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Post-harvest quality of onion bulbs in a controlled environment

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Abstract

The onion bulbs' post-harvest quality is essential for good commercialization; the longest storage time is critical to the producer in choosing the cultivar. Thus, this work aimed to evaluate the post-harvest quality of onion bulbs under storage periods in a controlled environment. The experiment was installed in a factorial scheme (6x4), represented by six onion cultivars (BR29, Itajubá, Mulata, Omega, Rainha, and Salto Grande), evaluated in four storage periods (40, 80, 120, and 160 days), in a randomized design, with three replications. The parameters of fresh matter loss, skin strength, bulb firmness, skin shine, pH, soluble solids, titratable acidity, and soluble solids and titratable acidity were analyzed. The cultivar Salto Grande presented better conservation of the physical-defined characteristics in the post-harvest at controlled temperature, less loss of mass of fresh matter, and more significant maintenance of the feature of skin strength, bulb firmness, soluble solids, and titratable acidity. At the same time, cultivar BR29 showed more significant losses in the studied attributes and had less storage capacity among the evaluated cultivars.

Keywords: physical-chemical analysis; post-harvest conservation; storage; titratable acidity; soluble solids.

Practical Application: Genotype and post-harvest storage can significantly affect onion bulbs' quality during storage.

1 Introduction

In economic terms, onion is Brazil's third most crucial vegetable, preceded by potatoes and tomatoes. It is preferably consumed fresh in salads, spices, and condiments. This vegetable consumption has been growing over the years, highlighting the importance of production for human consumption (Rodrigues et al., 2015).

When buying onion bulbs, the consumer market prioritizes specific characteristics, such as the bulb's color and size, as these properties are determined by its genotype and/or conservation factors (Rodrigues et al., 2015). The post-harvest quality of the bulbs depends on some physical properties and components, which are related to a cultivar, as well as the pre and post-harvest treatments and a proper bulb harvest time (Muniz et al., 2012).

Post-harvest storage can alter the chemical structure of onion bulbs; depending on temperature conditions, time and lyophilization can affect the quality of the bulbs during storage (Ren et al., 2020). Thus, to maintain conservation, it is recommended to use available chambers with controlled conditions to delay the bulbs' physical and chemical degradation. However, even in controlled environments, the bulbs have physiological alterations ranging from loss of fresh matter mass to deterioration.

The quality of post-harvest bulbs can be measured according to some physical properties and components, including loss of fresh mass, color, firmness, soluble solids, titratable acidity, pungency, and pH to the external appearance of the bulb (Muniz et al., 2012). Therefore, parameters such as bulb mass, skin strength, soluble solids, and pH, for example, configure physiological changes during the storage period.

The loss of moisture from fresh products causes excellent concern in post-harvest conservation since it reduces the product's market value and mass. Therefore, during the drying and storage of the bulbs, there is mass loss due to metabolic activity and breathing, in addition to eliminating moisture during sweating (Islam et al., 2019).

Thus, the objective of the present work was to analyze the physical-chemical characteristics of onion cultivars under storage periods in a controlled environment.

2 Materials and methods

2.1 Bulb production in the field

The experiment was developed in a commercial field in Pato Branco-PR municipality, located at 16º16'12.2" S and 52°39'55.5" W coordinates in a dystrophic Red Latosol, with clay texture (56% clay, 25% clay silt, and 19% sand), with the following chemical characteristics of the topsoil (0-0,20 m) layer: pH in $CaCl_2$ = 4.8; P (Mehlich-1) = 34.45 mg dm^{-3}; K, Ca, Al = 0.83, 27.27, 0.20 cmolc dm^{-3}, respectively; CTC = 16.60, V = 6.63%, and MO = 46.91 g dm^{-3}. The climatic condition during bulb production can be seen in Figure 1.

For onion fertilization, the result of the chemical analysis of the soil was taken into account, making planting and top dressing

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fertilization following the recommendations of the manual of fertilization and liming for the state of Paraná (Sociedade Brasileira de Ciência do Solo, 2017). Nutrients were applied uniformly and in the same dose for all treatments/cultivars.

