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# Growth and ripening of two cultivars of *Cucumis anguria* L. fruits

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**ABSTRACT:** To establish the optimal horticultural harvest stage of *Cucumis anguria* L. fruit, it is necessary to identify the morphological and physiological changes of the two commercial cultivars. Fruits of the cultivars 'Maxixe do Norte' and 'Maxixe Liso de Calcutá' were harvested at 1, 3, 6, 10, 13, 15, 17, 19, and 22 days after anthesis. The fruits of both cultivars showed a simple sigmoidal growth curve, with a maximum rate on the 11$^{th}$ day after anthesis. Respiration showed a sharp decline as the fruit grew, showing no increase in the later stages of development. Both the soluble solids content and titratable acidity decreased throughout the growth.

**Key words:** *Cucumis anguria* L.; development; harvest; physiology

# Crescimento e amadurecimento de frutos de duas cultivares de *Cucumis anguria* L.

**RESUMO:** Para estabelecer o estágio de colheita hortícola ideal dos frutos de *Cucumis anguria* L. é necessário identificar as alterações morfológicas e fisiológicas das duas cultivares comerciais. Frutos das cultivares Maxixe do Norte e Maxixe Liso de Calcutá foram colhidos aos 1, 3, 6, 10, 13, 15, 17, 19 e 22 dias após a antese. Os frutos de ambas as cultivares apresentaram curva de crescimento sigmoidal simples, com taxa máxima no 11º dia após a antese. A respiração apresentou uma queda acentuada à medida que os frutos cresceram, não mostrando aumento nas fases posteriores do desenvolvimento. Tanto o teor de sólidos solúveis quanto a acidez titulável tiveram redução ao longo do crescimento.

**Palavras-chave:** *Cucumis anguria* L.; desenvolvimento; colheita; fisiologia

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## Introduction

Fruit growth and ripening are characterized by expressive changes on texture, on chemical constituents and physiological events. After anthesis cell division followed by cell expansion take place increasing the fresh mass of the fruits and depending on the species may show single or double sigmoid. Little is known on the growth pattern of fruits from the family Cucurbitaceae. Fruits of *Cucumis sativus* and *Cucurbita pepo* have a typical single sigmoid pattern of growth (Hurr et al., 2009; Purquerio et al., 2019). Nevertheless, there is no mention about the kind of growth and changes on fruit mass and volume are associated with the development of *Cucumis anguria* L. fruits.

*Cucumis anguria* L. fruits are extremely popular in many regions of Brazil being used in stews, vinaigrettes and salads. In addition, Brazilians living in the USA are potential consumers, opening a new vegetable crop for the American farmers and new option for exports from Brazil to the USA (Mangan et al., 2008; Mangan et al., 2012)

Chlorophyll and carotenoid pigments are frequently utilized to characterize changes on fruit growth and ripening. In most fruits, chlorophyll is hydrolyzed during ripening, while carotenoids in general accumulate or reveled with profound changes in the color and quality (Ge et al., 2017). Regardless the cultivar and destination, in the case of *Cucumis anguria* L., the fruits must retain the green color for best consumer's quality. Silva et al. (2015) showed that a postharvest treatment of *Cucumis anguria* L. fruits with adequate packaging and the use of ethylene absorber keep the green color for longer period, extending the shelf life by reducing the rate of yellowing and water loss.

Ripening of fruits is characterized by changes on carbohydrate metabolism and composition, and respiration affecting the taste, flavor and the shelf life. No previous work was done before focusing on the morphology and physiology of *Cucumis anguria* L. fruits from the anthesis up to ripening. In this work, the development and commercial quality of two distinct cultivars of *Cucumis anguria* L. were determined.

## Materials and Methods

The field experiment was established in 2015 in a region located at 651 m above the sea level, latitude south 20°45'20'' and west longitude 42°52'40'', climate Cwa.

