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Influence of the tea polyphenol treatment on the colour, texture, and antioxidant activity in fresh-cut potatoes

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Abstract: This study evaluated the quality changes of fresh-cut potatoes during storage by treating with different concentrations of tea polyphenol (0.125, 0.25, 0.5, and 1.0 $g \cdot L^{-1}$). During the storage, the ΔE value (colour change of fresh-cut potatoes), browning degree, chewiness, malondialdehyde (MDA) content, polyphenol oxidase (PPO) and peroxidase (POD) activity gradually increased. But the hardness and elasticity first increased and then decreased. Compared with the control, the tea polyphenol treatment could effectively inhibit the increase of ΔE value, browning degree, chewiness, MDA content, PPO and POD activity of potato slices, and delay the decrease of slice hardness, elasticity and brittleness in the later storage period. Among them, 0.25 $g \cdot L^{-1}$ tea polyphenol has the best effect. It can maintain the colour of fresh-cut potatoes, inhibit the increase of PPO and POD active enzyme activities, reduce the production of browning substances, and improve the storage quality of fresh-cut potatoes.

Keywords: browning; hardness; enzyme activity; storage

Potatoes (*Solanum tuberosum* L.) are important non-grained crop and vegetable, and their tubers contain a large amount of starch, as well as nutrients such as protein, amino acids, vitamins, and minerals (Camire et al. 2009). Potatoes can be used as fresh-cut vegetables, but with enhanced respiration and a rapid decline in nutritional quality after being cut off. The cut surface will also undergo browning and microbial infection, which seriously affects the appearance and nutritional value of the product (Gunes et al. 1997; Montouto-Graña et al. 2012; Hou et al. 2014). Tsouvaltzis et al. (2011) found that 55 °C hot water blanching treatment can inhibit the occurrence of potato slice browning, with 10 min of hot water treatment having the best effect. Amaral et al. (2015) found in their study of potato slices that ultrasound can effectively avoid inhibiting potato browning, as it can inactivate enzymes by damaging cell membranes. In addition, studies have suggested that treatments such as ozone aqueous solution (Dong et al. 2019), pullulan polysaccharides (Chen et al. 2016), and plant extracts (Qiao et al. 2021) can effectively inhibit the browning of potato slices and improve their storage quality.

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Tea polyphenols are a general term for polyphenolic substances in tea, including flavanols, anthocyanins, flavonoids, flavonols, and phenolic acids (De-Zai and Shi-Hong 2004). Research has shown that tea polyphenols have antioxidant, radiation resistant, antibacterial, and enzyme inhibitory activities (Yi et al. 2010; Macedo et al. 2011; Xu et al. 2015). As antioxidants, preservatives, and colour preservatives, tea polyphenols are widely used in food processing and preservation. Some reports have shown that tea polyphenols can be used for fresh-cutting and preservation of fruits such as kiwifruit (Zhang et al. 2014), cantaloupe (Yu and Shi 2020) and winter melon (Miao et al. 2020). However, there are still few reports on the application of tea polyphenols in the preservation of fresh-cut potatoes. This experiment treated fresh-cut potatoes with different concentrations of tea polyphenols to study their effects on the quality changes of sliced fresh-cut potatoes during storage, in order to provide reference for the storage and preservation of fresh-cut potatoes.

MATERIAL AND METHODS

Material and chemicals. Fresh potatoes (Favorita) of consistent size (about 200.0 g), without damage, diseases or pests for later experiments were purchased from the local market in Yichun City, Jiangxi Province. Potatoes were cleaned with clean water and cut into thin potato slices about 5 mm thick. Then, they were randomly divided into 5 groups, soaked in clean water [control group (CK)] and tea polyphenol solutions of 0.125, 0.25, 0.5, and 1.0 $g \cdot L^{-1}$ for 15 min. They were taken out and drained, and every 5 pieces were wrapped in cling film and stored in a 4 °C fresh-keeping cabinet.

