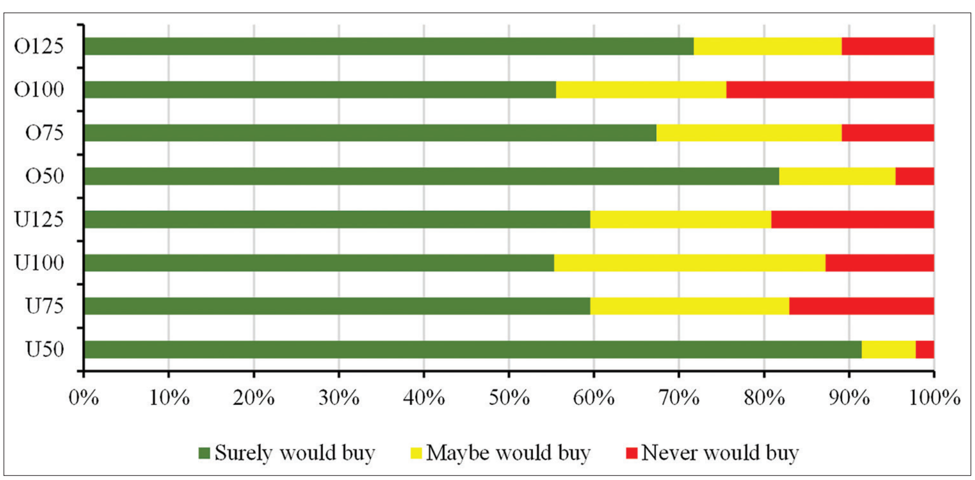

Fig 3. Classes of ideal scale for intention of purchase of sweet-grape tomatoes in the treatments U50 (Urea 50%), U75 (Urea 75%), U100 (Urea 100%), U125 (Urea 125%), O50 (Organo-mineral 50%), O75 (Organo-mineral 75%), O100 (Organo-mineral 100%), and O125 (Organo-mineral 125%). Percentage of tasters that attributed each grade in the ideal scale test in the sensorial analysis

The treatments that presented higher potential for tomato fresh market were urea 50%, organo-mineral 50%, and organo-mineral 125%. Thus, tomato fruits from plants grown in soils fertilized with organo-mineral fertilizer presented greater intention of purchase. In addition, the tomato fruit size affects the intention of purchase by consumers, as found in other studies evaluating different types of tomato that showed preference of consumers mainly affected by the fruit size (Andreuccetti et al., 2005; Costa et al., 2020). This reinforces the importance of sensorial analysis, since most tomatoes fruits are marketed fresh, making visual characteristics important for the consumer (Weingerl and Unuk, 2015; Ylahy et al., 2018).

CONCLUSIONS

The physical characteristics of sweet-grape tomatoes (*Solanum lycopersicum* var. *cerasiforme*) showed better results when using the organo-mineral nitrogen fertilizer. The N rate of 50% (urea or organo-mineral) resulted in fruits with greater acceptance by consumers when considering the parameters appearance and firmness.

The two N sources used (urea and organo-mineral) showed satisfactory results, considering the test of ideal scale in the sensorial analysis; however, fruits from the treatment with organo-mineral nitrogen fertilizer presented greater intention of purchase than those from the treatment with urea. The sensorial test was satisfactory for the technological evaluation and can be used for management evaluations.

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CONTRIBUTIONS OF THE AUTHORS

Paixão, C. F. C. wrote, reviewed, and corrected the manuscript. Santos, L. N. S. designed the field study. Teixeira, M. B. designed the field study. Soares, F. A. L. carried out statistical analyses. Egea, M. B. designed the sampling and collected the sensorial data. Soares, J. A. B. wrote, reviewed, and corrected the manuscript. Vidal, V. M. reviewed and corrected the manuscript. Gomes, L. F. carried out statistical analyses, Fernandes, L. O. carried out the sampling and data collection. Lira, L. C. carried out the sampling and data collection.

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