Scientific Article

Starch and total soluble sugar content in torch ginger postharvest [1]

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ABSTRACT

Floral opening stage during harvest and use of postharvest techniques, such as inflorescence coating with carnauba wax, may influence quality maintenance for commercialization. The aim was to evaluate the carbohydrate content of torch ginger inflorescences harvested at two different opening stages and treated with different concentrations of carnauba wax. The inflorescences were harvested with semi-open (basal bracts beginning their expansion process) and open bracts (fully expanded basal bracts and opening of the smaller bracts on interior of the inflorescence) and received the application of carnauba wax at concentrations of 0.75%; 1.5% or 3.0%, in addition to a control treatment, without wax application. After the treatment, the floral stems were maintained at 16 and 21 ºC for 20 days. During the storage period, five bracts samples (external and internal bracts separately - in open inflorescences, external and internal bracts together - in semi-open inflorescences) were carried out every three days for evaluation of total soluble sugars and starch content. Contents of total soluble sugars and starch differed between the different types of bracts collected and throughout the storage period evaluated, and could indicate a remobilization of reserves. The concentration of 3.0% carnauba wax induced higher total soluble sugar content. However, this content does not affect the longevity of torch ginger at the two evaluated floral opening stages.

Keywords: *Etlingera elatior*, longevity, storage, tropical flowers, biofilm.

RESUMO

Amido e açúcares solúveis totais em pós-colheita de inflorescências de bastão-de-imperador

O estádio de abertura floral na colheita e o uso de técnicas pós-colheita, como o revestimento das inflorescências com cera de carnaúba, podem influenciar na manutenção da qualidade para comercialização. Assim, objetivou-se avaliar o conteúdo de carboidratos em inflorescências de bastão-do-imperador colhidas em dois diferentes estádios de abertura e tratadas com diferentes concentrações da cera de carnaúba. As inflorescências foram colhidas com brácteas semiabertas (brácteas basais iniciando seu processo de expansão) e abertas (brácteas basais totalmente expandidas e abertura das brácteas menores do interior da inflorescência) e receberam a aplicação de cera de carnaúba nas concentrações 0,75%; 1,5% ou 3,0%, além de um tratamento controle, sem aplicação da cera. Após o tratamento, as hastes florais foram mantidas a 16 e 21 º C por 20 dias. Ao longo do período de armazenamento realizaram-se cinco amostragens de brácteas (brácteas externas e internas separadamente – em inflorescências abertas; brácteas externas e internas em conjunto – em inflorescências semiabertas), a cada três dias para avaliação dos teores de açúcares solúveis totais e amido. Os teores de açúcares solúveis totais e amido diferiram entre os diferentes tipos de brácteas coletadas e ao longo do período de armazenamento avaliado, podendo indicar uma remobilização de reservas. A concentração de 3,0% de cera de carnaúba proporcionou um maior teor de açúcares solúveis totais, entretanto esse teor não interfere na longevidade do bastão-do-imperador nos dois estádios de abertura floral avaliados.

Palavras-chave: *Etlingera elatior*, longevidade, armazenamento, flores tropicais, biofilme.

1. INTRODUCTION

Torch ginger belongs to the genus *Etlingera* and, due to its exotic characteristics and beauty, has become one of the tropical ornamental plants with the greatest commercialization potential, although the information about this tropical plant is still restricted (LOGES et al., 2008). Its commercialization is based on different harvest stages, starting from "closed" (stage in which the basal bracts begin to expand) to the full expansion (RIBEIRO et al., 2012; MATTOS et al., 2017).

The floral opening stage, in which the inflorescences are harvested, among other aspects, influences the longevity, the commercialization period, as well as the durability (vase life) (BARBOSA et al., 2006; CARNEIRO et al., 2014). Floral opening is related to cell expansion and carbohydrate balance. Therefore, for floral opening, the cells need to expand, requiring energy (VAN DOORN

DOI: http://dx.doi.org/10.14295/oh.v24i4.1205

[1] Received in 15/05/2018 and accepted in 11/09/2018

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and VAN MEETEREN, 2003, COSTA and FINGER, 2016; SALES et al., 2018) and water absorption; thus, this phenomenon is dependent on reserve mobilization, as demonstrated in *Tweedia caerulea* flowers, in which an increase in sugars concentrations induces decrease on osmotic potential. This contribut to water influx that will maintain the pressure potential, an aspect that is maybe involved in cell expansion and floral opening (ICHIMURA et al., 2013).