Tea polyphenols (food grade), Yinuo Biotechnology Co., Ltd. (China), The main chemical component was catechins, which was white amorphous crystalline substances. Ethanol, trichloroacetic acid, hydrogen peroxide, 2-thiobarbituric acid, guaiacol, hydroquinone, disodium dihydrogen phosphate dodecahydrate, and disodium dihydrogen phosphate dihydrate were purchased from Xilong Science Co., Ltd. (China). All the chemicals were of analytical grade.

Determination of colour difference and texture. Measurement of colour according to the method of Li et al. (2011). Ten potato slices were randomly selected for each treatment, and the L^* value (lightness), a^* value (redness), and b^* value (yellowness) on both sides of the slices were measured by CR-400/410 colourimeter (KONICA MINOLTA, Japan). ΔE was calculated according to Equation 1, and the ΔE value were used to represent the colour change of fresh-cut potatoes.

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \quad (1)$$

where: ΔE – colour change of fresh-cut potatoes; L^* – lightness, a^* – redness; b^* – yellowness.

Hardness, brittleness, elasticity, and chewiness were measured by TA.XTC-18 texture analyser (Baosheng Industrial Development Co., Ltd., China). Texture analyser parameters was: probe type: needle probe; test type: downward pressure; target mode: displacement; target value: 3 mm; time: 5 s; trigger point type: force; trigger point value: 10 gf (magnitude of gravity); pretest speed: 3 $mm \cdot s^{-1}$; test speed: 1 $mm \cdot s^{-1}$; speed after testing: 1 $mm \cdot s^{-1}$ (Zhao et al. 2018).

Determination of browning degree and malondialdehyde content. The browning degree was quantified using the extinction value method and the malondialdehyde (MDA) content was quantified using the thiobarbituric acid method described by Zheng et al. (2019).

The browning degree: 2.0 g of potato sample powder was placed in a centrifuge tube, and 10 mL of 80% ethanol solution was added. The mixture was stirred and extracted at room temperature in the dark for 30 min. After centrifuging the extract at 8 000 g [relative centrifugal force (rcf)] for 10 min, the supernatant was taken and the absorbance value was measured at 420 nm. 80 °C ethanol was used as the blank, and the average value was taken from three measurements. Calculated browning degree according to Equation 2:

$$Browning\ degree = \frac{A420 \times V}{m} \quad (2)$$

where: $A420$ – measured absorbance value; V – volume of the extraction solution; m – sample mass.

MDA content: 2.0 g of potato sample powder was placed in a centrifuge tube, and 10 mL of 0.05 $mol \cdot L^{-1}$ phosphate buffer solution was added. The mixture was centrifuged at 8 000 g (rcf) for 15 min. 2 mL of supernatant was placed into a test tube, and 2 mL of 0.5% thiobarbituric acid solution was added. After shaking well, it was boiled in a boiling water bath for 30 min. After cooling, its absorbance was measured at 532, 600, and 450 nm. Using 0.5% thiobarbituric acid solution as blank, it was repeated 3 times for each group. The MDA content was calculated according to Equation 3:

https://doi.org/10.17221/139/2024-CJFS

$$\text{MDA } content = \frac{\left[6.452 \times (A532 - A600) - 0.559 \times A450\right] \times 10}{V \times m} \quad (3)$$

where: MDA – malondialdehyde; $A532$, $A600$, and $A450$ – measured absorbance value.

Determination of peroxidase and polyphenol oxidase activity. The activity determination of peroxidase (POD) and polyphenol oxidase (PPO) activity was carried out according to the method described by (Ciou et al. 2011). A 1.00 g sample was added to 5 mL of 0.1 mol·L^{-1} phosphate buffer (pH = 6.8) and then ground to a slurry on ice. This was followed by centrifugation at 8 000 g (rcf) and 4 °C for 20 min. The supernatant was collected for POD and PPO activity assay.

