horticulturae

MDPI

Article

Preharvest Foliar Spraying Combined with Postharvest Salicylic Acid Treatment Regulates Panzao (*Ziziphus jujuba* Mill. cv. 'Jingcang1') Fruit Quality and Softening during Storage

Yang Geng [1,2,†], Binbin Li [3,†], Ping Zhang [1], Lian Yang [4], Xiaomei Zhao [1,5,*] and Yupeng Tan [6,*]

1 Research Institute of Farm Products Storage and Processing in Xinjiang Academy of Agricultural Sciences, Urumqi 830091, China; gywjyouxiang@163.com (Y.G.); zhangpingyys@163.com (P.Z.)
2 Beijing Weishiyuan Food Technology Co., Beijing 101200, China; 15299660073@163.com
3 Institute of Agricultural Products Processing in Xinjiang Academy of Agricultural Reclamation Sciences, Shihezi 832000, China
4 College of Food and Pharmaceutical Science Xinjiang Agricultural University, Urumqi 830052, China; yang18798682647@126.com
5 Organisms Energy Research Institute in XinJiang Academy of Agricultural Sciences, Urumqi 830091, China
6 Garden Science and Technology Branch in XinJiang Agricultural Professional Technology College, Changji 831100, China
* Correspondence: zxm2003076@163.com (X.Z.); tanyupeng067@163.com (Y.T.)
† Yang Geng and Binbin Li contributed equally to this work and should be considered co-first author.

Abstract: Panzao (*Ziziphus jujuba* Mill. cv. 'Jingcang1') have a short shelf-life, which hampers their marketability. To investigate effects of combined pre- and postharvest treatments on quality and softening during storage, preharvest Guomantian foliar fertilizer (FF) spray and postharvest salicylic acid (SA) dip were applied to panzao. By day 63 of storage, fruit firmness responded to treatment in the order of FF+SA treatment > FF or SA treatments > Control. All treatments inhibited fruit reddening during storage and, compared with those of the control, alleviated the decline in total soluble solids, ascorbic acid, and phenol contents and decreased the oxidative aging process, which was consistent with the change in firmness. The FF+SA treatment reduced the activities of amylase, cellulase, polygalacturonase, and β-glucosidase, which decreased the degradation of macromolecules including starch, cellulose, and pectin. Principal component analysis showed that FF+SA exhibited a synergistic effect and was the most effective treatment for maintaining fruit quality during storage. FF increased accumulation of nutrients during growth and improved quality, while SA delayed the decline in fruit quality and reduced softening. These results provide the theoretical basis and technical knowledge for improving the shelf-life of panzao during storage and long-distance transportation.

Keywords: foliar fertilizer; salicylic acid; *Ziziphus jujuba* Mill. cv. 'Jingcang1'; storage quality; softening

Citation: Geng, Y.; Li, B.; Zhang, P.; Yang, L.; Zhao, X.; Tan, Y. Preharvest Foliar Spraying Combined with Postharvest Salicylic Acid Treatment Regulates Panzao (*Ziziphus jujuba* Mill. cv. 'Jingcang1') Fruit Quality and Softening during Storage. *Horticulturae* **2023**, *9*, 1260. https://doi.org/10.3390/horticulturae9121260

Academic Editor: Michailidis Michail

Received: 17 October 2023
Revised: 12 November 2023
Accepted: 20 November 2023
Published: 23 November 2023

1. Introduction

The panzao (*Ziziphus jujuba* Mill. cv. 'Jingcang1') is Beijing Forestry University and Cangxian Jujube National Breeding Base together by winter jujube (*Zizyphus jujuba* Mill. cv. Dongzao) selection and breeding of excellent fresh food varieties. The panzao is large, flat, and round, shaped like a flat peach, with an attractive appearance and sweet and sour taste loved by consumers. However, because of its thin skin, high water content, easy loss of water during harvesting and transportation, and short storage period, the market supply of panzao is severely restricted [1].

Several crop storage and preservation methods, including fumigation (i.e., the use of gas to inhibit or kill pathogenic microorganisms on the surface of fruits and vegetables; the gases penetrate into the fruit and alter its physiology across multiple scales) [2], gas conditioning (i.e., placing fresh dates in a specific gas-conditioning storage facility with cold storage; achieved by adjusting the concentration of O_2 and CO_2, and other gases in the storage environment to attain preservation) [3], chemical preservatives (i.e., entails the application of chemicals that inhibit microbial reproduction and slow fruit metabolic functions) [4], and film coating (i.e., coating fruit surfaces with a polymer liquid film layer, creating a selective moisture and gas barrier that slows the deterioration of the fruit by slowing down the physiological processes of the fruits and inhibiting microbial processes) [5] have been used to prolong the storage time and improve fruit quality. In addition, some preharvest treatments, such as spraying with foliar fertilizers and growth regulators, have been investigated. Preharvest spraying of blueberries, peaches, apricots, noni (*Morinda citrifolia* L.), grapes, and apples with gibberellins, selenium, calcium chloride, and boric acid delayed postharvest oxidative senescence, improved resistance and quality during storage, and extended shelf-life [6–12].

Salicylic acid is widely used as a preservative for the storage and preservation of fruit and vegetables and has the advantages of being safe, effective, and non-polluting [13]. Salicylic acid application improves storage quality by reducing ethylene production, reducing the respiration rate, maintaining fruit firmness, delaying softening and discoloration during storage, maintaining sugars, organic acids, and aromas, inhibiting cold damage, promoting resistance to pathogens, activating the antioxidant system, and reducing fruit decay [14]. Appropriate maturity of panzao for harvesting, and suitable storage and preservation conditions, were defined in our preliminary research. We also found that foliar fertilization during the growth period of panzao increased the total soluble solid content in the fruit, thereby improving fruit quality [15]. Postharvest salicylic acid treatment maintains fruit quality by delaying the decline in ascorbic acid, total phenols, and other nutrients during storage [16]. Nevertheless, there is a lack of information on the synergistic effect of preharvest foliar fertilization in combination with postharvest salicylic acid treatment on delaying fruit quality decline and softening during storage.

In this study, we aimed to investigate the effect of foliar fertilizer treatment (during the growth period of panzao combined with postharvest salicylic acid treatment on storage quality and delaying softening. We explored the mechanism of preservation to provide a theoretical basis for optimizing the storage and preservation conditions of the fruit.

2. Materials and Methods

2.1. Samples and Storage Conditions

The raw materials were treated outside the Jujube Experiment Station in Kashgar Meghiti County, Xinjiang (Institute of Horticultural Crops, Xinjiang Academy of Agricultural Sciences, Urumqi, China). Specifically, three-year-old normal panzao trees that were developmentally and physically similar were selected as test samples, with the gray jujube as the rootstock, and the spacing between rows and lines of plants was 1.5 m × 4 m [15].

Guomantian compound foliar fertilizer (Weinan Lvdun Crop Products Co., Ltd. Shaanxi, China; humic acid-N-P_2O_5-K_2O 4.5%-14%-10%-6%), and Yimeigai foliar fertilizer (S. Carlo Biozim, Italy; Ca-Mg-N 8%-6.5%-10%) (13.3 mL of each fertilizer) were dissolved in 20 L of water and applied once on each of 30 June 2022, 15 July 2022, and 30 July 2022 (young fruit stage), using an electric sprayer. The control group was sprayed with an equal volume of water. One hundred fruit trees were sprayed per treatment. The ripe panzao was harvested during the first red stage (90 d after flowering).