Commercial seeds from cultivars 'Maxixe do Norte' and 'Maxixe Liso de Calcutá' were grown in a greenhouse in polystyrene trays with 128 cells filled with land from ravines and commercial substrate. When the plantlets reached 2 to 3 pairs of true leaves, they were transplanted to the bed spaced in 2.5 × 1.0 m. Before transplanting, the beds were prepared with land from ravines and the soil was managed according to the recommendations for cucumber cultivation (Modolo & Costa, 2003). The plants were irrigated by trickle system when necessary and allowed to grow in ground without any mechanical support. Female flowers were tagged at full opening and the fruits were harvested at 1, 3, 6, 10, 13, 15, 17, 19, and 22 days after anthesis.

Fruit longitudinal and transversal diameter were determined with the help of a caliper. The volume of the fruit was determined by the displace of water in a graduate volumetric flask. The fruits were placed in a forced air oven at 65 °C after being cut. After reaching constant weight, approximately after 72 hours, the dry matter mass of each fruit was determined. Total soluble solids in the pulp were determined in each fruit with the help of digital refractometer at 20 °C, and the concentration was expressed in °Brix. Titratable acidity of five grams of pulp was determined as described by IAL (1985) using 0.1 N NaOH with phenolphthalein as indicator.

Chlorophyll and carotenoid contents were extracted from the two grams of skin with 80% acetone and determined according to Lichtenthaler (1987) expressed in mg $g^{-1}$ fresh mass. Absorbance reading were performed at spectrophotometer at 647, 663, and 470 nm.

Soluble carbohydrates were extracted from five grams of fruit flesh with 80% hot ethanol for three times followed by centrifugation. The supernatant was used for total sugar determination by phenol-sulfuric method (Dubois et al., 1956) and the reducing sugars by Somogy-Nelson (Nelson, 1944). Non reducing sugars were determined by the difference on the content between the total soluble and reducing sugars. The precipitated residue from the soluble sugar was utilized for the analysis of starch concentration according to McCready et al. (1950). All carbohydrates were expressed in % of the fresh mass.

Production of $CO_2$ and ethylene were determined by accumulating the gases for one hour at 25 °C, afterwards it was removed 1.0 mL from the flask atmosphere and injected in gas chromatographer Shimadzu CG-14B equipped with a Porapak-Q column with nitrogen as the carrier gas at a flow rate of 30 mL $min^{-1}$ (Mapeli et al., 2009). The gas chromatograph was equipped with a flame ionization detector for ethylene and a thermal conductivity detector for $CO_2$ determination.

The experiment was established in a complete random design comprising four replicates of individual fruits. The data obtained were subjected to ananalysis of variance and regression, using the software SAEG (FUNARBE, 2007).

## Results and Discussion

Accumulation of fruit fresh mass had a simple sigmoidal behavior through growth in both cultivars (Figure 1A). At the end of exponential fruit growth both 'Maxixe do Norte' and 'Maxixe Liso de Calcutá' had similar fresh weight of 78 and 77.4 g, respectively. At the beginning of growth, fruit showed a low growth rate, followed by exponential phase with maximal rates at 9.5 and 10.5 days for 'Maxixe do Norte' and 'Maxixe Liso de Calcutá', respectively (Figure 1A); and at this stage the fruits had 39.6 and 39.3 g, respectively. Afterwards noticeable reduction of growth rates was observed in both cultivars, with stabilization of fresh mass growth at 22 days after anthesis.

During the evolution of a single sigmoid growth pattern the beginning is characterized by cell division and low cell expansion, followed by enlargement of the fruit and finally and stationary phase where ripening takes place (Hurr et al., 2009).

Like fresh mass accumulation, fruit dry matter showed similar trend, but still showing accumulation at 22 days after anthesis (Figure 1B). Maximal accumulation rates occurred at 15.3 days for 'Maxixe do Norte' and 12.4 days for 'Maxixe Liso de Calcutá'. At 22 days after anthesis, 'Maxixe do Norte' accumulated 16.7 g additional dry matter compared to 'Maxixe Liso de Calcutá' (Figure 1B), even though they had similar fresh mass (Figure 1A). This result shows that fruits of 'Maxixe do Norte' are stronger sinks compared to 'Maxixe Liso de Calcutá'.