Another aspect that has a direct relationship with the pot life of the plants is the water balance that can be altered during postharvest, due to the greater water loss to the environment in relation to its absorption, leading to water imbalance (SANKAT and MUJAFFAR, 1994).

An alternative that can be used in the face of the problem of greater transpiration in relation to respiration that culminates in dehydration is the use of waxes. This is used in anthurium, another species belonging to the group of tropical ornamental plants, in which the technique led to an extended vase life (MUJAFFAR and SANKAT, 2003). Carnauba wax was also an efficient alternative for increasing the commercialization period in fruits such as tangor (*Citrus sinensis* (L.) Osbeck x *Citrus reticulata* Blanco) 'Ortanique' (MACHADO et al., 2012) and 'Valência Delta' orange (*Citrus sinensis* (L.) Osbeck) (PEREIRA el al., 2014).

The application of Carnauba wax has already been evaluated in torch ginger (*Etlingera elatior*) 'Porcelana' considering the visual quality, due to its ability to provide brightness, without affect the water balance (MATTOS et al., 2017). However, there is still no information on its effect on carbohydrate content and on the floral opening stage (opening and expansion of the bracts) in which plants can be harvested.

Therefore, the objective was to evaluate the effect of carnauba wax on starch and total soluble sugars in inflorescences of torch ginger (*Etlingera elatior*) 'Porcelana'.

2. MATERIAL AND METHODS

For the experiment, torch ginger (*Etlingera elatior*) 'Porcelana' flower stems were harvested at two floral opening stages: inflorescences with open bracts (open and expanded basal bracts and open internal bracts) and semi-open bracts (basal bracts initiating opening and expansion). In order to evaluate the effect of carnauba wax on torch ginger postharvest, three concentrations of the wax (0.75, 1.5 and 3.0%) and one control without the application of the wax (0.0%) were tested. The carnauba wax (in liquid form) was diluted in water at room temperature (21 °C) and slowly homogenized. Subsequently, torch ginger inflorescences were immersed in carnauba wax solutions, according to the respective concentrations, for 20 s. The flower stems were then arranged in a vertical position, in a shaded environment at room temperature (21 ºC), until complete drying (approximately 2 hours). Subsequently, only 15 cm from the basal part (10 cm) were placed in plastic containers with a lid, containing water (part of the floral stem was inserted into the container through a central hole in the plastic lid) and storaged, with no solution exchange, performing only the replacement of the water volume lost by transpiration.

The treatments was divided into two experiments, being one storaged at 16 ºC in a cold chamber, since it is suitable for the minimum recommended temperature range (Loges et al., 2005), and the other experiment was storaged at 21 ºC in rooms with temperature controlled by air conditioning system. The results were evaluated at each temperature, without, however, comparisons. For both temperatures, the relative air humidity was 85% ± 5% and the total storage period was 20 days.

Only the inflorescences were treated with carnauba wax. The bracts were used as a plant material for quantification of total soluble sugars and starch contents.

Considering the two floral opening stages of torch ginger, the open inflorescences are larger, with greater number of bracts, in different sizes. This suggest different levels of maturation and expansion. Thus, for these inflorescences, external bracts and internal bracts were extracted for quantification of total soluble sugars and starch. For the semi-open inflorescences, due to their smaller size and variability in the size and expansion of the bracts, external and internal bracts were collected and mixed, consisting the same sample.

Total soluble sugars and starch contents were quantified from samples of 1 g bracts collected according to the type of inflorescence. Sampling was performed periodically, every three days, totaling five samples and staged at -20 ºC. No samples were collected after 12 days of storage, once the floral stems had no commercial quality.

