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# Use of Dimethylsulfoxide on the Postharvest Conservation and Quality of Strawberry and Peach

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***Authors' contributions***

*This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

**Objectives:** The objective of this study was to assess, the effect of dimethylsulfoxide (1%, 4% and 7%) on the storage and postharvest quality of strawberry and peach.
**Experimental:** It was used a completely randomized design.
**Location and Duration of Study:** The experiment was conducted in the Laboratory of Food Technology, belonging to the State University of Western Paraná (UNIOESTE), Marechal Cândido Rondon, Paraná State, Brazil, in the period from November to December 2017.
**Methodology:** The fruits were treated by immersion in solutions of dimethylsulfoxide (DMSO) and stored (20°C and 62% RH) for 9 days. The sampling were done at intervals of 2 days for the analyses of fresh weight loss and degradation of fruit and every 3 days for firmness, total soluble solids, total titratable acidity, soluble solids/acidity and ascorbic acid.
**Results:** During storage 4% DMSO showed a significant effect ($P< 0.01$) in the reduction of the microbial degradation in strawberries at 20°C, however, had no effect on the loss of fresh weight

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and firmness. In peach, 1% DMSO accelerated softening and senescence of fruits causing further degradation. Total soluble solids of strawberries was not influenced by DMSO during storage, but peaches suffered the influence of DMSO on the 3rd day at 4% and 7%. Strawberries treated with 4% DMSO showed higher total acidity than the control at 3 and 9 days of storage. Strawberries treated with DMSO showed retention of ascorbic acid similar to or lower than the control, however, peaches showed lower contents of ascorbic acid until the 6th day of storage.

**Conclusion:** This study showed that DMSO was efficient in delaying the degradation of strawberry, but peach has not responded positively to application of DMSO under the same conditions of storage. In addition, DMSO was able to influence the total acidity in strawberries and peaches, however, caused retention of ascorbic acid only in peaches.

*Keywords: Strawberry; peach; DMSO treatment; storage and quality.*

## 1. INTRODUCTION

The strawberry (Fragaria × ananassa Duch.) is a fruit much appreciated and consumed throughout the world, due to its pleasant aroma, bright color and delicious flavor. Due to non-climacteric pattern, strawberry is harvested at full maturity, in order to maintain their sensory attributes (visual appearance, firmness and color) and its nutritional quality (phytonutrients, vitamins and minerals) [1]. Due to the high respiration rate, soft texture, high sensitivity to mechanical shocks and vibrations strawberries have short postharvest life [2]. The shelf life of fresh strawberries stored at 0-4°C is approximately 8 days, while at 20°C it is 3-4 days [3], leading to a high degree of perishability [4].

The Peach is considered climacteric fruit and its consumption has shown high demands and high commercial value. The postharvest life is too short when stored at ambient temperature due to their high susceptibility to pathogens [5]. The reduction of the quality of the fruit is manifested mainly by means of fresh weight loss, wilting, softening and rapid degradation, which leads to considerable economic losses [6].

Brazilian strawberry production is the largest in South America, accounting for 155 thousand tons, in 4,300 hectares in 2017. Brazil occupies a prominent position in the world scenario, being among the 20 largest producers, but most of the intended for domestic supply. The main producing regions are Minas Gerais, Rio Grande do Sul and São Paulo. [7]. Brazil is also considered a major world producer of peaches, with a planted area of 17,118 hectares, produced about 248,583 tons of peaches in 2017, this production is concentrated in the South and Southeast of Brazil [8]. However, the high susceptibility to mechanical damage and attack of microorganisms on strawberries and peaches requires certain concerns in the form of post-harvest storage employed. Strawberries and peaches are products that withstand low temperatures and can be stored near 0°C. However, when stored at room temperature they exhibit very short post-harvest life [9,10]. Being one of the main obstacles of the productive system in the country.