Three treatment groups and a control group were established in the experiment. Foliar fertilizer treatment was applied to panzao during the expansion period, then postharvest panzao were soaked in 30 mmol L^{-1} SA (Hebei Kolondo Biotechnology Co., Ltd., Hebei, China) solution for 1 min; this was denoted as the FF+SA treatment group. The second treatment was by foliar fertilizer spray during the fruit expansion period of panzao, then the postharvest panzao were soaked in water for 1 min; this was denoted as the FF group. The third treatment was by foliage water spray during the panzao expansion period, then the postharvest panzao were macerated in 30 mmol L^{-1} SA solution for 1 min; this was denoted as the SA group. The control group were treated by foliage water spray at the expansion stage, then the postharvest panzao were macerated in water for 1 min. The panzao were dried naturally, then pre-cooled at 4 °C for 24 h and transported back to the cold storage of the Institute of Horticulture, Xinjiang Academy of Agricultural Sciences within 48 h for refrigeration (0 ± 1 °C). Some samples were used to determine firmness and total soluble solids content, while the rest were frozen with liquid nitrogen and stored in a refrigerator at −80 °C for the determination of physical and chemical indicators.

2.2. Firmness, Weight Loss Rate, Transverse and Longitudinal Diameter Loss Rates, and Color Differences

Ten fruits were randomly selected, and their skins were peeled from the center. The hardness of these fruits was then determined using the GY-4 (Shandong Lainde Intelligent Technology Co., Ltd., Shandong, China) type fruit hardness tester. This test was repeated three times; the final hardness value for the respective fruits was obtained values.

Twenty fruits were selected and numbered. Fixed fruit mass and changes in transverse and longitudinal diameters at fixed positions were measured manually at week 0, week 1, week 2, week 3, week 4, week 5, week 6, week 7, week 8, and week 9 of storage. The rates of weight loss, transverse diameter reduction, and longitudinal diameters reduction were expressed as the ratios of the mass of the fruits, and the transverse and longitudinal diameters lost during the storage period compared to that of the fruits on day 0 of storage were calculated.

Twenty fruits were selected, numbered, and marked at the equator of the fixed points, and the *L**, *a**, and *b** values of the fixed points were measured using a CR-10 colorimeter (Konica Minolta Holdings, Tokyo, Japan). This step was repeated three times for the respective fruits, and a final value was obtained by averaging the results.

All the steps above were conducted in accordance with published protocols [1].

2.3. TSS, TA, SS, AsA, Total Phenols, Flavonoids, and SP Content

Ten fruits were randomly selected, and the juice was filtered after the panzao fruits were cut to determine the total soluble solids (TSS) content using a PAL-1 hand-held digital refractometer; these results of each treatment were averaged. Titratable acid (TA) content was determined using sodium hydroxide titration. On the other hand, soluble sugar (SS) content was determined using anthrone colorimetry. Ascorbic acid (AsA) content was determined using 2,6-dichloroindophenol titration, whereas the total phenol and flavonoid concentrations were determined using UV spectrophotometry. The soluble protein (SP) content was determined using Coomassie blue staining. These steps were conducted in accordance with published protocols [1].

2.4. Determination of Antioxidant Properties

The scavenging effect of panzao fruit polyphenol extracts on DPPH and ABTS free radicals was determined following the previously published experimental protocol [1].

2.5. Determination of Starch and Cell Wall Material Content

2.5.1. Determination of Starch Content

Starch content was determined based on the method described by Cao et al. (2007) [17], with slight modifications. The frozen panzao tissues (1.0 g) were added to 5 mL 80% ethanol, centrifuged at 8000× g at 4 °C for 5 min, and then washed with 80% ethanol (5 mL × 3 times). The supernatant was discarded, 5 mL of distilled water was added, and the resultant liquid was shaken for 2 min then centrifuged at 8000× g for 5 min. The supernatant was collected and incubated in a boiling water bath; 0.98 mL of the supernatant was measured out and 0.02 mL of iodine solution was added, and the reaction was carried out for 10 min. The absorbance was determined at 660 nm and the starch content was calculated by substitution into the equation of the standard curve. Three independent replicates were analyzed for each treatment group.

2.5.2. Determination of Cellulose Content

The cellulose determination method was based on the method described by Liu et al. (2017) [18] with slight modifications. Frozen tissue (0.2 g) was added to 5 mL of 11.2 mol L^{-1} sulfuric acid solution, hydrolyzed at 0 °C for 30 min, then centrifuged at 8000× g for 15 min. The supernatant was diluted 500–1000 times, then 0.5 mL of anthrone reagent and 3 mL of concentrated sulfuric acid were added to 2 mL of the diluted supernatant. After cooling for 12 min, absorbance was measured at 620 nm. A standard curve was drawn using the cellulose standard resolution for each concentration. Three independent replicates were analyzed for each treatment group.

2.5.3. Determination of Pectin Content

The pectin determination method was based on the method described by Cao et al. (2007) [17] with slight modifications. Frozen tissue (0.25 g) was added to 5 mL 95% ethanol at 90 °C for 30 min, centrifuged at 10,000× g for 5 min, and then washed with 95% ethanol (5 mL × 3 times). The supernatant was discarded, 4 mL of distilled water was added, and the result was shaken for 5 min, then centrifuged at 10,000× g for 5 min. The supernatant was used for determining the soluble pectin content. The precipitate was extracted with 0.5 mol L^{-1} sulfuric acid solution in a boiling water bath for 1 h and centrifuged under the same conditions. The reaction mixture consisted of 0.5 mL supernatant and 3 mL concentrated sulfuric acid. The mixture was heated in a boiling water bath for 20 min. After cooling, 0.1 mL of carbazole solution was added and allowed to react under light-proof conditions for 30 min. Finally, absorbance was measured at 530 nm. The absorbance values were substituted into the corresponding standard curves to calculate the original and soluble pectin contents. Three independent replicates were analyzed for each treatment group.

2.6. Determination of Relevant Enzyme Activities

2.6.1. Determination of Amylase Activity

Amylase activity was determined using the method described by Cao et al. (2007) [17].

2.6.2. Cellulase (Cx), Polygalacturonase (PG), and β-glucosidase (β-glu) Activities

This assay was performed according to the method described by Liu et al. (2017) [18].

2.7. Data Processing and Statistical Analysis

Data are expressed as mean ± SD (standard deviation). Data were processed using Excel 2020 (Beijing Kingsoft Office Software Co., Ltd., Beijing, China). Statistical analyses were conducted via ANOVA tests using the SPSS version 19.0 software (IBM Corp., Armonk, NY, USA). Mean values were analyzed through Duncan's test at $p < 0.05$ level. In addition, the principal software component of Origin 2021 software (OriginLab, Northampton, MA, USA) was used for principal component analysis (PCA) and graphing.

3. Results

3.1. Firmness, Weight Loss Rate, Cross-Diameter Loss Rate, and Longitudinal Loss Rate

The firmness of the panzao in each treatment group declined as storage time increased (Figure 1A). During storage, the fruit firmness of the FF+SA treatment group was higher than that of the other treatment groups. The differences in fruit firmness among the treatment groups were not significant before 21 days of storage ($p > 0.05$). From day 28 to day 63 of storage, the firmness of control- and FF-treated fruit were significantly different from those of FF+SA-treated fruit ($p < 0.05$). The firmness of control- and FF-treated fruit were significantly different only by days 35 and 63 of storage, respectively, ($p < 0.05$). There was a significant difference ($p < 0.05$) in firmness between the control and SA treatment groups from day 35 to day 63 of storage. There was a significant difference between the FF+SA and SA treatment groups on days 35, 56, and 63 of storage ($p < 0.05$). The order of firmness of panzao in the different treatment groups on day 63 of storage was: FF+SA > SA > FF > control; that is, preharvest foliar fertilizer combined with postharvest salicylic acid treatment was more effective than single treatments or control in maintaining fruit firmness during the storage of panzao. Single foliar fertilizer or postharvest salicylic acid treatment was also more effective than control.