Transversal and longitudinal fruit diameter followed a simple sigmoid curve with a virtual absent lag phase at the beginning of fruit growth (Figure 2A and 2B). The maxima rate of growth for the transversal dimeter for 'Maxixe do Norte' is estimated 5.6 days after anthesis and 6.1 days for 'Maxixe Liso de Calcutá'. No significant change in the transversal diameter

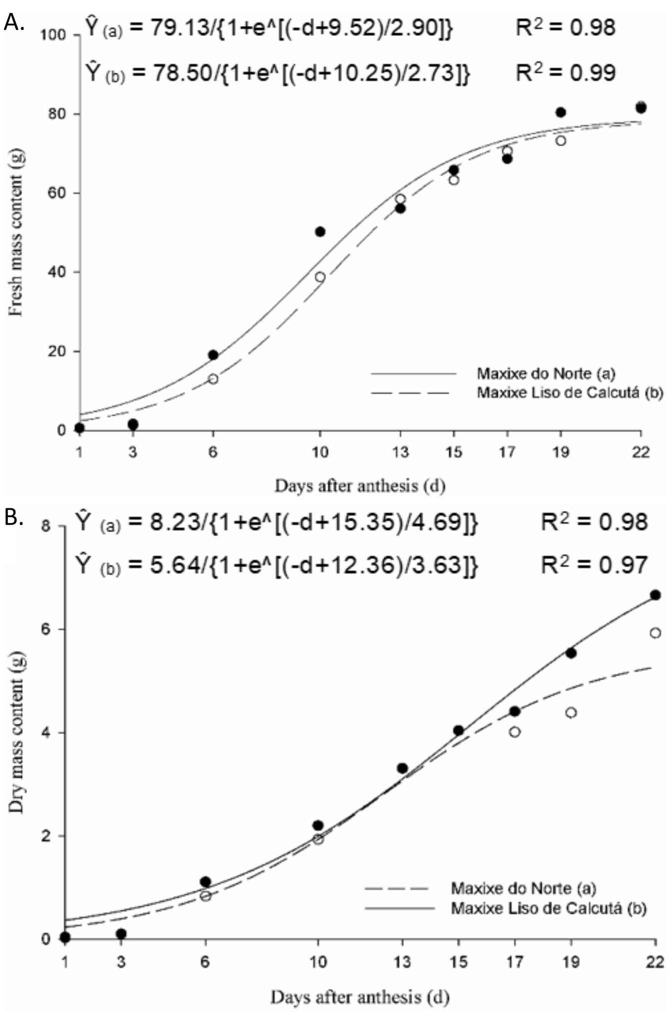


**Figure 1.** Fresh mass (g) (A) and dry mass content (g) (B) in *Cucumis anguria* L. fruits, cultivars 'Maxixe do Norte' (a) and 'Maxixe Liso de Calcutá' (b), depending on the development (days after anthesis).