The contents of total soluble sugars were quantified according to the Antrona method (DISCHE, 1962). To determine the starch content, the assay was performed by the method of Somogy adapted by Nelson (1944). Both analyses were performed using a spectrophotometer reading at the wavelength of 620 ηm (total soluble sugars) and 510 ηm (starch) and the results were expressed in g/100 g fresh matter.

The two floral opening stages (open - bracts fully open and expanded and internal open; and semi-open - basal bracts still opening) and the three concentrations of carnauba wax (0.75, 1.5 and 3.0%) plus the control, combined, comprised 8 treatments. Each treatment was replicated in four experimental plots consisting of two flower stems each. The treatments were randomized in a scheme of plots subdivided in time, due to the periodic bract collections.

The types of the bracts collected in the inflorescence, either internal or external for open inflorescences or both types (consisting of a set of external and internal bracts), as considered in semi-closed harvested inflorescences, were considered as a factor for biochemical analyses.

The obtained data were compared by the F test of the analysis of variance in a plot scheme subdivided in time. When significant differences were detected by the F test, the factors were evaluated using the Tukey test ($p < 0.05$). The experiments were analyzed separated. The assumptions

of normality and homogeneity of variances were verified by residue analysis, using the SAS 9.3 software (SAS, 2011). Statistical analyses were performed using SISVAR software (FERREIRA, 2014).

3. RESULTS AND DISCUSSION

In floral stems storaged at a temperature of 16 ºC, the external bracts collected from open inflorescences showed a higher content of total soluble sugars on the third day of storage, after which there was a decline. However, the external bracts in open and the semi-open inflorescences did not show differences with harvest period (Figure 1).

Comparing the types of bracts, only on the third day, the content of total soluble sugars for the external bracts was superior considering internal bracts and bracts collected from semi-open inflorescences. For the other days, all had similar contents (Figure 1).

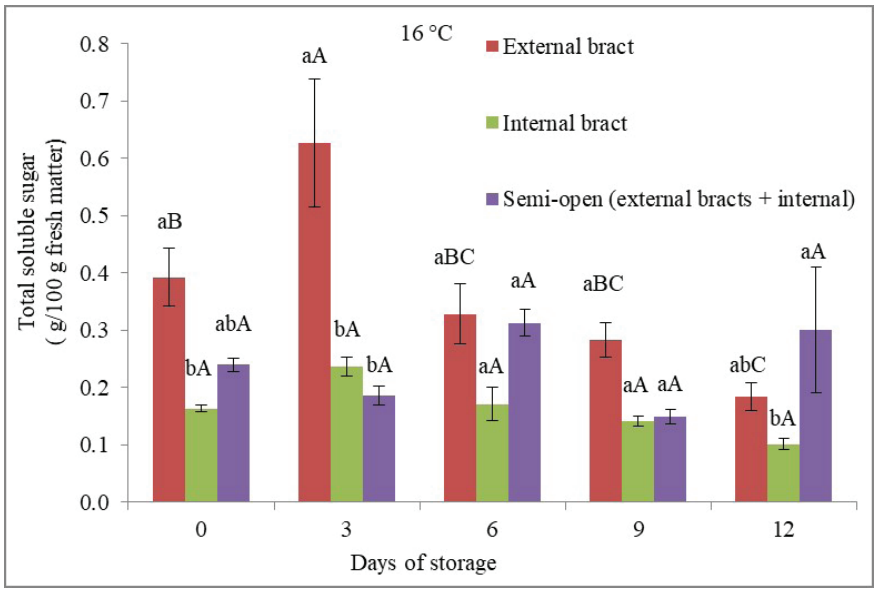

Figure 1. Total soluble sugar contents (g/100 g fresh matter) as a function of days of storage, external bracts and internal bracts (collected from open inflorescences) and bracts collected from semi-open inflorescences, both storaged at 16 ºC. Means followed by the same lowercase (comparing the types of bracts within each storage period, comparing each type of bract over time) or uppercase (comparing each type of bract over time) letters do not differ by the Tukey test at 5% probability.

Likewise, in the experiment at 21 °C, floral stems with open bracts, as well as floral opening stage, had a significant effect of the storage period and type of bracts collected in the inflorescence on the total soluble sugar content, demonstrated on the third day of storage for the external bracts, but not significantly different from zero and, on the 12th day, the internal bracts showed this increase in the content of total soluble sugars (Figure 2).