Open-pollinated onion cultivars were used, whose main characteristics can be seen in (Table 1). Sowing was performed on July 18, 2018, with a density of 13 seeds m^{-1}, to obtain a final population of 444,000 plants ha^{-1}. During the first four weeks after sowing, daily irrigations were performed. After this period, irrigations happened every three days in addition to rainfall, with the aid of Agropolo® sprinklers, model NY-30, with a pressure of 30 mca, a diameter of 31.80 meters range, and a flow of 2.66 m^3 h^{-1}.

Harvest was determined visually when 75% of the plants in the experimental unit presented a fall over of the shoot on December 18, 2018. After ten days of cure, the bulbs were removed from the site and sent to the laboratory.

2.2 Post-harvest quality of bulbs

The work was carried out in the Horticulture laboratory of the Universidade Tecnológica Federal do Paraná - Pato Branco campus, Paraná. It used bulbs commercially classified in class 3, as stated by Companhia de Entrepostos e Armazéns Gerais do Estado de São Paulo (2009), according to the methodology proposed by Resende et al. (2010).

The experiment was installed in a factorial scheme (6x4), with six onion cultivars (BR29, Itajubá, Mulata, Omega, Rainha, and Salto Grande), evaluated in four storage times (40, 80, 120, and 160 days after storage), in a randomized design, with three

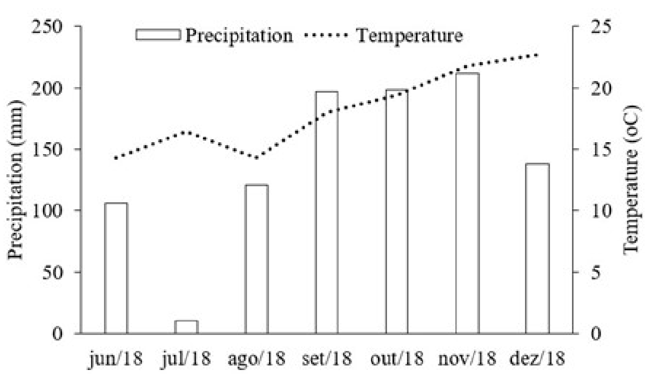

Figure 1. Precipitation (mm) and temperature (°C) during the onion bulb production period. Source: Sistema Meteorológico do Paraná (Sistema Meteorológico do Paraná, 2019).

repetitions, each repetition being composed of three onion bulbs. The bulbs were stored in a cold chamber, at a temperature of 5 ± 1 °C and with 75 ± 5% relative humidity (Muniz et al., 2012).

The fresh matter mass loss evaluation was obtained through the difference between the mass of the bulbs in each time interval, and the result was expressed in percentage according to Higashikawa & Menezes (2017). Bulb firmness was determined with the aid of a bench-top model SAMMAR, FT327®, with a 5 mm diameter probe. Three measurements were taken in each bulb's equatorial region, obtaining the force to penetrate in kgf. The readings were converted into N (Muniz et al., 2012).

The methodology described by Ferreira & Minami (2000) was used to evaluate skin strength using a texturometer model TA.XT Express Enhanced, Stable Micro Systems®, performing the collection at three median points on the equator of each bulb. In this rupture test, a pointed probe, model SMS P/2N, with a constant force of 0.20 N, was used up to a maximum penetration depth of 3 mm.

The external brightness of the skin (shine) was determined using the Minolta® colorimeter, model CR-400, using the L* color scale system (CIE LAB), previously calibrated. The parameter L* was determined according to Albuquerque et al. (2018).

For pH determination, 10 g of fresh onion sample was weighed, and 90 mL of distilled water was added to a blender for three minutes (Association of Official Analytical Chemists, 2005).

The determination of soluble solids was determined by digital refractometry according to Rodrigues et al. (2020) methodology, using a digital refractometer, and the results were expressed in °Brix.

The determination of titratable acidity was determined according to the methodology of Instituto Adolfo Lutz (2008). Measuring 5 mL of onion juice, 50 mL of distilled water, and three drops of 1% phenolphthalein are added. Afterward, titration was carried out with 0.1 mol L^{-1} NaOH until pH 8.2, where it was considered that all pyruvic acid, an organic acid predominant in onions, was titrated. The ratio of soluble solids and titratable acidity was determined from the expressed results of each characteristic.

The data were subjected to analysis of variance, and when there was a significant difference ($p \leq 0.05$), additional tests were deployed using the R software (R Development Core Team, 2018). The normality and homogeneity of the response variables were determined using the Shapiro-Wilk and Oneillmathews tests, respectively.