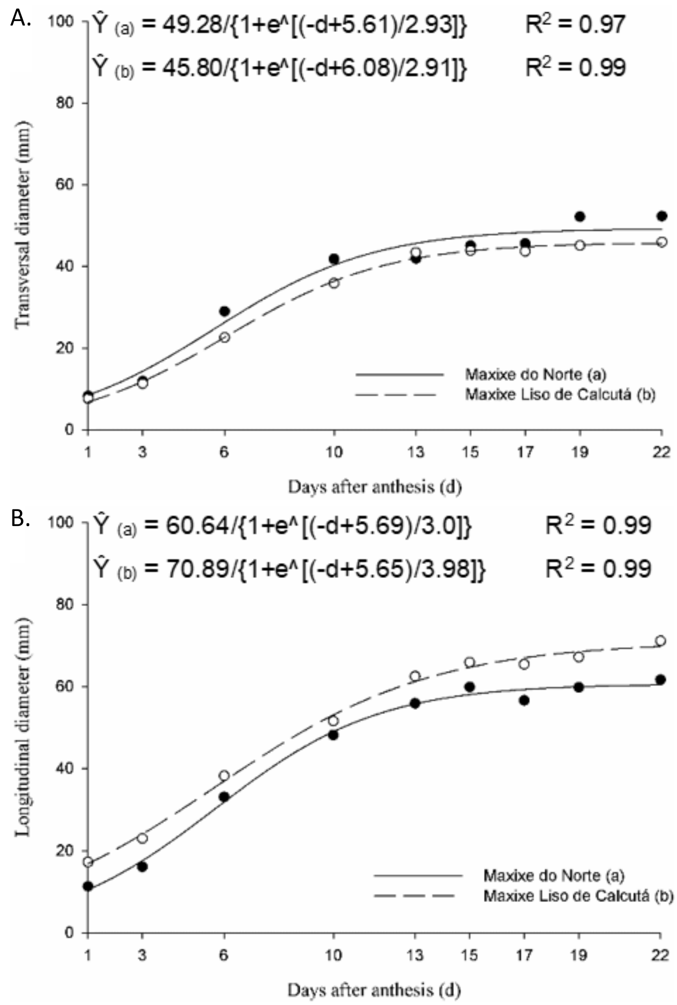


**Figure 2.** Transversal diameter (mm) (C) and longitudinal diameter (mm) (D) in *Cucumis anguria* L. fruits, cultivars 'Maxixe do Norte' (a) and 'Maxixe Liso de Calcutá' (b), depending on the development (days after anthesis).

happened after 11.5 days for 'Maxixe do Norte' and 11.9 days for 'Maxixe Liso de Calcutá'. The length of transversal diameter at the end of fruit growth was 30.3 mm for 'Maxixe do Norte' and 35.5 mm for 'Maxixe Liso de Calcutá' (Figure 2A). Longitudinal diameter followed similar curve observed for the transversal diameter, with length of 60.6 mm for 'Maxixe do Norte' and 70.9 mm for 'Maxixe Liso de Calcutá' at (Figure 2B). The absence of lag phase for both transversal and longitudinal diameter is related to the fast growth of the ovary, determined one day after the anthesis. Similar absence of lag phase was reported in fruits of *Cucumis sativus* cv. Manar (Hurr et al., 2009).

Fruit volume followed a simple sigmoid curve with a lag phase up to 8 days after anthesis, followed by exponential phase of growth (Figure 3). Regardless the cultivar, at 22 days after anthesis, the fruits had similar estimated volumes of 83.4 $cm^3$.

In the first day after anthesis, fruit respiration from 'Maxixe do Norte' was extremely high, reaching 1000 mL $CO_2$ $kg^{-1}$ $h^{-1}$, while 'Maxixe Liso de Calcutá' fruits had a much less $CO_2$ production of 600 mL $CO_2$ $kg^{-1}$ $h^{-1}$ at 25 °C (Figure 4). But

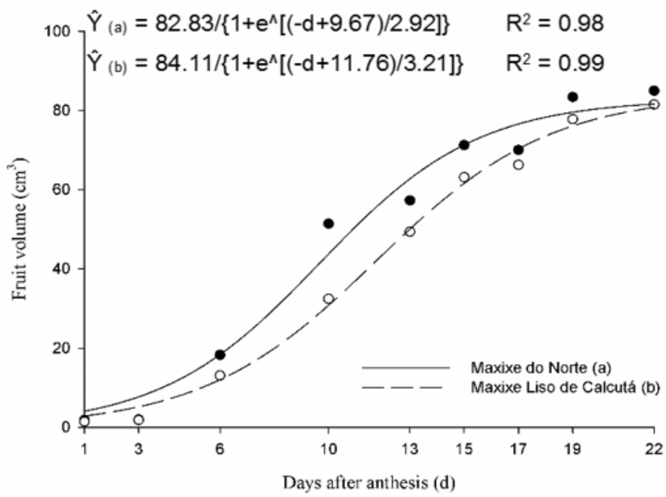


**Figure 3.** Fruit volume ($cm^3$) in *Cucumis anguria* L., cultivars 'Maxixe do Norte' (a) and 'Maxixe Liso de Calcutá' (b), depending on the development (days after anthesis).