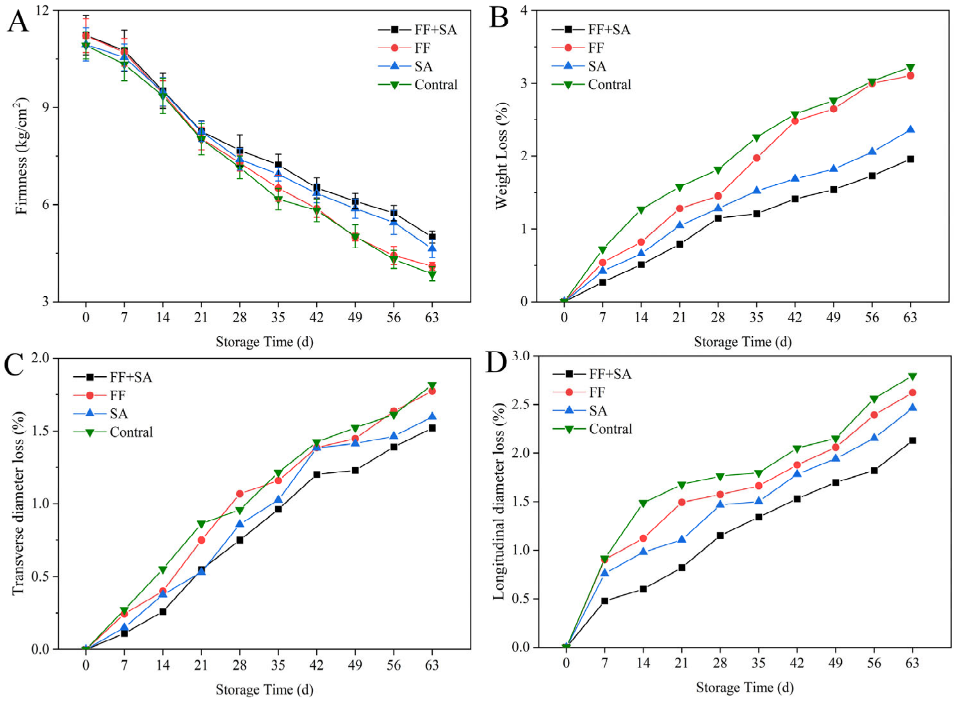

Figure 1. Firmness (**A**), weight loss rate (**B**), and transverse (**C**) and longitudinal (**D**) diameter loss rates of panzao during storage under different treatments. Note: FF+SA = preharvest Guomantian foliar fertilizer spray and postharvest salicylic acid dip; FF = preharvest Guomantian foliar fertilizer spray; SA = postharvest salicylic acid dip; Contral = preharvest and postharvest were treated with fresh water.

The weight, transverse diameter, and longitudinal diameter loss rates of the panzao increased during storage, and some differences between the treatment groups were observed (Figure 1B–D). At the end of storage, control > FF > SA > FF+SA, showing high consistency in the decrease in hardness during storage in each treatment group. In addition, the results showed that the results of the FF+SA and SA treatment groups were close to each other and the results of the FF and control treatment groups were close to each other, which indicated that the postharvest salicylic acid treatment had a positive effect on delaying water loss and fruit wrinkling during storage of panzao, among which the preharvest foliar fertilizer spray combined with postharvest salicylic acid treatment had the best effect.

3.2. Fruit Chromatic Value

The color of panzao peel gradually changed from green to red during storage. The brightness of the peel decreased continuously with extended storage time (Figure 2). The color parameters of L^*, a^*, and b^* values for different treatments are shown in Figure 3. The L^* values decreased slowly in each treatment group during the first 21 days of storage, with no significant differences ($p > 0.05$), and then decreased significantly from day 21 to day 42 of storage ($p < 0.05$). By day 63 of storage, the highest L^* values were observed in the FF+SA treatment group and were followed by the values in the SA and FF treatment groups. The lowest was observed in the control group. In contrast to the trend in L^* values, a^* values increased continuously during storage, indicating a gradual change in the color of panzao skin to red with faster changes in a^* values from day 21 to day 35 of storage. The b^* values of the different treatment groups exhibited an overall decreasing trend during storage. By the end of the storage period, the L^* values of panzao in the FF+SA, FF, SA, and control treatments decreased by 37.39%, 42.85%, 40.09%, and 45.65%, respectively, whereas the *a** values increased by 356.41%, 375.26%, 370.47%, and 391.71%, respectively, and the *b** values decreased by 26.03%, 30.52%, 29.17%, and 35.52%, respectively. The results indicated that preharvest foliar fertilizer spray treatment and postharvest salicylic acid treatment had a synergistic effect in delaying the decrease in peel brightness and reddening of panzao during storage.

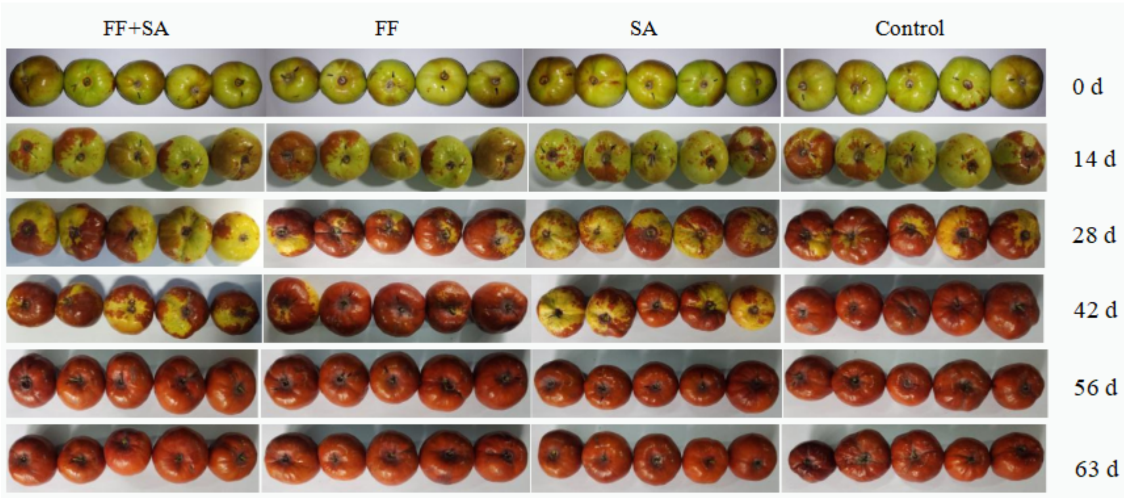

Figure 2. Changes in the appearance of panzao under different treatments during storage. FF+SA = preharvest Guomantian foliar fertilizer spray and postharvest salicylic acid dip; FF = preharvest Guomantian foliar fertilizer spray; SA = postharvest salicylic acid dip; Contral = preharvest and postharvest were treated with fresh water.