Statistical analysis. The experimental data was processed and plotted using Excel software (version 2010). Differences among results were studied by one way analysis of variance (ANOVA) using Duncan's test by SPSS software (version 20.0).

RESULTS AND DISCUSSION

The effect of tea polyphenol treatment on the colour of fresh-cut potatoes. The colour is an important indicator for evaluating the freshness and quality of fruits and vegetables, which can affect consumer purchasing behaviour (Gao et al. 2019). ΔE is the total colour difference of the sample, representing the overall difference in colour between the measured sample and the fresh sample. The variation of ΔE value of fresh-cut potatoes with storage time is shown in Figure 1. As time goes on, the ΔE value of the control group's fresh-cut potatoes gradually increased. Compared with the control, the ΔE values of potato slices treated with tea polyphenols increased slowly. After 6 days of storage for 10 days, the ΔE values of the tea polyphenol treated group were significantly lower than those of the control ($P < 0.05$). This indicated that tea polyphenols have a good effect on maintaining the colour of fresh-cut potatoes, which was similar to the results of Feng et al. (2019). Among the four treatment groups, the 0.25 g·L^{-1} tea polyphenol treatment group had the lowest ΔE value and the best effect.

The effect of tea polyphenol treatment on the texture of fresh-cut potatoes. Texture characteristics reflect the physical properties of fruits and vegetables related to mechanical properties. The measured indicators include hardness, brittleness, chewiness, resilience, and elasticity, which can to some extent reflect the changes in their texture characteristics and tissue structure (Oh et al. 2024). Figure 2 shows the changes in hardness, brittleness, chewiness, and elasticity of potato slices during storage.

During storage, the hardness, chewiness, and elasticity of potato slices showed an overall increase followed by a decrease. This may be due to the increase caused by the loss of moisture in the potato slices during the early stages of storage. In the later stages, as the slices age, the dissolution and degradation of pectin substances in the cell wall lead to softening of the slices. The hardness, chewiness, and elasticity of slices decrease in the later stage of storage (Toivonen and Brummell 2008). During storage, the brittleness of potato slices gradually decreases. Compared with the

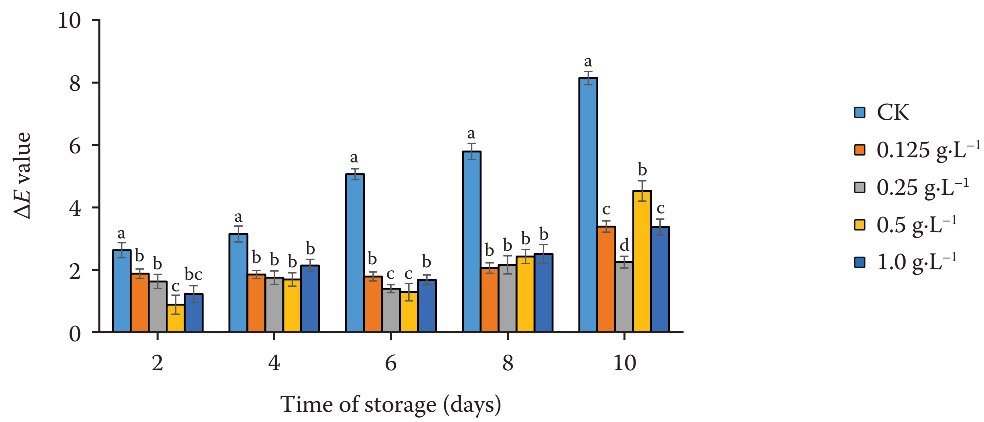

Figure 1. Effect of tea polyphenols treatment on ΔE value of fresh-cut potatoes

a–d – significant differences at $P < 0.05$; CK – control group (clean water); ΔE – colour change of fresh-cut potatoes