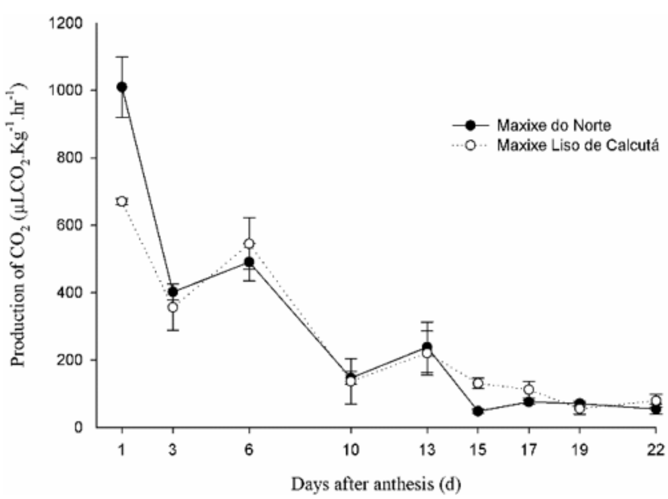


**Figure 4.** Production of $CO_2$ (mL $CO_2$ $Kg^{-1}$ $h^{-1}$) in *Cucumis anguria* L. fruits, cultivars 'Maxixe do Norte' and 'Maxixe Liso de Calcutá', depending on the development (days after anthesis).

in both cultivars a sharp drop takes immediately and at the third days after the anthesis the rate was 400 mL $CO_2$ $kg^{-1}$ $h^{-1}$, followed by smaller drops up to 15 days after anthesis. No virtual changes were noticeable afterwards up to 22 days of growth.

High respiratory activity at the first stages of fruit development is associated with intense cell division (Beshir et al., 2017). Such behavior was present in both cultivars of this work, where $CO_2$ production was much less intensity when the fruits expanded in volume. However, no ethylene evolution was detected above the minimum detection limit of 0.05 μL $L^{-1}$ (data not showed). The pattern of respiration throughout the fruit development, and unchanged and low respiration activity during the stages of fruits maturation and ripening suggest that *Cucumis anguria* L. fruits behave as non-climacteric fruit.

Both cultivars showed similar trend of total sugar accumulation during fruit growth (Figure 5A). Maximal