Table 1. General characteristics of onion cultivars.

Cultivars	Crop period (days)	Characteristics
Itajubá	160-180	Excellent storage capacity
Mulata	170-180	Excellent storage capacity
Ômega	160-170	High disease resistance and excellent post-harvest conservation
Rainha	160-170	Excellent architecture and uniform maturation
Salto Grande	170-180	High rusticity and productivity, thick scales, and intense coloring
BR29	185-195	Bulb quality and excellent tolerance to major foliar diseases

3 Results and discussion

The difference in the storage of onion cultivars described by Sharma et al. (2015) is visualized in the present work, where 40 days after storage, the cultivar Itajubá presented a more significant loss of fresh matter, with 1.57%, while the cultivars BR29, Rainha, Mulata, Salto Grande and Omega, presented 0.71, 0.52, 0.45 and 0.42% of fresh matter loss, respectively (Figure 2A). They also describe that the significant post-harvest losses are caused by processes related to the physiology of the bulbs, such as sprouting and rooting, thus contributing to mass losses, visual degradation, and quality changes.

When analyzing the final bulb storage time on the 160th day, it is noticed that the cultivars Itajubá, Mulata, and BR29 showed a more significant total loss, with 3.52, 3.60, and 3.32% of fresh bulb matter, respectively. Still, the cultivar Salto Grande stands out for fresh weight loss, showing less loss throughout the storage period, with 1.82%.

Differences in the storage capacity of different onion cultivars have also been reported by Petropoulos et al. (2016). Where they highlight the characteristics of the cultivar that can affect the storage capacity of the bulbs, in which the number and thickness of the tunics' layers and aspects of the skin are factors closely linked to the loss of fresh matter.

For skin strength, the cultivars Ômega, Salto Grande, and Mulata presented better results (Figure 2B). It is known that the skin's strength is closely linked to the loss of mass of the bulb, where it retains moisture, decreasing the process of loss of mass during the storage period (Petropoulos et al., 2016). It was possible to verify that the cultivars Salto Grande and Omega also showed less loss of fresh matter (Figure 2A).

The increase in skin strength during storage may be related to the transfer of moisture from the bulb to the onion skin, creating a greater elasticity and thus exercising a greater penetration force to break the skin (Petropoulos et al., 2016).