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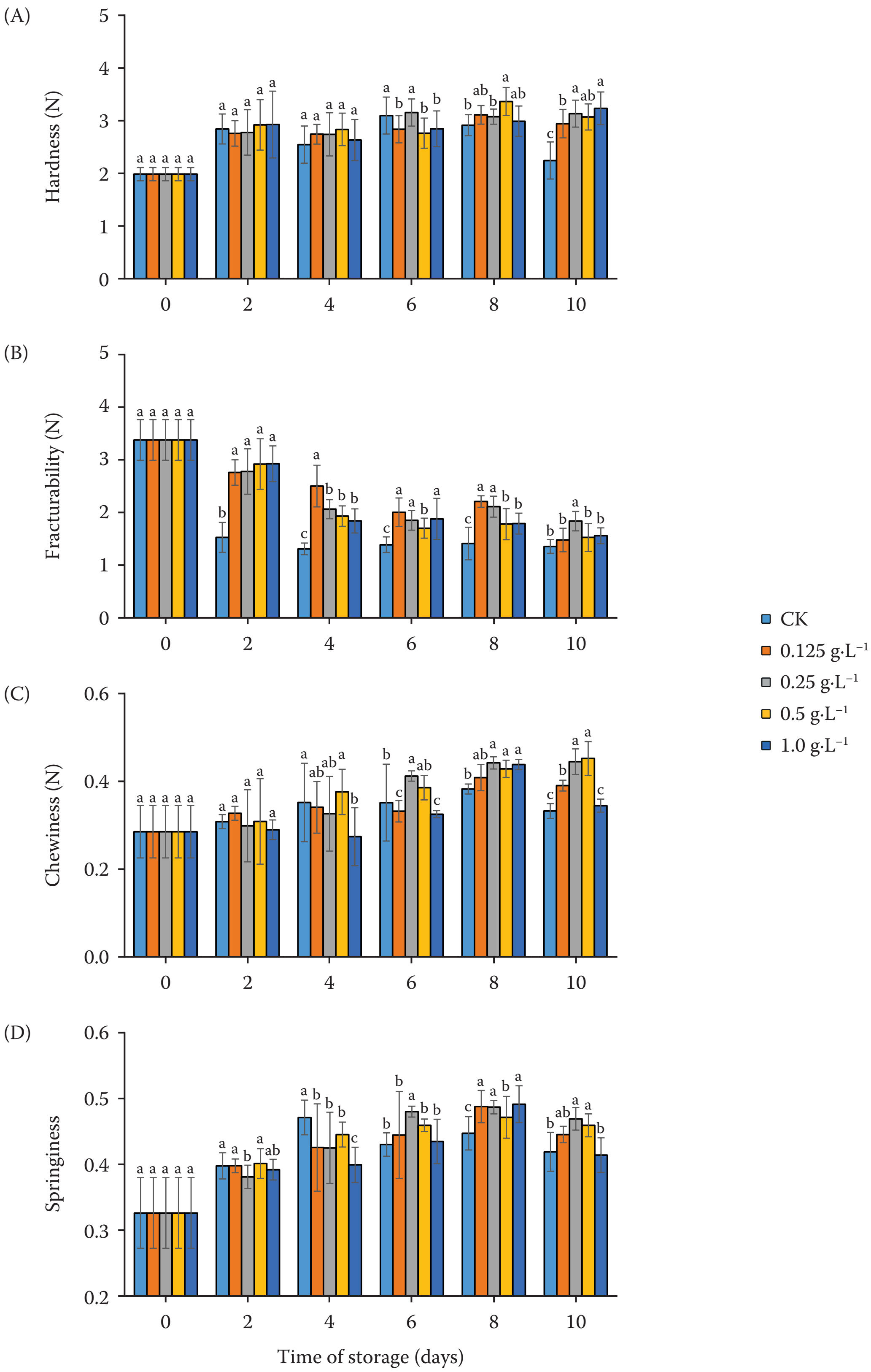