Dimethylsulfoxide (DMSO) is an organic solvent widely used due to its large capacity for solubilisation. The main reasons for multiple applications of DMSO are, low toxicity, the efficacy to solubilise various polar and non-polar compounds, excellent ability to permeate biological membranes without inducing changes of structural integrity, and inhibits growth of bacteria [11]. DMSO is widely used as a solvent in various medical applications, since it has the ability to permeate through cell membranes without causing damage [12]. In addition, DMSO has shown high antioxidant capacity [13] and antimicrobial action [14]. Such characteristics may make the DMSO a promising agent of postharvest conservation of plants. However, in literature was not found studies with the use of DMSO in postharvest of vegetables. Thus, the objective of this study was to evaluate for the first time the effect of DMSO in postharvest conservation of strawberries and peaches.

## 2. MATERIALS AND METHODS

### 2.1 Plant Material and Experimental Plan

Samples of strawberry cv. 'Albion' and peach cv. 'Chiripa' were collected directly from the producer, in the municipality of Marechal Cândido Rondon, located in the western region of Paraná, Brazil, Western (420 meters altitude, latitude 24°33'24"S and longitude 54°3'24"W). The strawberries were picked when ripe (80 to 90% red) [15], and the peaches were harvested

at the whitish green stage [6]. Fruits of uniform in size, shape and colour and without signs of mechanical damage or symptoms of disease were rigorously selected for the experimental sample.

The experimental design was completely randomised in split plot in time. Were tested three doses of DMSO (1%, 4% and 7%, dissolved in distilled water) plus the control (untreated samples), with four replicates per treatment. A destructive group was composed for analyses of firmness, total soluble solids (TSS), total titratable acidity (TTA) and ascorbic acid (AA), and another group not destructive for the analyses of fresh weight loss (FWL) and degradation was also considered. A total of 260 fruit for each species was used in the assessments. The fruits were treated by immersion in solutions of DMSO (5 sec.), in accordance with the doses. Later, the fruits were dried at room temperature for 1 hour. After treatment, strawberries and peaches were placed in styrofoam trays and packaged in a modified atmosphere with PVC film. After they were stored for 9 days at 20°C and 62% RH. The ratings occurred every 2 days for samples not destructive and three days for the destructive.

FWL (%) was determined by means of successive weighings in semi-analytical balance. The firmness of fruits was determined by digital texturometer workbench (Brookfield, CT3), using a metallic rod with a plate of deformation (30 mm diameter), with displacement and strain rate of 10 mm and 3.0 mm $s^{-1}$, respectively. The firmness was expressed in Newton (N) [16].

The rate of degradation of fruits [4] was evaluated using empirical scale with six notes, being: 0) fruit healthy; 1) 1% to 20% of the surface of infected fruit; 2) 21% to 40% of the surface of infected fruit; 3) 41% to 60% of the surface of infected fruit; 4) 61% to 80% of the surface of infected fruit; and 5) ≥81% of the surface of infected fruit and showing sporulation. The degradation index was expressed as a weighted average of degradation by the percentage of the maximum level possible, calculated by the following formula:

$$D = \sum^{(dxf)/}_{(NxD)} x100$$

Where *d* is the note of intensity of degradation punctuated the fruit, and *f* is the frequency; *N* is the total number of fruits examined (i.e., healthy and infected); and *d* is the highest note of intensity of degradation that occurred in the empirical scale.

The juice of a combined sample of 3 fresh strawberries was used for measurements of TTA, TSS and AA. TSS was analysed from the juice extracted from the fruits, and measured with the aid of digital refractometer Atago PAL-1 (°Brix 0-53%), with readings in triplicate, and the results were expressed in °Brix [17]. TTA was determined through acid-base titration, where aliquots of 10 mL of fruit juice was diluted in 90 mL of distilled water and filtered in qualitative paper, followed by titration with sodium hydroxide solution (0.01 mol/L) and phenolphthalein indicator, and the results were expressed in % of citric acid. The TSS/TTA [18] was also determined. AA was determined by the titrimetric method Tillmans (modified) [19], where 2.6-diclorofenolindofenol-sodium is reduced by ascorbic acid, and the results expressed in mg of ascorbic acid per 100 mL of the sample (mg 100 $g^{-1}$).