Comparing the types of bracts, the external bracts showed a higher content of total soluble sugars, but not differing from the internal bracts only on the 12th day.

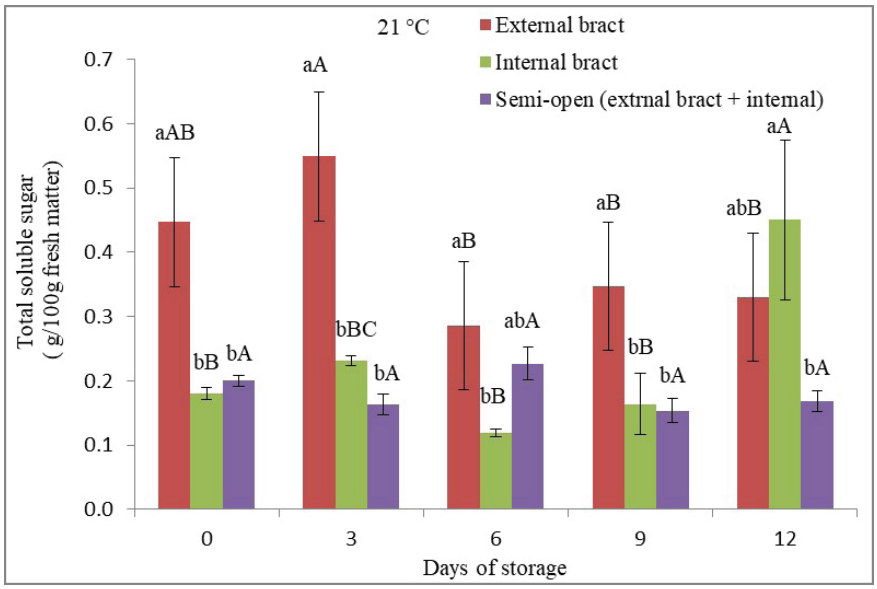

Figure 2. Total soluble sugar contents (g/100 g fresh matter) as a function of days of storage, external bracts and internal bracts (collected from open inflorescences) and bracts collected from semi-open inflorescences, both storaged at 21 ºC. Means followed by the same lowercase (comparing the types of bracts within each storage period, comparing each type of bract over time) or uppercase (comparing each type of bract over time) letters do not differ by the Tukey test at 5% probability.

It was observed that, for the results of total sugar content, the bracts collected from semi-open inflorescences (sample formed by external and internal bracts) maintained, on average, their total soluble sugar contents without changes, throughout the evaluation period.

Considering the starch contents for floral stems storaged at 16 °C, bracts types, and postharvest days, all showed differences. Bracts from semi-open inflorescences showed a higher average, compared to the internal and external bracts from open inflorescences (Figure 3).