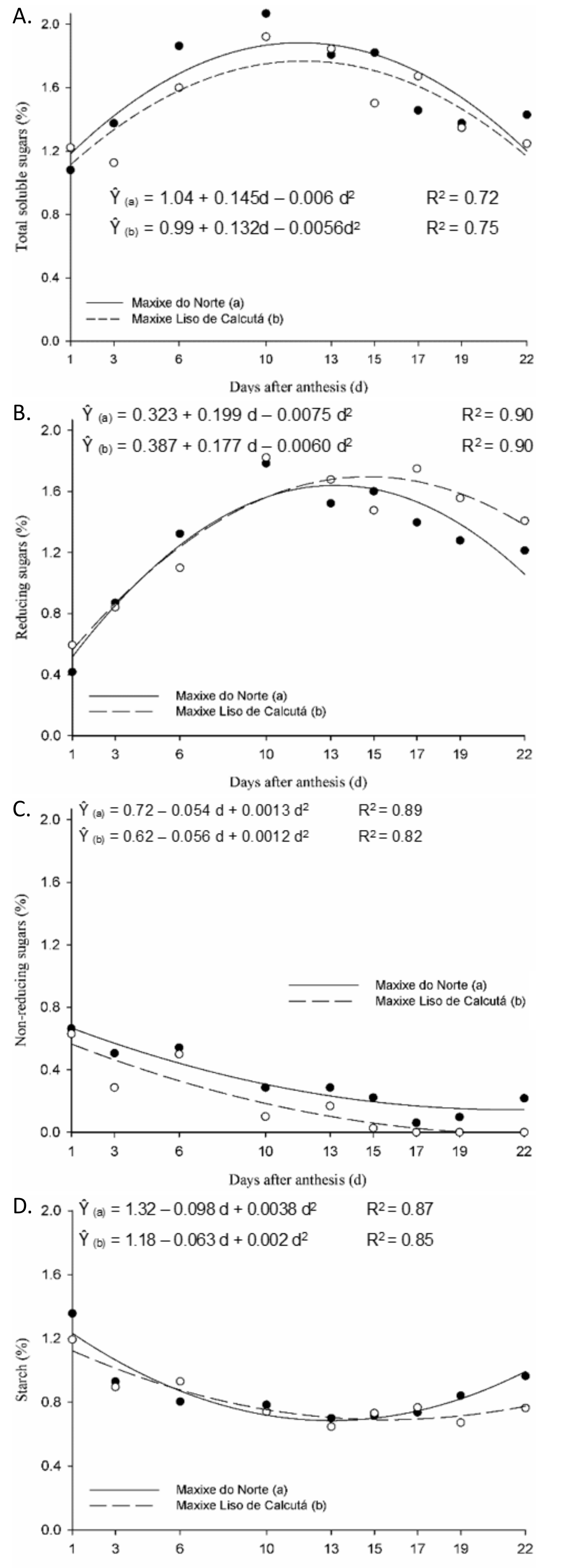


**Figure 5.** Total soluble sugars (%) (A), reducing sugars (%) (B), non-reducing sugars (%) (C) and starch (%) (D) in *Cucumis anguria* L. fruits cultivars 'Maxixe do Norte' (a) and 'Maxixe Liso de Calcutá' (b), depending on the development (days after anthesis).

amount of total soluble sugar of 1.9% was reached at 11.5 days after anthesis for the 'Maxixe do Norte' and 1.8% for 'Maxixe Liso de Calcutá' at 11.8 days. At the end of fruit development, the soluble sugars decayed to 1.1%. The total soluble sugar content was comprised most by reducing sugars (Figure 5B). Reducing sugars account for more than 90% total soluble sugars at the end of fruit growth. Non-reducing sugars had consistent reduction throughout fruit growth, which were not detected in ripe fruits of 'Maxixe Liso de Calcutá' and for 'Maxixe do Norte', they accounted only for 0.2% (Figure 5C). The decrease in non-reducing sugars is associated to the hydrolysis of sucrose-by-sucrose synthase and/or invertases (Boo et al., 2010; Desnoues et al., 2014), which seems to be responsible for the accumulation of the reducing sugars, fructose and glucose in the fruits of both cultivars.

Compared to the beginning of fruit development, starch content showed reduction on its content in both cultivars, of 45.2% at 12.9 days after anthesis for 'Maxixe do Norte' with total content of 0.69% (Figure 5D). While starch from 'Maxixe Liso de Calcutá' was reduced by 39.0% with lowest content at 15.7 day with 0.68% on the fresh matter. These decreases in starch are closely related to the increases in total soluble sugar and reducing sugars (Figure 5A, 5B, and 5D).

Total soluble solids dropped sharply during fruit growth in both cultivars (Figure 6A). At the beginning of fruit growth, they had the highest amounts of soluble solids, with an estimated content of 5.66 °Brix for 'Maxixe do Norte' and 6.81 °Brix for 'Maxixe Liso de Calcutá'. This behavior showed that during fruit growth, the expansion of cells, water uptake and metabolic activities related to fruit metabolism resulted in decreased content of solids on the dry matter (Shi et al., 2014; Beshir et al., 2017).