## 2.2 Statistical Analysis

The data were submitted to analysis of variance and the F test parameters, which was considered significant, were applied to the Tukey test ($P < 0.05$), with the aid of the software assistat [20].

## 3. RESULTS AND DISCUSSION

### 3.1 Fresh Weight Loss, Firmness and Degradation

There was no significant effect of DMSO on the loss of fresh weight of strawberries during storage, because they showed no significant differences in relation to the control group (Fig. 1A). The fresh weight loss observed during the storage, regardless of the treatments, increased sharply, reaching almost 26%, which was expected for the strawberry because the conditions of ambient temperature (average 20°C). The fresh weight loss occurs due to the difference of vapour pressure between the fruit and the atmosphere, reducing its water content. This variable has great importance during storage and marketing of fruit, because high losses can cause reactions due to wither, wrinkling and loss of brightness, resulting in a reduction in the quality of the final product [21].

The fruit firmness was not influenced by DMSO, since there were no significant differences

between fruits treated and control (Fig. 1B). During the storage, there was a reduction of the firmness of the strawberries that ranged from 30.6 to 13.6 N, i.e., a reduction of 55%, which was independent of the treatments. This loss of firmness of strawberries occurs due to the increase in the activity of enzymes involved in the degradation of cell walls, as pectinmethylesterase and polygalacturonase [22]. The firmness of strawberries has considerably decreased during the storage, negatively influencing the acceptability of the consumer [23].

In case of degradation of strawberries (Fig. 1C), the results suggest that the dose 4% DMSO was able to delay the degradation of fruit, because it showed percentages of degradation significantly ($P$<0.01) lower during the storage period. With two days of storage, fruits treated with 4% DMSO showed no symptoms of degradation (0 %), while the degradation of control was 4% and at doses of 1% and 7% DMSO the Degradations were 5% and 3%, respectively. In a relevant way, on the 6th day of storage the dose 4% DMSO showed degradation of 4%, while the control showed 13%. In addition, 4% DMSO exhibited lower degradation and severity of grey mould and rot in the Rhizopus (confirmed by morphological evaluation in microscope) compared to non-treated fruits, demonstrating that 4% DMSO had an inhibitory effect of fungal growth on strawberries stored.

As well as on strawberry, DMSO has not been able to reduce the fresh weight loss of peach (Fig. 2A), i.e., fruits treated with DMSO did not differ from the control and there was no effect between treatments. The fresh weight loss occurs mainly by evaporation/transpiration, which depends on the gradient of the vapor pressure of the water between tissue of the fruit and the surrounding atmosphere, but that, on a smaller scale, can occur due to the loss of carbon stocks as a result of breathing [2]. DMSO also does not interfere with the firmness of peach (Fig. 2B).