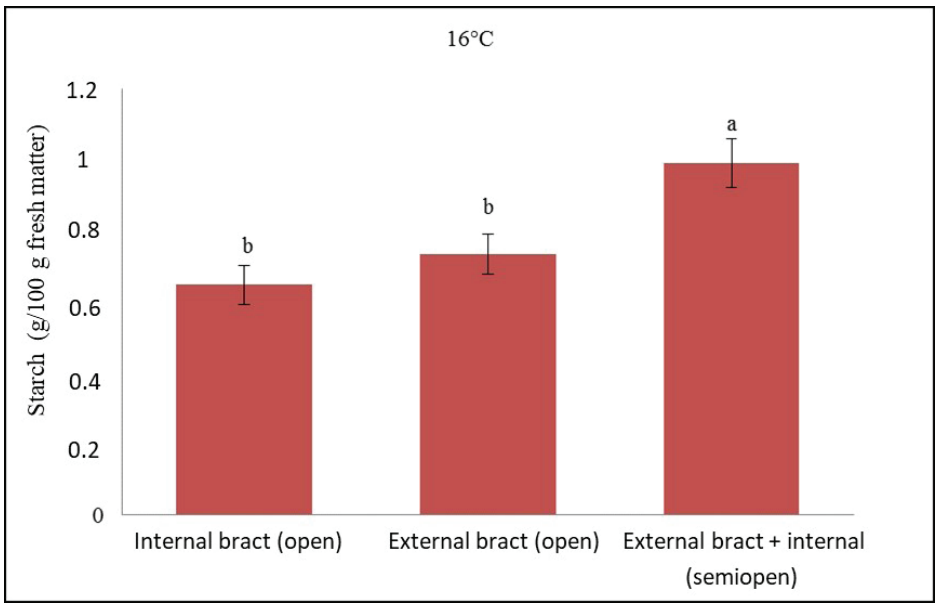

Figure 3. Starch contents (g/100 g fresh matter) as a function of the region of collection of the bracts in semi-open (internal + external bracts) and open (internal and external bracts, separately) inflorescences, stored at 16 ºC. Means followed by the same letter do not differ by the Tukey test at 5% probability.

In general, at the temperature of 16 ºC, regardless of the bracts position (external or internal or both), a higher starch content was found on the 9th storage day, but did not differ from the 3rd and 12th days (Figure 4).

When the bracts were storaged at 21 °C, the results for starch content showed an interaction between types of bracts and postharvest times. The external and internal bracts presented higher starch contents on the 12th day, for the internal and external bracts from open inflorescences. For the bracts from semi-open inflorescences, the starch content was maintained throughout the evaluation period. (Figure 5).

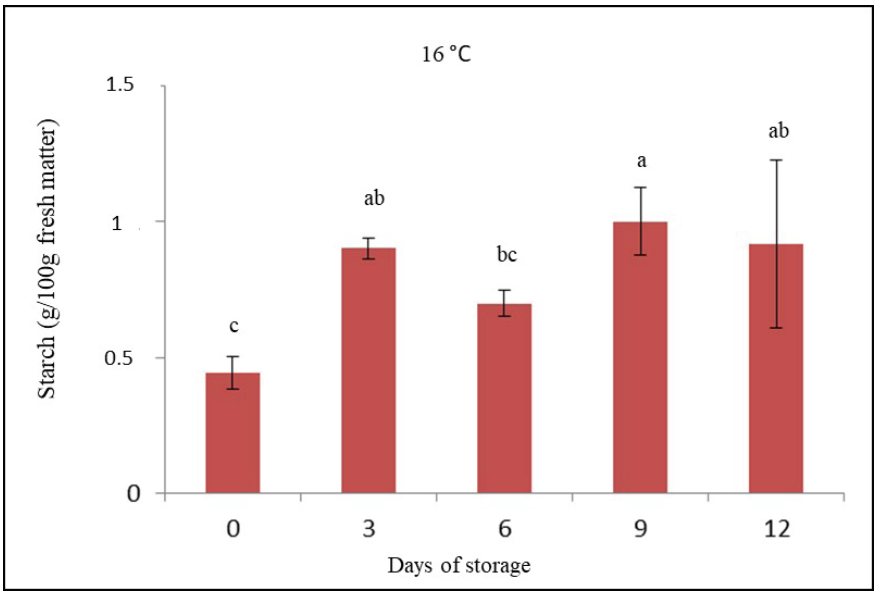

Figure 4. Starch contents (g/100 g fresh matter) in bracts collected as a function of storage days for floral stems stored at 16 °C. Means followed by the same letter do not differ by the Tukey test at 5% probability.