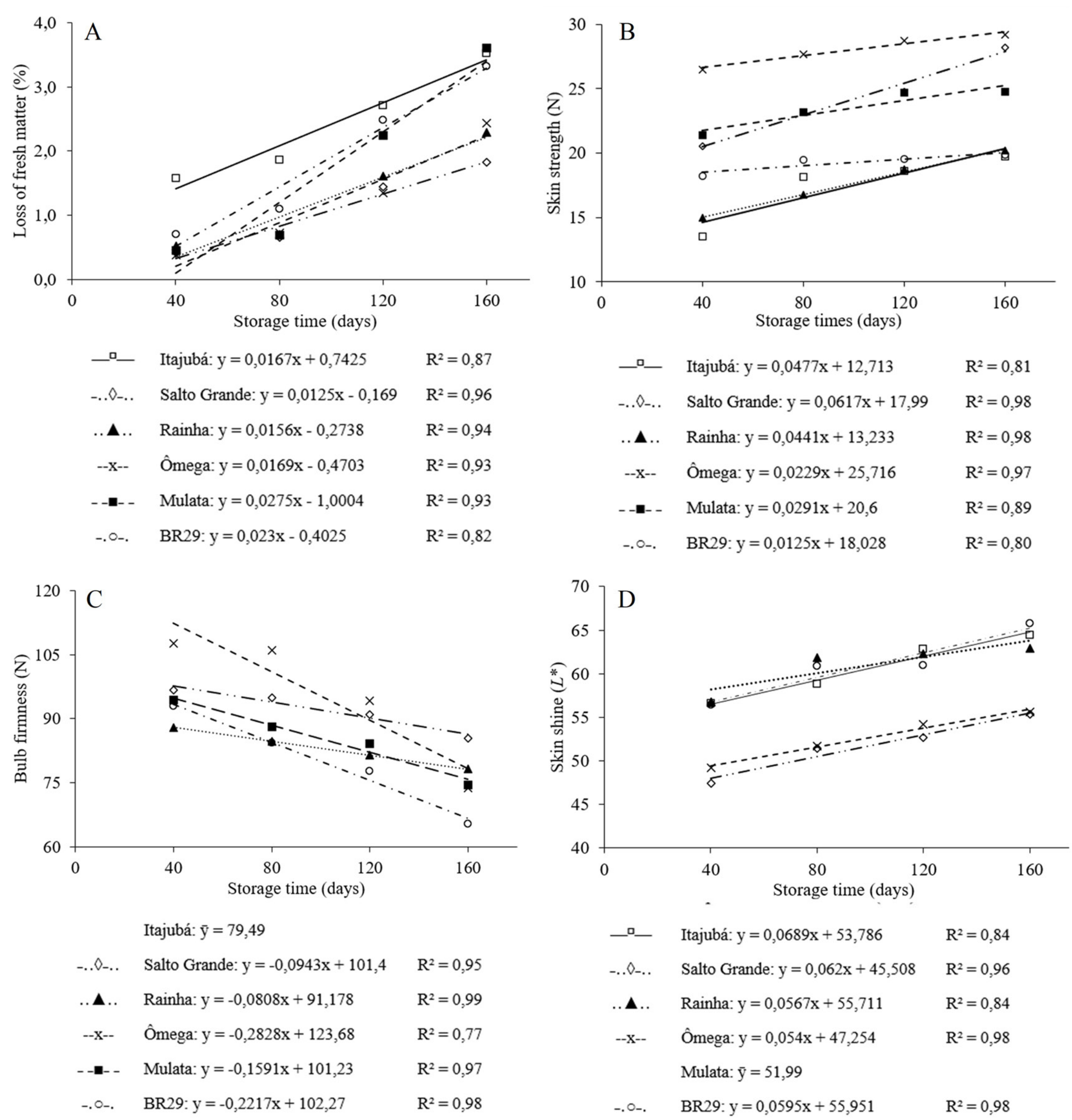

Figure 2. Loss of fresh matter (A), skin strength (B), bulb firmness (C), and skin shine (D) of onion cultivars at different storage times in a controlled environment.

For bulb firmness, there was a decreasing behavior in the results with the increase of the storage time, where the cultivars Ômega and BR29, at the end of the storage time, presented the most significant losses of the firmness characteristic when compared to the other cultivars, with 31.40 and 29.49%, respectively. It is also noteworthy for the Itajubá cultivar, which presented lower losses (6.80%), thus maintaining for a longer time the original bulb firmness since the beginning of storage. For Rainha, Salto Grande, and Mulata cultivars, there was a loss of 11.07, 11.67, and 21.05% concerning the initial value (Figure 2C). Ferreira & Minami (2000) also described the firmness difference between bulbs, thus showing that different genotypes have different characteristics during storage.

Onion respiration is regarded as very low compared with other vegetables; characteristics such as skin strength and bulb firmness, combined with a suitable curing process, are essential parameters that contribute to better post-harvest quality (Dotto et al., 2022).

Compared to the other cultivars, the firmness attribute presented a relation between the bulb's firmness and the skin's strength, corroborating with what was described by (Petropoulos et al., 2016).

The decrease of firmness in fruits and vegetables is associated with biochemical reactions of cell wall degradation during the ripening, senescence, and deterioration process; however, there is conservation variability between cultivars (Murmu & Mishra, 2018).

Ômega and Salto Grande cultivars showed darker color than the cultivars Rainha, BR29, and Itajubá (Figure 2D). The luminosity parameter (L*), also known as skin shine/brightness, varies from 0 to 100, with a value of 0 indicative of black coloring and a value of 100, for white (Albuquerque et al., 2018). Sarkar et al. (2019), studying soil parameters, physiology, biochemical compositions of nutrients, and onion growth, describe that bulbs with peel color values (L *> 50) indicate onion peels with light color.

The brightness of the onion peel (skin shine) is a characteristic taken into account at the time of purchase by the consumer, who prefers, onions with darker coloring, such as the cultivars Salto Grande and Omega (Ferreira & Minami, 2000). The variation in the color parameter may be associated with the composition of the bulbs, especially regarding antioxidant content and enzyme activity (Sarkar et al., 2019).