Figure 2. Effect of tea polyphenols treatment on (A) hardness, (B) brittleness, (C) chewability, and (D) elasticity of fresh-cut potatoes

a–c – significant differences at $P < 0.05$; CK – control group (clean water)

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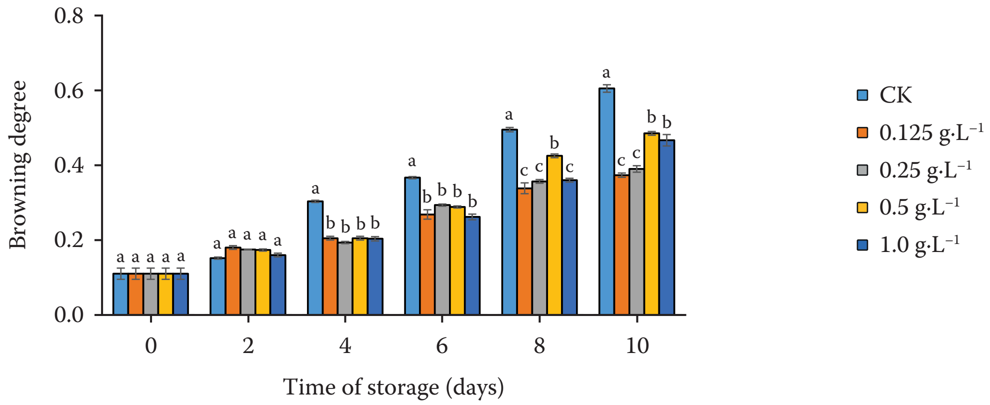

Figure 3. Effect of tea polyphenols treatment on browning degree of fresh-cut potatoes

a–c – significant differences at $P < 0.05$; CK – control group (clean water)

control, tea polyphenol treatment had a better maintenance effect on the hardness, brittleness, elasticity, and chewiness of fresh-cut potatoes. Among them, the 0.25 $g \cdot L^{-1}$ tea polyphenol treatment group had a better effect, which was similar to previous research results (Guan et al. 2019).

The effect of tea polyphenol treatment on the browning degree of fresh-cut potatoes. Browning is an important factor affecting the quality of fruits and vegetables. After cutting, enzymatic browning occurs due to the oxidation reaction of phenolic substances and polyphenol oxidase in the presence of oxygen (Zheng et al. 2019). As shown in Figure 3, the browning values of the control group were higher than those of the treatment group, reaching 0.58 on the 10^{th} day. Compared with the control group, the browning degree of the tea polyphenol treatment group was lower, with values of only 0.3 in the 0.125 $g \cdot L^{-1}$ and 0.25 $g \cdot L^{-1}$ treatment groups on the 10th day, significantly lower than the CK ($P < 0.05$). The browning degree of the CK increased significantly compared to the treatment group, indicating that tea polyphenols indeed had the effect of reducing the degree of browning in fresh-cut potatoes. This was similar to Guan et al. (2024) research, which suggest that tea polyphenols could inhibit enzymatic browning of fresh-cut potatoes by regulating reactive oxygen species metabolism and vitamin C-glutathione cycle (Vc GSH).

The effect of tea polyphenol treatment on the malondialdehyde content of fresh-cut potatoes. MDA is a product of membrane lipid peroxidation that can lead to membrane permeation, causing localised phenols to come into contact with substrates and undergo enzymatic browning (Xia et al. 2019). As shown in Figure 4, the MDA content of potato slices gradually increased during storage. However, the MDA content