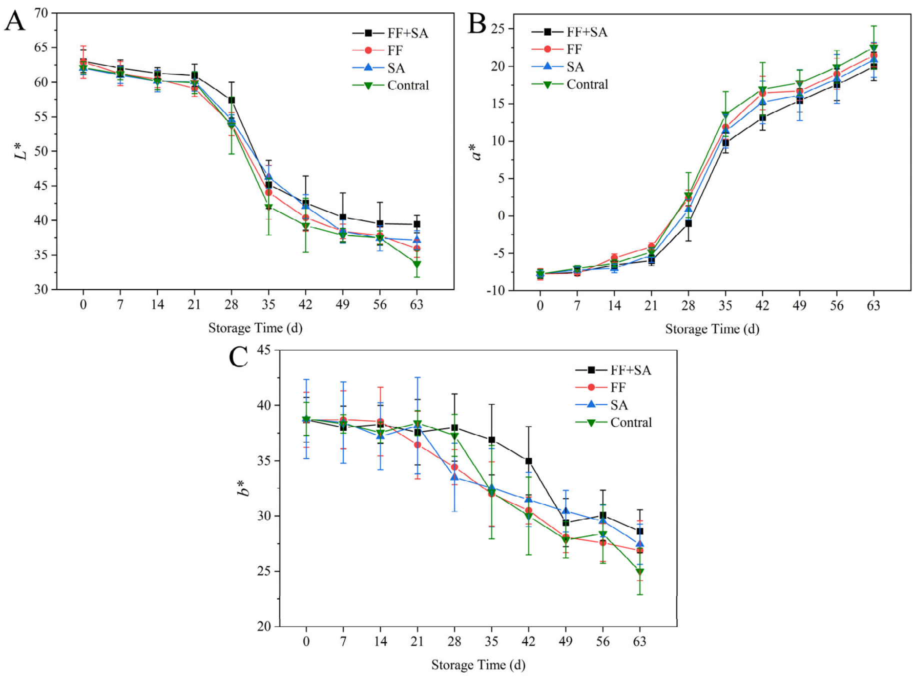

Figure 3. Fruit chromatic values from panzao during storage under different treatments. Note: FF+SA = preharvest Guomantian foliar fertilizer spray and postharvest salicylic acid dip; FF = preharvest Guomantian foliar fertilizer spray; SA = postharvest salicylic acid dip; Contral = preharvest and postharvest were treated with fresh water.

3.3. Total Soluble Solid, Titratable Acid, and Soluble Sugar

As shown in Figure 4A, the TSS content of panzao first increased and then decreased during storage. The maximum TSS contents of panzao in the FF+SA, FF, SA, and control treatment groups appeared on days 42, 35, 42, and 35 of storage, respectively, indicating that salicylic acid treatment delayed the increase in TSS content during storage and post-ripening of panzao. In addition, the TSS content of jujube fruit in the FF treatment group was significantly higher than that in the control treatment group before and after storage ($p < 0.05$). Foliar fertilizer treatment during the growth period of panzao promoted the accumulation of TSS in panzao and maintained a relatively high TSS content during storage, and its synergistic treatment with salicylic acid had a positive effect on improving and maintaining the flavor and taste of panzao during storage.

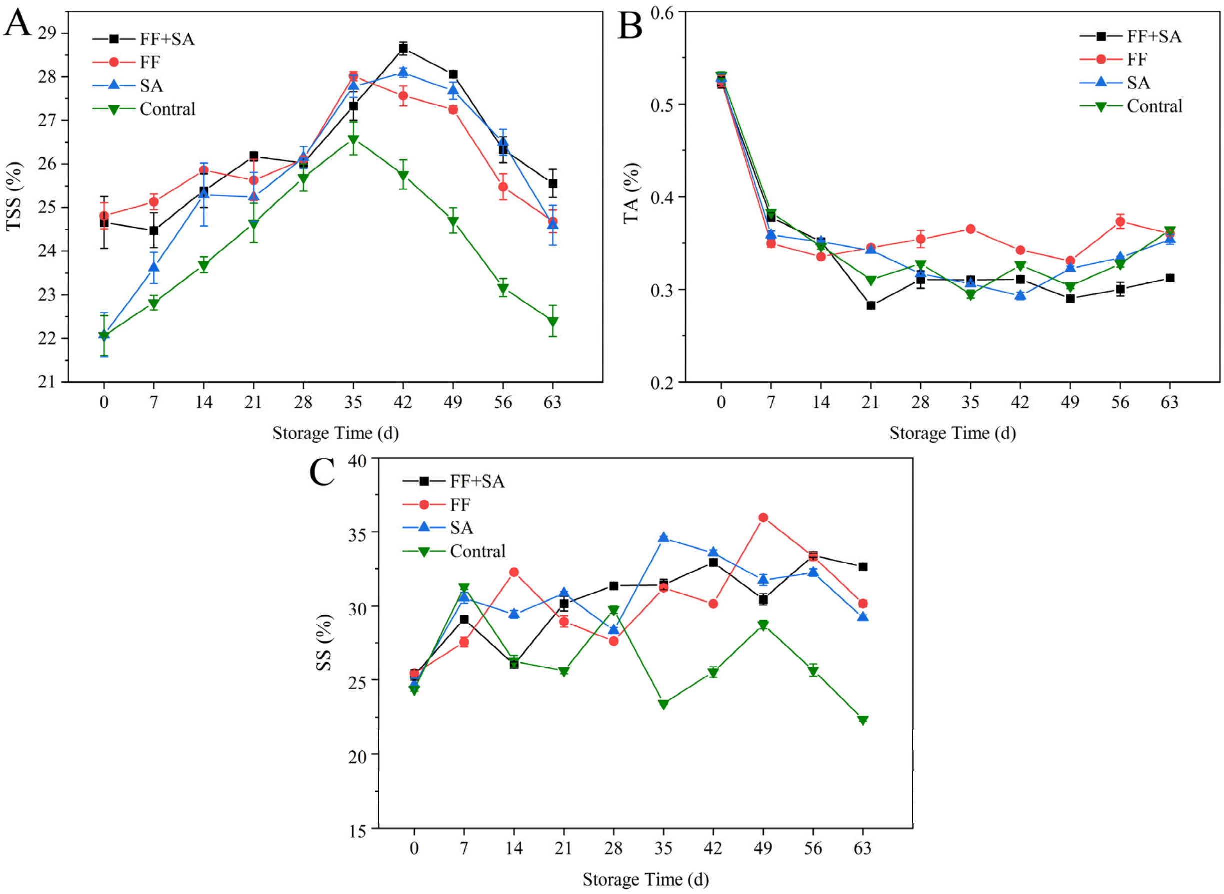

Figure 4. Total soluble solid (**A**), titratable acid (**B**), and soluble sugar (**C**) contents of panzao during storage under different treatments. Note: FF+SA = preharvest Guomantian foliar fertilizer spray and postharvest salicylic acid dip; FF = preharvest Guomantian foliar fertilizer spray; SA = postharvest salicylic acid dip; Contral = preharvest and postharvest were treated with fresh water.

There was no significant difference ($p > 0.05$) between the foliar fertilization treatments in the accumulation of TA in the fruit of panzao during growth. The TA content in the panzao of the different treatment groups showed a rapid decrease during storage days 0–7 and an increasing trend during the later storage period (Figure 4B). From day 21 to the end of the storage period, the TA content in the FF+SA treatment remained low. At the end of the storage period, the TA contents in the panzao of the FF+SA, FF, SA, and control treatments were 0.31%, 0.36%, 0.35%, and 0.36%, respectively. There was no significant difference in TA content between the FF and control treatment groups ($p > 0.05$), and the TA contents in both FF+SA and SA treatments differed significantly ($p < 0.05$) from that in the control panzao. These results indicate that salicylic acid treatment delayed the increase in TA content during the late storage period of panzao.