All onion cultivars showed a similar response during the storage process, with a pH reduction with increasing storage time (Figure 3A). Also noteworthy is the cultivar Salto Grande, which obtained 27.72% loss of this characteristic after 160 days of storage, the one with the lowest losses of this parameter against 31.26, 32.49, 32.52, 33.14 and 33.94% of the cultivars Rainha, BR29, Itajubá, Ômega, and Mulata, respectively.

The pH indicates a vegetable's flavor, having an inverse relationship to acidity. Because of the natural buffer systems found in vegetables can be acidified by organic or inorganic acids until the buffer system is saturated without showing significant variation in pH (Chitarra & Chitarra, 2005).

The onion cultivars showed a decreasing linear behavior for the variable of soluble solids (Figure 3B); it is also noticed that the cultivar Itajubá at 40 days of storage showed a higher average with 11.47 °Brix. However, this characteristic showed a more significant loss (20,06%) after 160 days of storage. It is also noted that the cultivar Rainha during the storage period, presented the lowest values of soluble solids with 10.63, 9.80, 8.83, and 8.63 °Brix for the evaluated periods. Soluble solids represent the concentration of substances dissolved in the cellular content, including vitamins, pectins, phenols, organic acids, pigments, and sugars (Beckles, 2012). Still, according to Beerli et al. (2004), the reduction in the soluble solids during storage probably occurs due to the consumption of substrates in the respiratory metabolism, characteristic of catabolic reactions of senescence.

°Brix reduction during the storage of onion bulbs corroborates the studies carried out by Melo et al. (2012), where, studying the cultivars Beta Cristal and Óptima during 60 days of storage, describe that the levels of soluble solids decreased differently between cultivars during the days of cold storage at 5 °C. The values presented by the cultivar Beta Cristal started with 14 °Brix; at the end of its storage, it presented values of 10 °Brix, while the cultivar Óptima presented values varying from 6 to 5 °Brix during the storage time.

The difference in soluble solids depending on the storage periods may be related to the characteristics of the cultivars themselves, as well as to the degree of maturation of the bulbs used in the analysis because, in this case, with ripening, the starch is hydrolyzed. The complex sugars are transformed into simple sugars (Chitarra & Chitarra, 2005).

Itajubá and Salto Grande cultivars showed lower titratable acidity values during storage periods (Figure 3C). The maximum results for both cultivars were 0.22 and 0.26% of pyruvic acid at 160 days after storage.

Resende et al. (2010) describe that titratable acidity is related to the levels of organic acids in the juice or pulp of fruits and vegetables. The high level of titratable acidity in onion bulbs is a desirable characteristic for industrialization. It measures pungency when expressed as a percentage of pyruvic acid.

For the soluble solids/titratable acidity (SS/AT) ratio, a decreasing linear behavior was observed with increasing storage time (Figure 3D), due to the increase in acidity, due to the storage time, being more significant than the observed for soluble solids.

Muniz et al. (2012), during studies with onion cultivars in storage times, describe an increase in the ratio of soluble solids and titratable acidity due to the decrease in the concentration of organic acids, thus indicating the maintenance of the organoleptic characters of the onions. Analyzing the cultivars, it can be noted that the cultivar Itajubá was superior to the other cultivars, thus presenting better flavor and aroma characteristics.

According to Chitarra & Chitarra (2005), the SS/AT ratio is one of the best ways of evaluating the taste of fruits and vegetables, being more representative than the isolated measurement of sugars or acidity, as it reflects the balance between these compounds.

During curing and storage, several changes occur in the bulb's composition, which interferes with its final quality. Water loss is the most evident change, being more intense in curing. Changes in compounds related to bulb flavor are also significant. For example,