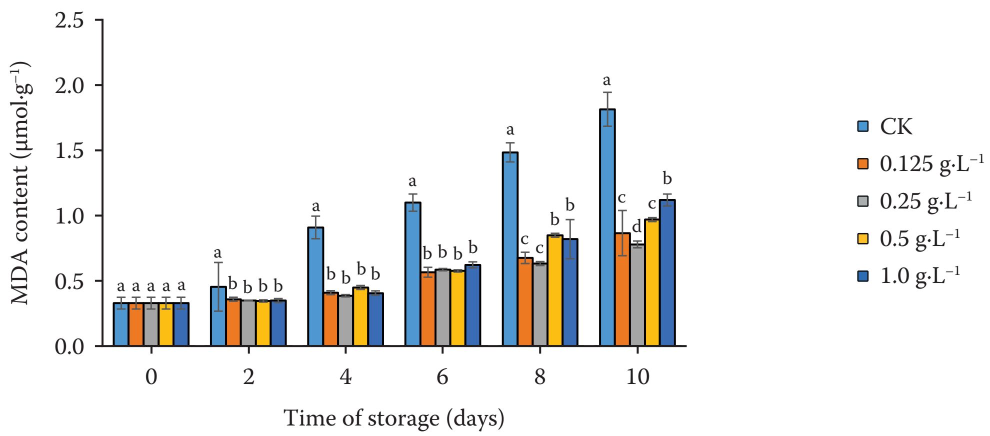

Figure 4. Effect of tea polyphenols treatment on malondialdehyde content of fresh-cut potatoes

a–d – significant differences at $P < 0.05$; CK – control group (clean water); MDA – malondialdehyde

https://doi.org/10.17221/139/2024-CJFS

in the control group slices increased rapidly, significantly higher than that in the treatment group after 4 days of storage. Which may be due to the inhibition of MDA accumulation by tea polyphenol treatment (Zhu et al. 2020). Among the four treatment groups, the MDA content in potato slices treated with 0.25 $g \cdot L^{-1}$ concentration remained at the lowest level. After 10 days of storage, the MDA content was only 0.78 $\mu mol \cdot g^{-1}$, which was only 42.98% of the control group. This indicated that the 0.25 $g \cdot L^{-1}$ tea polyphenol treatment effectively inhibited the accumulation of MDA in fresh-cut potatoes and maintained the lowest MDA content.

The effect of tea polyphenol treatment on the peroxidase activity and polyphenol oxidase activity of fresh-cut potatoes. PPO and POD are widely distributed in plant tissues, they have a synergistic effect on the oxidation of phenols (Lu et al. 2010). PPO can oxidise phenols into quinone compounds under aerobic conditions. POD is an important endogenous active oxygen scavenger in plants, and it can also catalyse the oxidation reactions of many important phenolic substances (Kasnak et al. 2020). As shown in Figure 5A, the overall PPO activity of potato slices in the control group showed a gradually increasing trend during storage. In the early stage of storage, the PPO activity in the control group increased rapidly. The initial PPO activity in the control group was 8.26 U, and it reached 12.44 U after 4 days of storage, an increase of 102.30%. In the later stage, the growth was slower, reaching the maximum value of 20.41 U after 10 days of storage. The PPO activity of potato slices treated with tea polyphenols showed an overall increase followed by a decrease, reaching its maximum value after 6 days of storage. Compared with the control group, the PPO activity of potato slices treated with tea polyphenols was lower. Among them, the PPO activity of 0.25 $g \cdot L^{-1}$ tea polyphenol treatment remained at a lower level and was significantly lower than the control group ($P < 0.05$). The changes in PPO activity of potato slices were similar to PPO (Figure 5B). Compared with the control, the activity