The SS content in the panzao of the different treatment groups fluctuated during storage (Figure 4C). The SS contents in the panzao in the FF+SA, FF, and SA treatment groups were higher than that of the control group, except on days 7 and 21 of storage; however, the differences between the above treatment groups were not significant ($p > 0.05$). By the end of the storage period, the SS contents in the FF+SA, FF, SA, and control treatment groups were 32.65%, 30.16%, 29.21%, and 22.37%, respectively. The highest SS contents in the fruit in the FF+SA, FF, SA, and control treatment groups were 32.65%, 30.16%, 29.21%, and 22.37%, respectively, with the highest SS content in the FF+SA treatment group and the lowest SS content in the control group. These results indicate that preharvest foliar fertilizer spray combined with postharvest salicylic acid treatment delayed the decline in SS content in panzao during the late storage period.

3.4. Ascorbic Acid, Total Phenol, Flavonoid, and Soluble Protein

The AsA contents in panzao from the different treatment groups gradually decreased with increasing storage time (Figure 5A). The differences in AsA content between the SA treatment and control groups before storage were not significant ($p > 0.05$). By the end of storage, the AsA contents in panzao were 1.85, 1.56, 1.63, and 1.47 mg g^{-1} in the FF+SA, FF, SA, and control treatment groups, respectively, and showed significant differences among all groups ($p < 0.05$). These results indicate that postharvest SA treatment delayed the decline in AsA content in panzao during storage. Preharvest foliar fertilization combined with postharvest salicylic acid treatment was beneficial for maintaining AsA content in panzao after storage and the two treatments exhibited a synergistic effect.

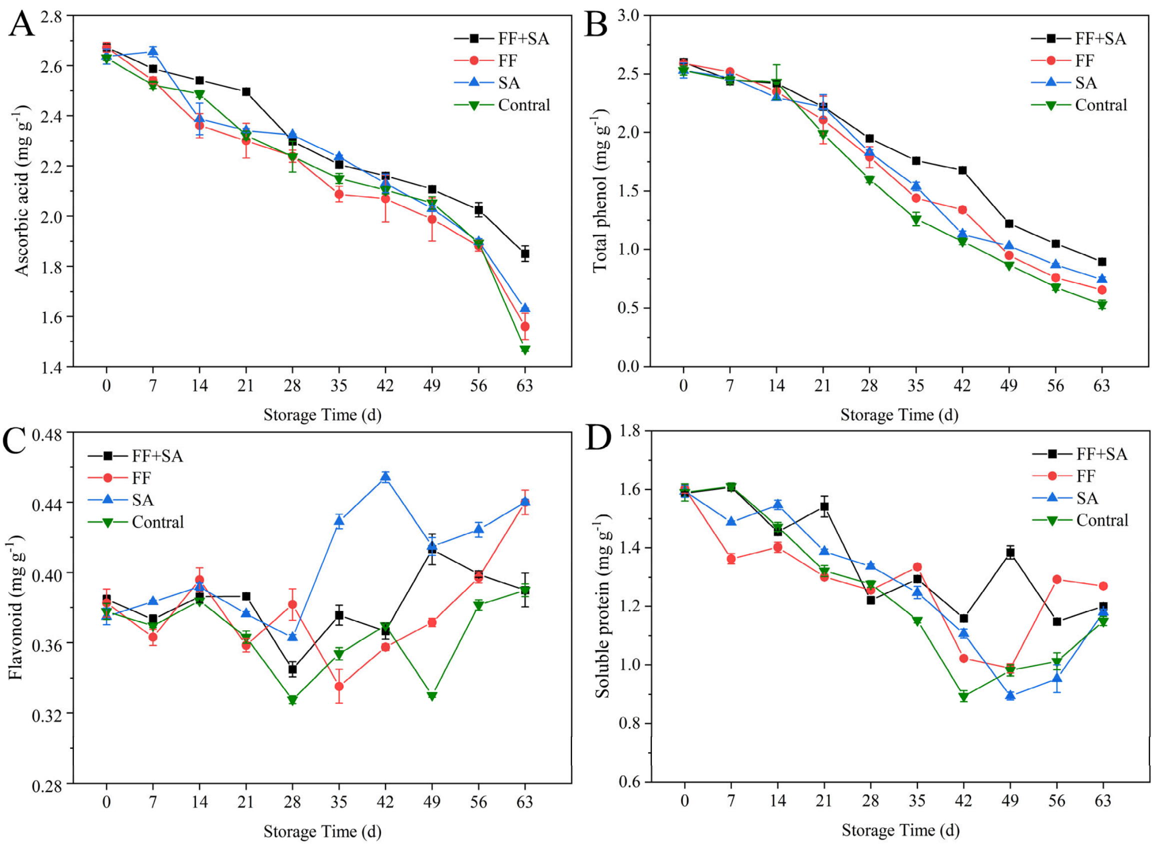

Figure 5. Ascorbic acid (**A**), total phenol (**B**), flavonoid (**C**), and soluble protein contents (**D**) of panzao during storage under different treatments. Note: FF+SA = preharvest Guomantian foliar fertilizer spray and postharvest salicylic acid dip; FF = preharvest Guomantian foliar fertilizer spray; SA = postharvest salicylic acid dip; Contral = preharvest and postharvest were treated with fresh water.

The total phenolic content of panzao in each treatment group significantly decreased after 14 d of storage (Figure 5B). The foliar fertilizer spray treatment improved the total phenol content of panzao, but the difference compared with the control group was not statistically significant ($p > 0.05$). The total phenolic content of panzao in the control group was lower than those in the other treatment groups from day 21 to day 63 of storage, whereas the total phenolic content of jujube fruit in the FF+SA treatment group was higher than those in the other treatment groups. At the end of the storage period, the total phenolic contents of the panzao in the FF+SA, FF, SA, and control treatments were 0.90, 0.66, 0.74, and 0.53 mg g^{-1}, respectively, with significant differences ($p < 0.05$) among the treatment groups. The results indicated that preharvest foliar fertilizer spray combined with postharvest salicylic acid treatment delayed the decline in the total phenolic content of panzao during storage.

The flavonoid content in panzao from the different treatment groups exhibited an increasing trend (Figure 5C). Foliar fertilizer spraying had no significant effect on the flavonoids in postharvest panzao ($p > 0.05$). After 63 days of storage, the flavonoid contents of the FF+SA, FF, SA, and control treatment groups of panzao were 0.39 mg g^{-1}, 0.44 mg g^{-1}, 0.44 mg g^{-1}, and 0.39 mg g^{-1}, respectively, which were increases of 1.83%, 14.73%, 17.64%, and 1.99%, respectively relative to those on day 0 of storage. After storage, the flavonoid contents of panzao were higher in the FF and SA treatment groups than in the FF+SA and control treatment groups.

During storage, the overall trend of the SP content in the panzao of the different treatment groups decreased. The SP content of panzao in the control group decreased sharply, reaching the lowest value of 0.89 mg g^{-1} at day 42. By the end of storage, the SP contents of FF+SA, FF, SA, and control treatment groups were 1.20, 1.27, 1.18, and 1.15 mg g^{-1}, respectively, which indicated that foliar fertilizer spray treatment and postharvest salicylic acid treatment were both effective in delaying the decline of SP contents of panzao during storage.