Total acidity reached a minimum at 10 and 12.2 days after anthesis for 'Maxixe do Norte' and 'Maxixe Liso de Calcutá', respectively (Figure 6B). Afterwards, accumulation of acids occurred, reflecting the low respiratory activities during the later stages of fruit development in both cultivars.

Independent of cultivar, a linear drop of skin fruit chlorophyll took place from the beginning of fruit growth (Figure 7A), with higher rate of hydrolysis for the 'Maxixe do

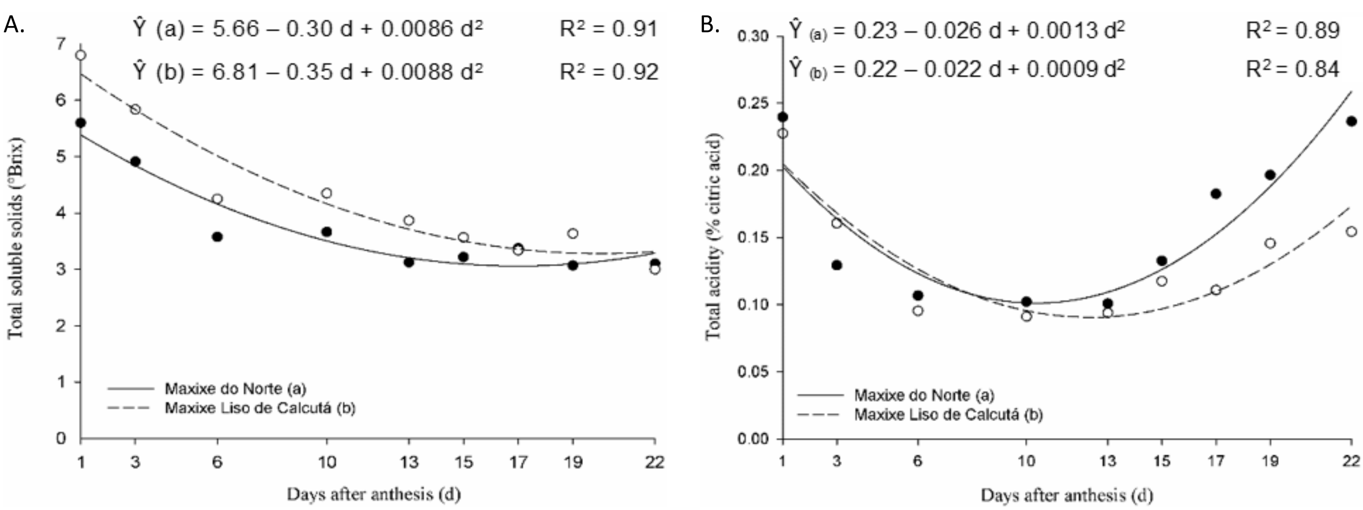


**Figure 6.** Total soluble solids (°Brix) (A) and total acidity (% citric acid) (B) in *Cucumis anguria* L. fruits cultivars 'Maxixe do Norte' (a) and 'Maxixe Liso de Calcutá' (b), depending on the development (days after anthesis).