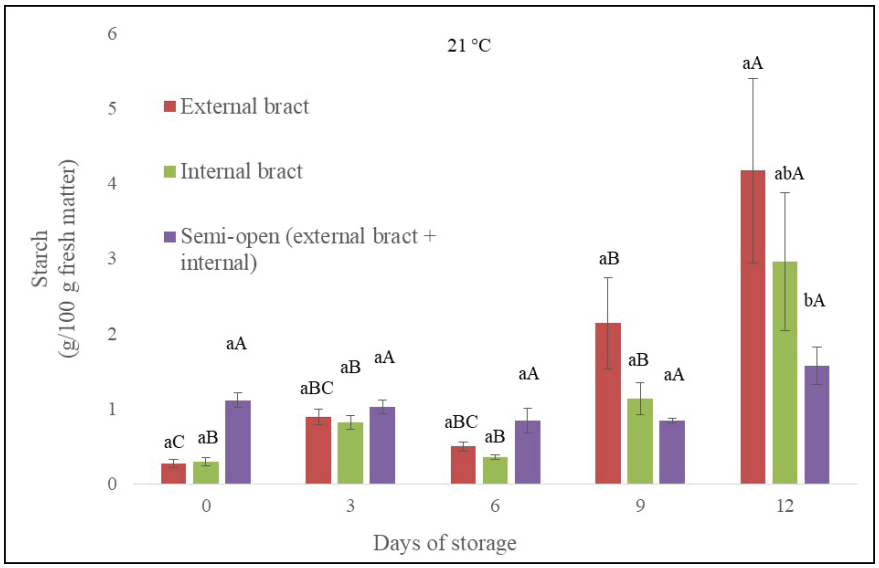

Figure 5. Starch contents (g/100 g fresh matter) as a function of days of storage, external bracts and internal bracts (collected from open inflorescences) and bracts collected from semi-open inflorescences, both storaged at 21 ºC. Means followed by the same lowercase (comparing the types of bracts within each storage period, comparing each type of bract over time) or uppercase (comparing each type of bract over time) letters do not differ by the Tukey test at 5% probability.

The difference in the content of total soluble sugars throughout storage, with an increase followed by a decrease for external bracts, may be possibly justified by the mobilization and consumption of reserves by respiration during the senescence process. This process of reserve consumption can be perceived along the storage of flowers such as 'Vega' roses (*Rosa* sp.) (PIETRO et al., 2010; PIETRO et al., 2012).

Considering the type of external bracts collected from inflorescences with the open floral opening stage, it was observed that there was an alteration throughout the evaluated period, with an increase followed by its decrease, which can mean a remobilization of carbohydrates to the internal bracts, as observed in the experiment maintened 21 ºC. In this experiment, there was an increase in the total soluble sugar content for external bracts on the third day of evaluation and, on the other days, this value was lower, whereas at day 12 there was an increase in the total soluble sugar content in the internal bracts. For roses, it was verified that the surface and the concentration of sugars increased for the internal petals after the removal of external petals, demonstrating that the competition may be related to water absorption and expansion of the internal petals (MARISSEN, 2001).

Thus, the higher starch content of the bracts of semi-open inflorescences maintained at 16 ºC can be justified by the earlier development stage of the stems with semi-open inflorescences and, therefore, the non-occurrence of starch degradation in sugars for their use in bract expansion.

The increase in sugars may also be related to the maturation process and results from the starch hydrolysis, as it was already observed in 'Prata' and 'Nanicão' bananas (*Musa* sp.) (NASCIMENTO JÚNIOR et al., 2008), as well as in fruits of fig tree (GONÇALVES et al., 2006). However, in both experiments, no reduction in starch contents was observed; on the contrary, there was an increase over the storage period. In some cases, as in woody stakes of blueberry (*Vaccinium ashei* Reade), starch resynthesis occurs, thus increasing the starch content. However, the resynthesis of starch is accompanied by a decrease in the content of total soluble sugars (OLIVEIRA et al., 2012). This effect was not observed in internal bracts of open inflorescences at the end of the storage period (day 12) at 21 ºC, which had an increase in this content, as well as the bracts of semi-open inflorescences, which maintained the average level of total soluble sugars at both temperatures and throughout the evaluated period.

This specific increase condition in starch contents may also suggest not a resynthesis, but rather a consequence of the constant loss of fresh matter due to the water loss by transpiration throughout the storage period, as verified by Mattos et al. (2017) for the same torch ginger cultivar. This may cause the starch concentration to become high in relation to the fresh matter of the inflorescence.

Additionally, for the experiment maintened at 16 ºC, the increase in starch content can also be justified by the reduction in the metabolic processes as a consequence of the low storage temperature (CUNHA JUNIOR et al., 2010).