3.5. Antioxidant Activity

The scavenging rate of DPPH and ABTS radicals by the ethanol extract of panzao in each treatment group decreased gradually with the extension of storage time (Figure 6A,B), indicating that the fruit of panzao gradually oxidized and aged and that the free radical scavenging ability weakened, which was related to a decrease in antioxidant substances such as AsA and total phenols in the fruit. However, the scavenging rates of DPPH and ABTS radicals by the panzao ethanol extract in the FF+SA and FF treatment groups were higher than those in the SA and control treatment groups. At the end of the storage period, the scavenging rates of DPPH and ABTS radicals by the ethanol extract of panzao in all treatment groups was in the order FF+SA > SA > FF > control, which was consistent with the results for AsA and total phenol contents in panzao. The results indicated that preharvest foliar fertilizer spray combined with postharvest salicylic acid treatment delayed the decline in antioxidant substance content during storage and maintained relatively high antioxidant activity, which is important for the maintenance of fruit quality.

3.6. Starch and Cell Wall Material

Starch maintains fruit cell expansion pressure to support the cell wall, and the hydrolysis of starch to soluble sugars causes decrease in cell tension, which plays a key role in fruit softening after ripening. The starch content of panzao in each treatment group continued to decrease with increasing storage time (Figure 7A). The decreasing trend in amylose content in salicylic acid-treated panzao was gentler in the early stage of storage than in those without salicylic acid treatment, and the rate of decrease accelerated in the later stage of storage. The results indicated that the foliar fertilizer combined with salicylic acid treatment had a positive effect on delaying the degradation of panzao during storage.

Cellulose and pectin are the main components of the fruit cell wall, and they have supportive and protective effects on cells. The cellulose content of panzao gradually decreased during storage (Figure 7B), with the greatest decrease in cellulose content in the control treatment group and the highest cellulose content at the end of storage in the FF+SA treatment group, followed by the SA and FF treatment groups. The trends in protopectin and soluble pectin contents in panzao in the different treatment groups were the same during storage. The protopectin content of the control-treated panzao decreased significantly after 7 d of storage. At the end of storage, there was a significant difference ($p < 0.05$) between the FF+SA and control treatments, but there were no differences ($p > 0.05$) between the FF and SA treatments and the control. The soluble pectin contents in the treatment groups descended in the order control > FF > SA > FF+SA, and there were significant differences ($p < 0.05$) among the treatment groups. The results indicated that preharvest foliar fertilization combined with postharvest salicylic acid treatment delayed the decline in cellulose and protopectin content during storage, thus delaying the softening process of panzao.

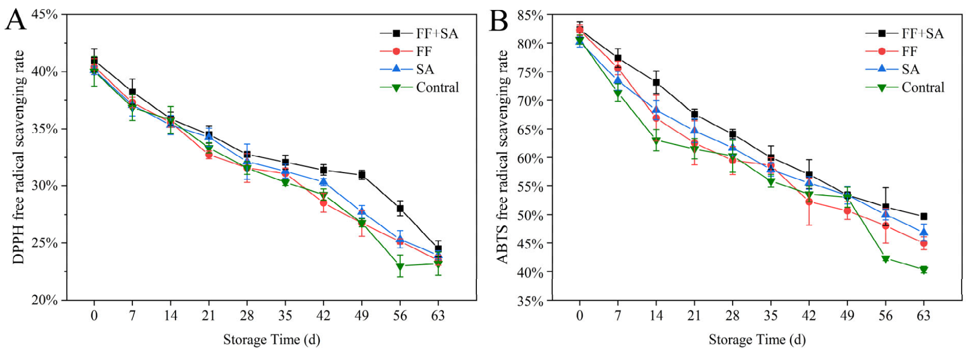

Figure 6. Antioxidant capacity of panzao during storage under different treatments. Note: FF+SA = preharvest Guomantian foliar fertilizer spray and postharvest salicylic acid dip; FF = preharvest Guomantian foliar fertilizer spray; SA = postharvest salicylic acid dip; Contral = preharvest and postharvest were treated with fresh water.

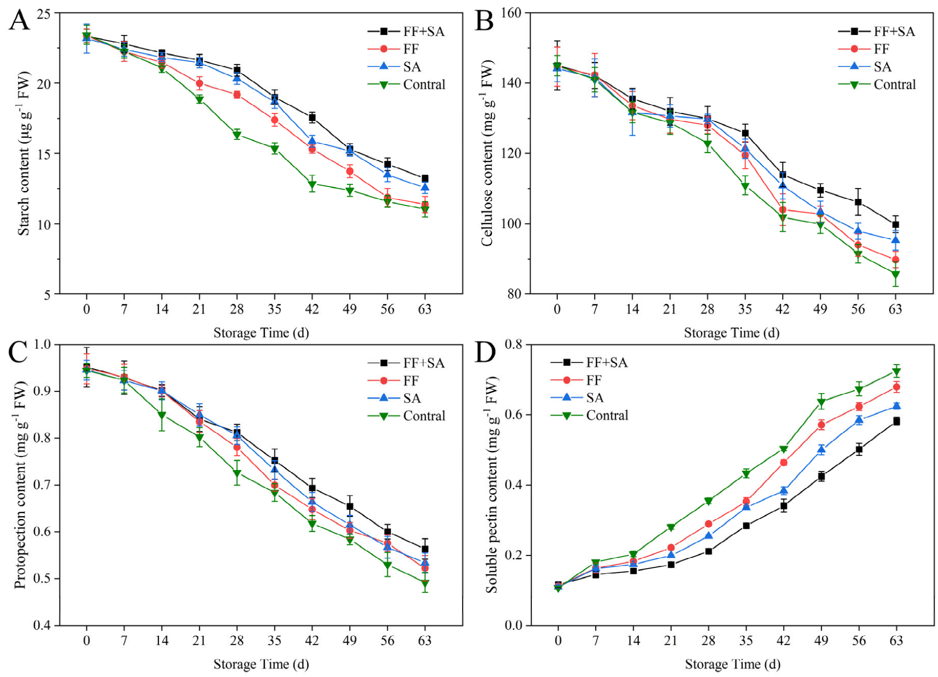

Figure 7. Contents of starch and cell wall matter of panzao during storage under different treatments. Note: FF+SA = preharvest Guomantian foliar fertilizer spray and postharvest salicylic acid dip; FF = preharvest Guomantian foliar fertilizer spray; SA = postharvest salicylic acid dip; Contral = preharvest and postharvest were treated with fresh water.

3.7. Enzyme Activities

The amylase activity of panzao increased during storage (Figure 8A,B). In general, the amylase activity of panzao treated with salicylic acid (FF+SA and SA) was lower than that of fruit not treated with salicylic acid (FF and Control). *α*-Amylase breaks the *α*-1,4 covalent bond within starch, thus degrading branched chain starch. The *α*-amylase activity in panzao increased then decreased and then increased again; the overall pattern of change was similar to that of amylase. On day 63 of storage, the amylase and *α*-amylase activities of the FF+SA-treated panzao were significantly lower than those of the other treatments ($p < 0.05$).