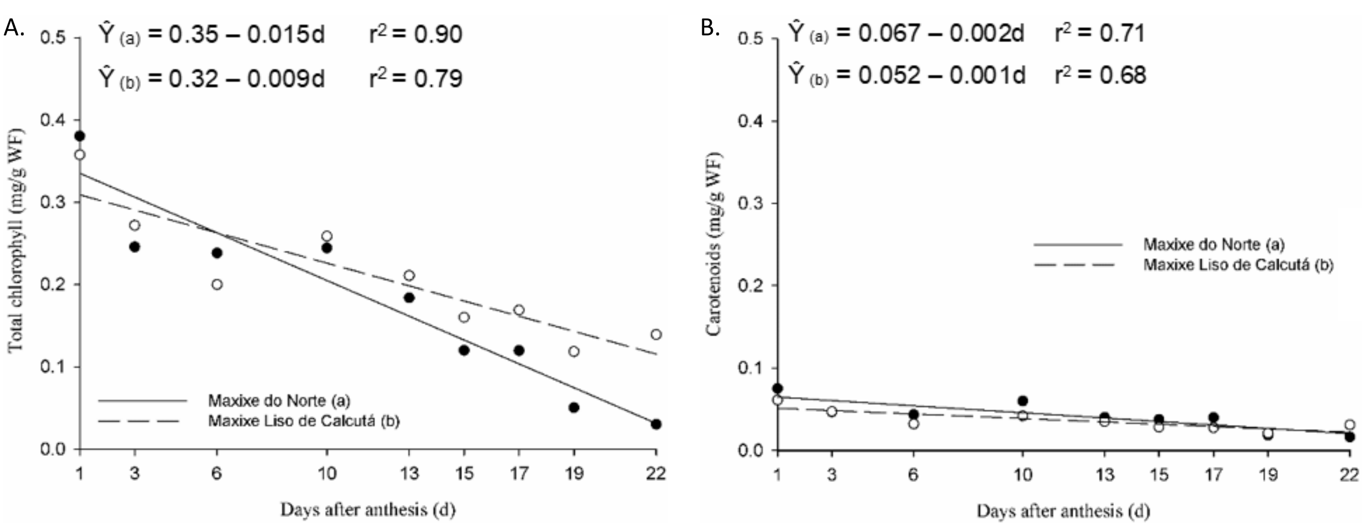


**Figure 7.** Total chlorophyll (mg/g WF) (A) and carotenoids (mg/g WF) (B) in *Cucumis anguria* L. fruits cultivars 'Maxixe do Norte' (a) and 'Maxixe Liso de Calcutá' (b), depending on the development (days after anthesis).

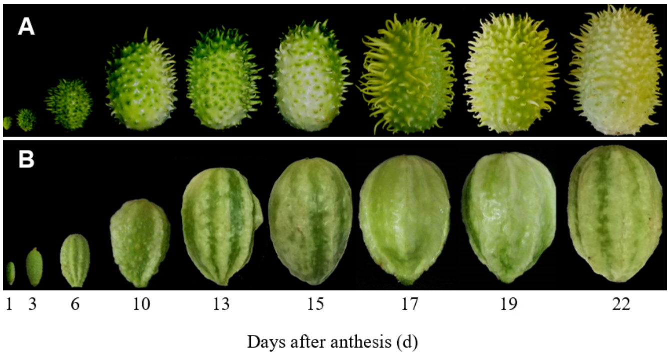


**Figure 8.** Physical changes during the process of growth, days after anthesis (d), of *Cucumis anguria* L. fruits cultivars 'Maxixe do Norte' (a) and 'Maxixe Liso de Calcutá' (b).

Norte' fruits. At 22 days after anthesis, ripe 'Maxixe do Norte' fruits showed a yellowish color for the and the 'Maxixe Liso de Calcutá' fruits a pale green color (Figure 8). In a much less scale hydrolysis compared to chlorophyll, carotenoids also decreased during fruit development (Figure 7B). During the degreening of skin fruit, carotenoids had almost no influence in determining that ripe color of the fruit.

## Conclusion

Fruits of both cultivars showed similar single sigmoid curve of growth with maxima rate at 11$^{th}$ day after anthesis. The fruits showed a non-climacteric respiration pattern during ripening. Yellowing at the end of fruit development indicates the lack of commercial quality.

## Compliance with Ethical Standards

**Author contributions:** Conceptualization: FCSR, FLF; Data curation: FCSR; Formal analysis: FCSR, AMP, FRR; Investigation: FCSR, WSR, LCC; Project administration: FCSR; Supervision: FCSR; Visualization: FCSR; Writing - original draft: FCSR, FLF, WSR; Writing - review & editing: FCSR, FRR.

**Conflict of interest:** Authors declare to have not conflict of interests.

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