Regarding the treatment with carnauba wax, there was an interaction only between storage times and concentrations applied at a temperature of 21 °C. However, there was a significant effect only when 3.0% carnauba wax was used. The other concentrations applied and the control did not lead to significant differences, when compared to each other and over time (Figure 6).

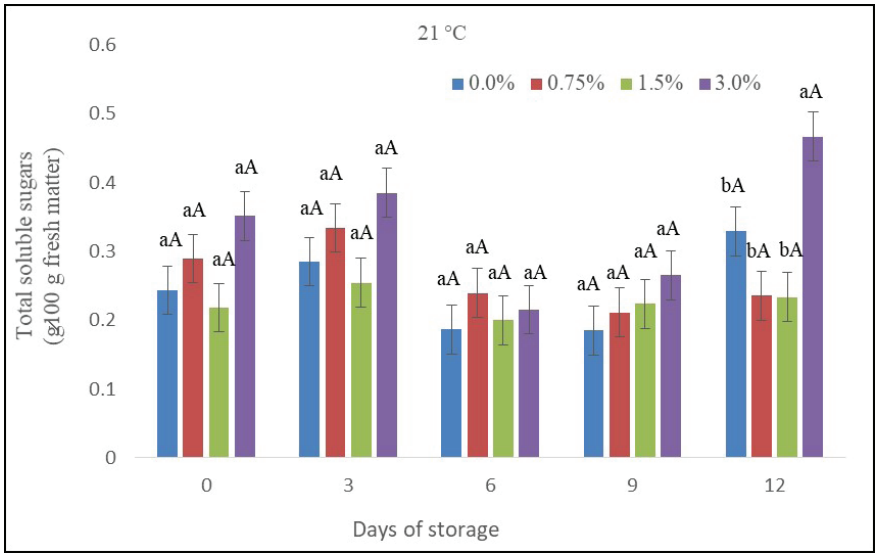

Figure 6. Total soluble sugars (g/100 g fresh matter) over the storage days at 21 °C, according to the doses of carnauba wax (0.0; 0.75%; 1.5%; 3.0%). Means followed by the same lowercase (comparing the doses of carnauba wax within each storage period) or uppercase letters (comparing each dose of carnauba wax over time) do not differ by the Tukey test at 5% probability.

Results observed in torch ginger using the same concentration of carnauba wax demonstrated that there was no effect on transpiration or coverage of stomata (Mattos et al., 2017). These factors could interfere on respiration and, consequently, the consumption of reserves, but also did not have an effect on durability, which was depended only on the floral opening stage. Therefore, despite the increase in the total soluble sugar content for the 3.0% concentration of carnauba wax at the end of the evaluated period, this increase does not contribute effectively to the postharvest durability of torch ginger. Differently, according to Robles et al. (2008), concentrations of 12%, 15% and 18% of carnauba wax also did not show any significant effect on the durability of priprioca (*Cyperus articulatus* L.), an ornamental cut foliage. However, they yielded a higher quality maintenance in comparison to the control.

4. CONCLUSIONS

The contents of total soluble sugars and starch differ between the different types of bracts collected and throughout the storage period evaluated. Differences in the contents of total soluble sugars and starch may indicate reserve remobilization.

The concentration 3.0% carnauba wax yields a higher content of total soluble sugars. However, this content does not interfere with the longevity of torch ginger at the two evaluated floral opening stages.

ACKNOWLEDGEMENTS

This study was supported by FAPEMIG (financial support), CNPq (scholarship and financial support) and CAPES (scholarship).

AUTHORS CONTRIBUTIONS

D.G.M. 0000-0001-8343-0468: Preparation of the experiment, installation and conduction of the experiment, data collection and statistical analysis, preparation of the article. **P.D.O.P.** 0000-0001-7997-8420: Idea, preparation and advising of the experiment, preparation and article review. **H.H.S.E.** 0000-0002-9264-1168: Advising and assistance in conducting biochemical analyses and data interpretation. **E.V.B.V.B.** 0000-0002-0252-695X: Correction and important suggestions for the study. **L.F.R.** 0000-0001-6871-274X: Assistance in conducting the experiment and biochemical analyses. **R.C.L.** 0000-0002-8558-5217: Assistance in conducting the experiment and biochemical analyses.

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