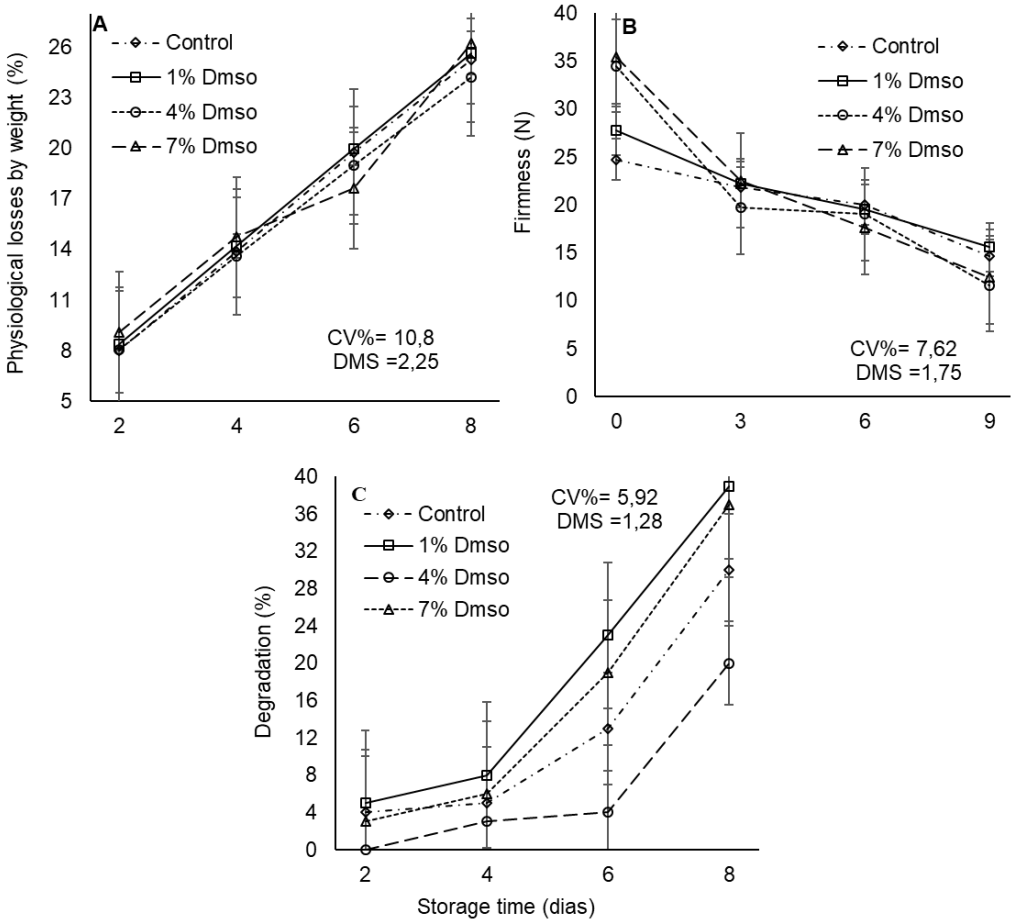


**Fig. 1. Physiological losses by weight (A), firmness (B) and (C) degradation of strawberries treated with DMSO in different storage times**

There was a strong reduction of fruit firmness at 3rd day of storage, indicating that DMSO was not effective in reducing the softening of peaches during storage. Peaches are delicate and sensitive fruits to post-harvest injury as well as strawberries. Among seed rosacea, such as peach, susceptibility to post harvest disturbances is only greater in cherries and nectarines. It is one of the main limiting factors for its in natura storage [24]. Firmness is an important indicator of fruit quality after harvest [25]. According to Zhou et al. [26], the rapid physiological changes that occur in climacteric fruits such as peaches are responsible for the short interval of postharvest maturation, which reflects in a softening of the fruit due to loss of turgidity and consequent degradation of the cell wall by hydrogen peroxide produced during storage which induces the loss of firmness.

The antioxidant activity of fruits tends to diminish with the ripening due to increased oxidative stress at this stage, physiological, which also has great influence on the reduction of post-harvest quality of climacteric fruits, as the peach [6]. An efficient antioxidant system could reduce oxidative stress and atrazar senescence in fruit, but the treatment with DMSO was not able to retard the loss of fresh weight and firmness in peaches stored at 25°C.