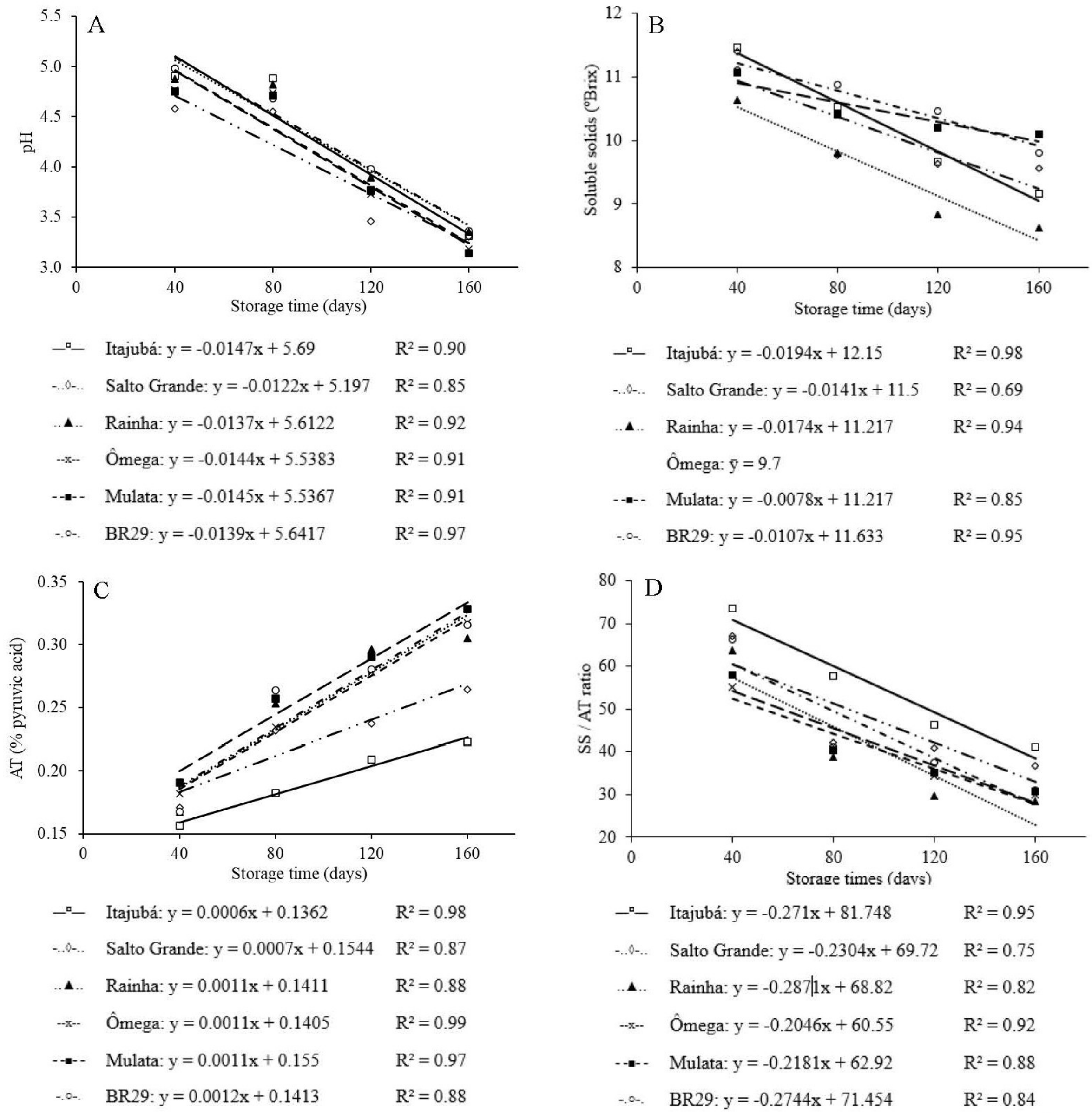

Figure 3. pH (A), soluble solids (B), titratable acidity (C), and soluble solids titratable / acidity ratio (D) of onion cultivars at different storage times in a controlled environment.

the total amount of sugars decreases when storage is prolonged. The pyruvic acid content, responsible for the intense flavor (pungency), may increase or reduce during storage, depending on the cultivar. The success of onion producers concerning the economy depends not only on the management adopted during the onion cultivation but also on the physical and chemical characteristics each cultivar offers during storage (Sekara et al., 2017).

4 Conclusion

Salto Grande cultivar showed greater conservation of physical and chemical characteristics in the post-harvest at controlled temperature, presenting less loss of fresh matter mass and more significant maintenance of skin strength, bulb firmness, soluble solids, and titratable acidity. These characteristics are desirable for the producer, who can store the bulbs to make the sale at the ideal time, and for the final consumer, who values the excellent quality of the bulbs. The cultivar BR29, on the other hand, showed more significant losses in the studied attributes, the one with the lowest storage capacity among the evaluated cultivars.

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