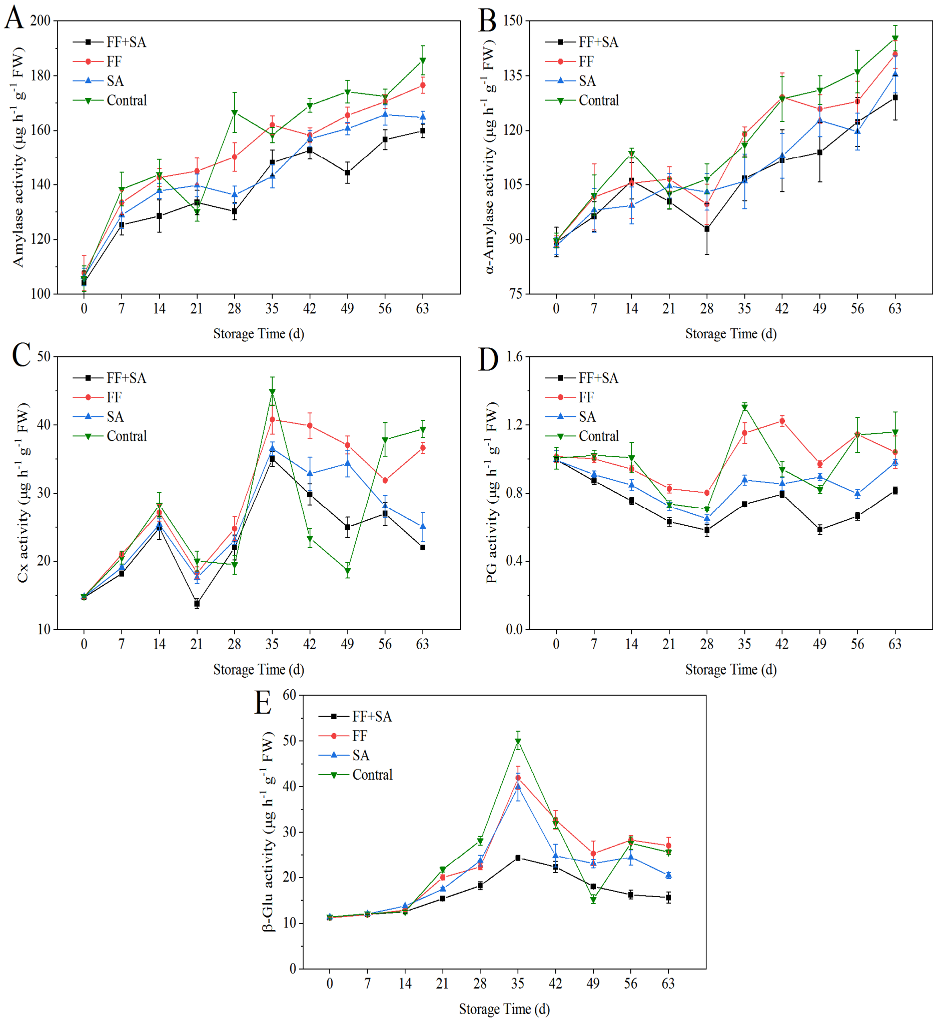

Figure 8. Softening-related enzyme activities of panzao during storage under different treatments. Note: FF+SA = preharvest Guomantian foliar fertilizer spray and postharvest salicylic acid dip; FF = preharvest Guomantian foliar fertilizer spray; SA = postharvest salicylic acid dip; Contral = preharvest and postharvest were treated with fresh water.

Cx hydrolyzes the fibrous tissues of panzao, leading to fruit softening. During storage, the Cx activity of panzao from all treatment groups fluctuated and reached a maximum on day 35, with the highest Cx activity in the control treatment group and the lowest in the FF+SA treatment group. At the end of storage, the Cx activities of the SA treatments (FF+SA and SA) were significantly lower than those of the non-SA treatments (FF and control) ($p < 0.05$), and the softening rates of the non-SA treatments (FF and control) were faster.

The PG activity of panzao followed a relatively flat trajectory during storage. The PG activities of jujube fruit treated with salicylic acid (FF+SA and SA) were lower than those of panzao without salicylic acid treatment (FF and control), indicating that salicylic acid treatment inhibited the increase in PG activity in panzao during storage. In the middle of storage, PG activity increased to some extent, but the peak in the control group appeared earlier than that in the other treatment groups, and its PG activity was significantly higher than those of the other treatment groups ($p < 0.05$). At the end of storage, the PG activity of the FF+SA treatment group was significantly lower than those of the other treatment groups ($p < 0.05$), indicating that the preharvest foliar fertilizer spray and postharvest salicylic acid treatment were beneficial in delaying the increase in PG activity during the storage of panzao.

During storage, the β-glu activity of panzao increased and then decreased; on day 35 of storage, β-glu activity of all treatment groups reached the maximum value and then decreased, but the β-glu activity of the FF+SA treatment group remained at a lower level. The preharvest foliar spray or postharvest SA treatment both delayed the elevation of β-glu activity during *Ziziphus jujuba* Mill. cv. 'Jingcang1' storage to some extent, and the combination of both treatments had a synergistic effect.

3.8. Principal Component Analysis

To comprehensively analyze the changes in quality of panzao in the different treatment groups during storage, PCA was performed on the 25 indicators measured in the experiment. Twenty-five indices were automatically divided into several principal components, and two principal components with eigenvalues greater than one and larger contribution rates were selected for analysis (Table 1). The contribution rates of the first and second principal components were 72.7% and 9.0%, respectively, and the cumulative variance contribution rate reached 81.7%, indicating that the two principal components reflected more than 80% of the information in the original jujube fruit data, which met the requirements of principal component analysis.

Table 1. Loading matrix of first two principal components.

Indicators	PC1	PC2
Firmness	0.23071	−0.03907
Weight loss	−0.22551	−0.08505
Transverse diameter loss rate	−0.23215	0.03392
Longitudinal diameter loss rate	−0.22527	0.00497
L^* value	0.22644	0.01097
a^* value	−0.22678	−0.00648
b^* value	0.22127	0.09139
TSS	−0.08195	0.50447
TA	0.13174	−0.41801
SS	−0.06772	0.49485
AsA	0.2239	0.0589
Total phenol	0.23044	0.02615
Flavonoid	−0.06574	0.07779
SP	0.19798	−0.09027
ABTS free radical scavenging rate	0.22943	−0.02986
DPPH free radical scavenging rate	0.22988	8.8183×10^{-5}
Starch	0.22905	0.07139
Cellulose	0.23061	0.05648
Protopectin	0.23136	0.01815
Soluble pectin	−0.22685	−0.10698
Total amylase activity	−0.21989	0.00355
α-amylase activity	−0.2188	−0.13681
Cx	−0.1669	−0.02606
PG	−0.04918	−0.49871
β-glu	−0.14691	0.00473

The protopectin, cellulose, and total phenol contents, ABTS, DPPH radical scavenging rate, AsA content, starch content, hardness, L^* value, b^* value, SP content, and TA content were located on the right side of PC1 which indicates a positive correlation between the above indicators and PC1 (Figure 9). The TSS content, SS content, b^* value, flavonoid content, cross-longitudinal diameter loss rate, L^* value, AsA content, total phenolic content, DPPH radical scavenging rate, starch, cellulose, protopectin content, total amylase activity, and β-glu activity were located on the right side of PC2 which indicates a positive correlation between these indicators and PC2.