DMSO has not been able to reduce the degradation of peach during storage (Fig. 2C). The degradation of treated fruits did not differ statistically from the control. The treatment with 1% DMSO caused further degradation of peaches during storage, differing significantly ($P$< 0.01) of fruit not treated and the doses of 4% and 7%, and this was because of a higher incidence of *Rhizopus* in fruits [27]. On the 8th day of storage degradation of peaches treated with 1% DMSO (40%) was higher than the control group (25%). The treatment with DMSO may have favoured the biological activity of enzymes of degradation of the cell wall, which may have facilitated the invasion of pathogens and, consequently, increased degradation of peach fruits due to the loss of integrity of the

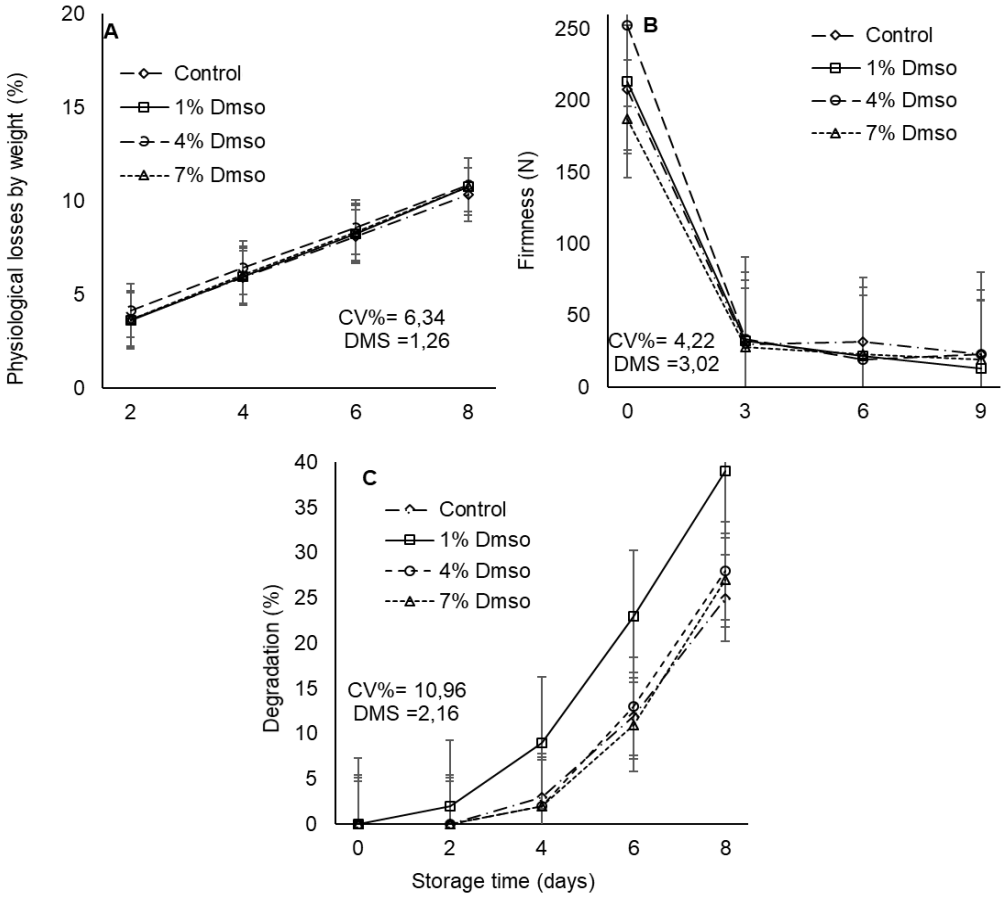


**Fig. 2. Physiological losses by weight (A), firmness (B) and (C) degradation of peaches treated with DMSO in different storage times**

shell. The loss of cell integrity under stress of senescence during the storage of fruits can be caused by oxidative stress. There are several studies that suggest that the enzymatic antioxidant system can slows the lipid peroxidation of cell walls and thus delaying senescence in fruits [6]. However, for the peach, the application of DMSO did not induce response of component in the activation of the antioxidant system.