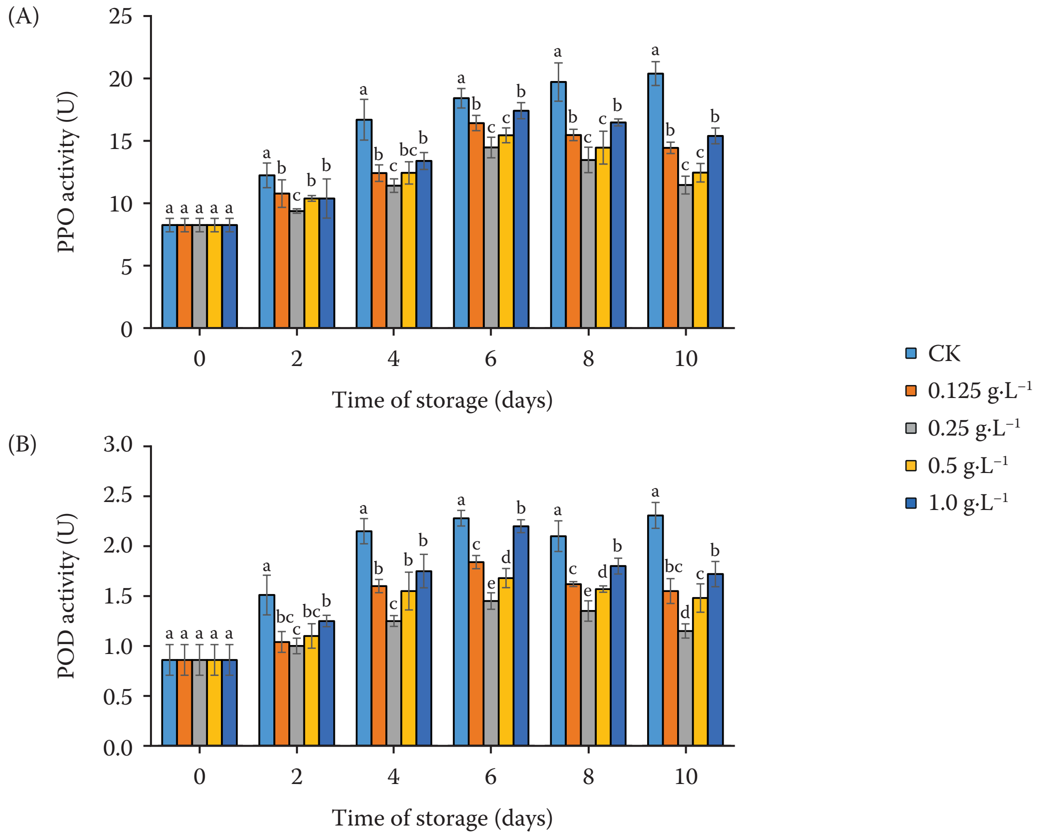

Figure 5. Effect of tea polyphenols treatment on (A) polyphenol oxidase activity and (B) peroxidase activity of fresh-cut potatoes

a–e – significant differences at $P < 0.05$; CK – control group (clean water); POD – peroxidase activity; PPO – polyphenol oxidase activity

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of tea polyphenol treatment remained at a lower level, and was significantly lower than the control in the later stage of storage ($P < 0.05$). Among the four treatments, 0.25 $g{\cdot}L^{-1}$ tea polyphenol treatment had the best effect, and the POD activity of potato slices was only 49.83% of the control after 10 days of storage. The above results indicated that tea polyphenol treatment may inhibit the generation of brown quinones and prevent potato slice browning by delaying the increase of PPO and POD activities in potato slices (Kasnak et al. 2020). The results of the Bobo et al. (2022) showed that tea polyphenols exhibited good ability to inhibit potato browning in various natural plant extracts. Further analysis revealed that gallic acid and myricetin were the main phenolic compounds in green tea extracts.

CONCLUSION

During storage, the ΔE value, browning degree, chewiness, MDA content, PPO and POD activity of potato slices gradually increased, while hardness and elasticity first increased and then decreased, and brittleness gradually decreased. Compared with the control, tea polyphenol treatment can effectively inhibit the increase of ΔE value, browning degree, MDA content, PPO and POD activity in potato slices, and delay the decrease of slice hardness, elasticity, and brittleness in the later stage of storage. The 0.25 $g{\cdot}L^{-1}$ tea polyphenol treatment had the best effect, as it can maintain the colour of fresh-cut potatoes, inhibit the increase of PPO and POD activity enzymes, reduce the production of browning substances, and improve the storage quality of fresh-cut potatoes.

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