### 3.2 Total Soluble Solids, Total Titratable Acidity, Ascorbic Acid and Soluble Solids/ Total Acidity

Fig. 3 presents the results of TSS, TTA and TSS/TTA of strawberry and peaches treated with DMSO. Until the third day of storage (20°C) strawberries had significant increases of TSS, but there were no significant differences between the treatments with DMSO, or between the treatments and the control group (Fig. 3A), but in this period, peaches treated with 4% and 7% DMSO showed levels of TSS (12.36 and 12.13 °Brix, respectively) were significantly higher than the control group (11.23 °Brix) (Fig. 3B). These increases in TSS can be much more related to the concentration of sugars due to the loss of fresh weight, than the physiological processes of metabolism, once that parallel studies showed high fresh weight loss of fruits in this period. In addition, throughout the storage period, no treatment of DMSO was able to influence levels of TSS strawberries or peaches significantly lower than the control. Changes in the TSS content are due to the solubilisation of poliuronídeos and hemicelluloses of cell wall in ripe strawberries and are usually accompanied by pleasant flavor and greater acceptance by consumers [1]. On the 6th day of storage, there was a reduction in the levels of TSS in peach fruits in all treatments applied. However the 9th day of storage the averages observed were greater for dose 4 and 7% DMSO (12.53 and 12.96 °Brix, respectively) compared to control treatments and 1% DMSO (11.56 and 11.20 °Brix).

Strawberries treated with 4% and 7% DMSO showed ATT was significantly higher ($P$<0.01) than strawberries treated with 1% up to six days of storage (Fig. 3C). The averages observed in contents of ATT of strawberries for the dose of 4% DMSO were higher (3.84%) in relation to the control group (2.56%) to 3rd day of storage. The ATT of strawberries treated with 4% and 7% DMSO not changed until the 6th day of storage, while in control there has been an increase. In addition, in the 9th day of storage, fruits treated with 4% DMSO also showed ATT (4.69%) higher than the control group (3.84%). Strawberries treated with 1% DMSO showed the lowest levels of ATT during 6 days of storage. For peaches, were not observed significant increases ($P$<0.05) of ATT in doses of 4% and 7% DMSO during 9 days of storage in relation to the control group (Fig. 3D). However, the dose of 1% DMSO showed ATT significantly ($P$<0.01) higher during 6° and 9th days of storage when compared to non-treated fruits (4.69% and 3.84%, respectively). Generally, the reduction of the ATT in fruits after harvesting is related to the increase of the water in cells due to respiratory metabolism, which interferes with the concentration of organic acids present in fruits [28]. On the other hand, increase the content of ATT can represent an increase in the shelf life of fruits such as strawberry and peach [16].

The TSS/TTA of strawberries (Fig. 3E) was higher in the 1% DMSO concentration at 3° (3.25) and 6° (3.22) days of storage in comparison to the control (2.8 and 2.13, respectively). With respect to the peach TSS/ATT was significantly higher ($P$<0.01) in fruits treated with 4% DMSO (48.3) when compared with control fruits (32.9) in the 3th day of storage (Fig. 3F). However at 6th and 9th days of storage peaches treated with 7% DMSO showed a relationship STT/ATT (26.7 and 40.53, respectively) greater than the control group (23.1 and 30.1, respectively). The concentration of 1% DMSO presented the lowest averages observed during the entire period of storage. The flavour of fruit, such as strawberries and peaches is conditioned mainly by the balance between the soluble solids and titratable acidity. A high TSS/TTA gives the fruit a better balance between sweet and sour, conferring more pleasant flavour, making them more attractive [29]. Resende et al. [30] evaluated the TSS/TTA of different cultivars of strawberry and associated results with the acceptance by the consumer and observed that the largest TSS/ATT relations are associated with better perception of the flavour of fruit. In this case, the results of this study showed that the strawberries had depreciation of the global flavor, because TSS/TTA reduced during storage, while the peach, apparently, there was an improvement of taste.

Strawberries treated with DMSO showed less retention of AA during storage (Fig. 4A). Strawberries untreated (control) showed higher levels of AA in 6° and 9th days of storage (68.05

and 27.77 mg 100 $g^{-1}$, respectively). The dose of 1% DMSO presented the lowest averages observed in all storage times. With respect to the peach, there was a significant effect of DMSO on retention of AA (Fig. 4B). In the 3rd and 6th days of storage, all doses of DMSO resulted in peaches with higher levels of AA than the fruits of the control. Higher averages of AA were observed with 4% DMSO (14.55 mg 100 $g^{-1}$), followed by 7% and 1% (12.50 and 11.11 mg 100 $g^{-1}$, respectively), while peaches of control showed significantly lower levels (6.94 mg 100 $g^{-1}$) in the same period (3th). In addition, at 6th day there was a constant reduction in levels of AA peaches, however, the dose of 1% DMSO showed higher levels of AA (8.33 mg 100 $g^{-1}$) in relation to the control group that was 5.55 mg 100 $g^{-1}$.

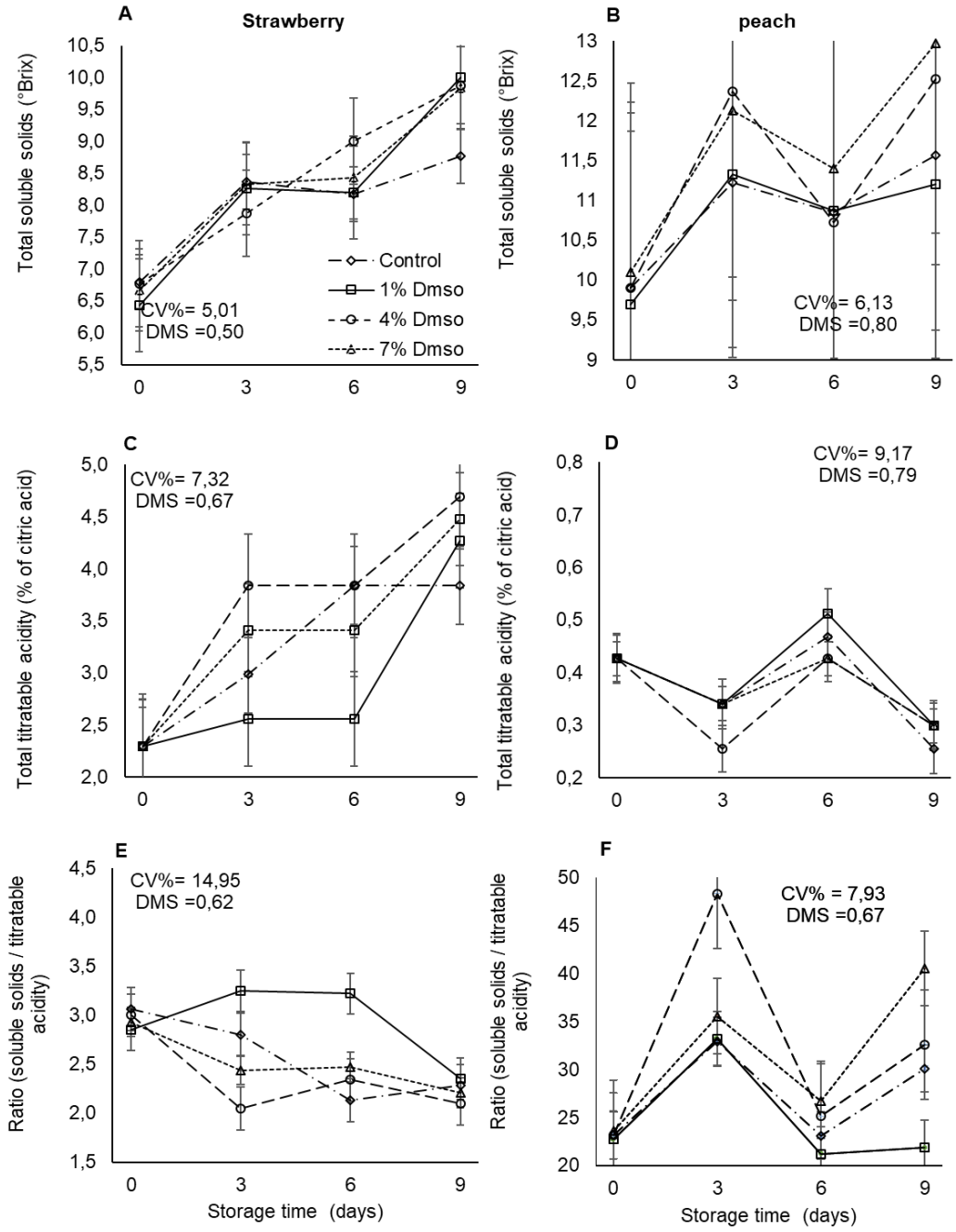


**Fig. 3. Total soluble solids (A and B), total titratable acidity (C and D) and soluble solids/acidity ratio (E and F) of strawberries and peaches treated with DMSO at different times of storage at 20°C**

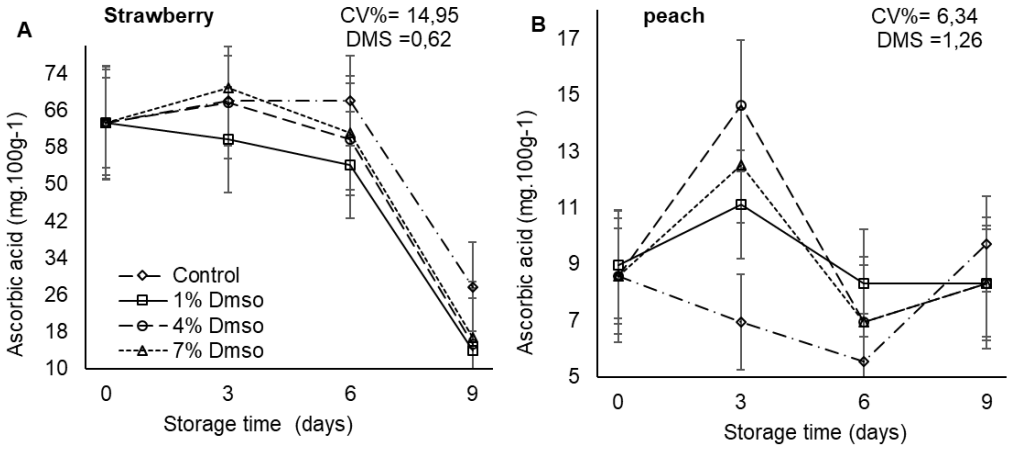


**Fig. 4. Ascorbic acid strawberries (A) and peaches (B) treated with DMSO in different storage times**

In normal conditions of postharvest ascorbic acid from fruit and vegetables decreases during storage, due to the direct action of the enzyme ascorbate oxidase, or by the action of other enzymes, such as peroxidases. Moreover, during the postharvest storage, there is an increase in respiratory rate that causes reactions of oxidation and spoilage of ascorbic acid in the fruit [31].

## 4. CONCLUSION

This study showed that DMSO at a dose of 4% was efficient in delaying the degradation of strawberry, but did not influence the loss of fresh weight and firmness of the fruit. The peach does not respond positively to the application of DMSO when stored at ambient temperatures. The use of DMSO did not influence the content of TSS of strawberries, but peaches showed increases in TSS when treated with 4% and 7%. In the dose 4% DMSO ATT of strawberries was higher and in peaches was lower. In addition, DMSO was able to influence the ATT strawberries and peaches, but observed retention of contents of AA only in peaches.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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