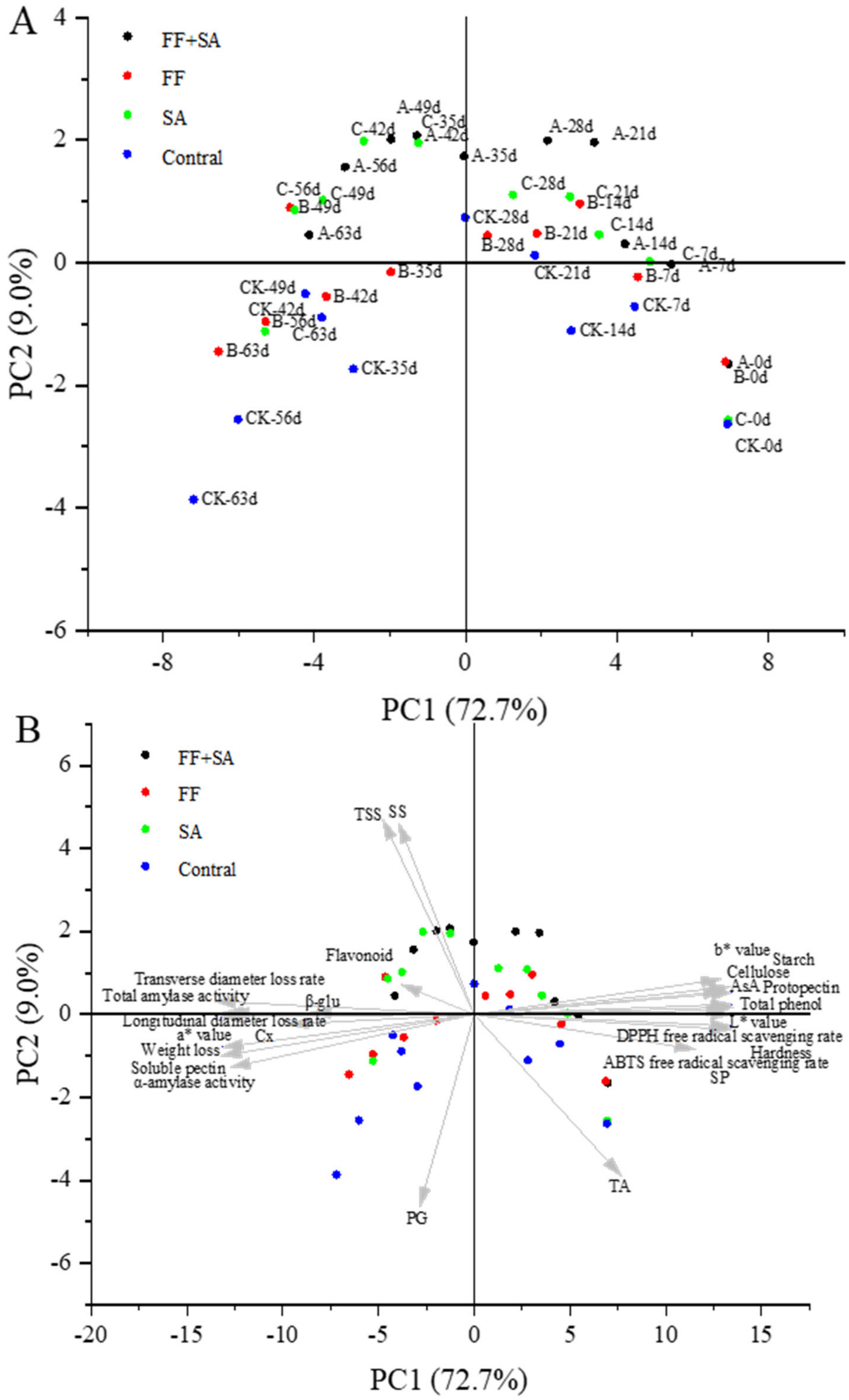

Figure 9. PCA loading plot of panzao with different treatments. Note: FF = preharvest Guomantian foliar fertilizer spray; SA = postharvest salicylic acid dip. The dots in the figure represent the scores; the arrows represent the loads; the numbers represent the storage times of different treatment groups. Score plot (**A**); Loading plot (**B**).

The data points of samples from different storage periods of panzao were primarily distributed in PC1. The data points were relatively discrete between the foliar fertilizer treatment and non-foliar fertilizer treatment groups on day 0 of storage, indicating that foliar fertilizer treatment improved the postharvest quality of the fruit. The data points for each treatment group gradually moved from the fourth quadrant to the third quadrant in a counterclockwise direction as the storage time increased, indicating that the quality of the panzao in each treatment group changed significantly. Changes in TSS content, SS content, protopectin content, cellulose content, total phenolic content, ABTS, DPPH radical scavenging rate, AsA content, and starch content contributed more to the variation in the data points of the panzao samples. During the storage period, the data points of the FF+SA treatment group became the least discrete and located closer to the positive direction of PC1 and PC2. At 63 days of storage, only the FF+SA treatment group was located in the second quadrant, while all other treatment groups were located in the third quadrant. The scores of data points in PC1 and PC2 for each treatment group descended in the following order: FF+SA > SA > FF > control, indicating that the combination of preharvest foliar fertilizer spray with postharvest salicylic acid treatment was the most effective treatment in preserving the freshness of panzao.

4. Discussion

Most terrestrial plants rely on their roots to absorb nutrients, but the leaves of plants are also capable of absorbing exogenous substances such as gases, nutrients, and pesticides. The leaves as well as the roots can absorb water while absorbing nutrients into the plant body [19]. Previous studies have found that foliar fertilization prevented nutrient fixation in the soil and exhibited high and effective nutrient delivery, thus increasing the nutrient content in the fruit and improving fruit quality [10,12,20]. Salicylic acid is a natural phytohormone that is generally safe for fruit [21,22] and can replace synthetic preservatives to reduce their harmful effects [23,24]. Preharvest spraying [25], postharvest fumigation [26], postharvest maceration [27,28], and postharvest coating [29] with salicylic acid are widely used for fruit preservation. Salicylic acid reduces postharvest losses in horticultural crops by regulating plant-related physiological and metabolic processes [30,31]. In this study, we found that the content of soluble solids, soluble sugars, ascorbic acid, and other nutrients in jujube fruit significantly increased after foliar fertilizer spray treatment, which effectively inhibited the weight loss rate, firmness decrease, nutritional quality, and antioxidant properties during the storage of panzao and maintained the quality of the fruit.

Starch content is an important indicator of agronomic properties, eating quality, maturity, and storability of fruit and vegetable products [32]. During storage, starch is constantly hydrolyzed by amylase, which acts on the non-reducing end of starch to produce monosaccharides or oligosaccharides. Changes in amylase activity significantly influence the rate of starch hydrolysis [17,32]. The continuous hydrolysis of starch resulted in a phase increase in soluble solids and soluble sugar content in panzao, which were continuously depleted during storage; however, treatment with foliar fertilizer and salicylic acid delayed the decrease in starch content in the fruit.

Firmness is an important factor determining fruit storage life and quality of fruit [33]. The decrease in firmness of fruit and vegetables is associated with the degradation of pectin and cellulose network structures in the cell walls [34]. In the present study, this degradation of cell wall components led to a decrease in the strength of the cell wall, and consequently, to a decrease in the firmness and softening of panzao, similar to the results of previous studies [35]. PG enzymes are cell wall-degrading enzymes that destroy the cell wall structure by degrading macromolecules, leading to further softening [34]. Hydrolases primarily hydrolyze the non-reducing terminal β-D-glycosidic bond to generate β-D-glucose [18]. Cellulases degrade cellulose in the cellulose–hemicellulose network of the fruit cell wall [18,36]. The degradation of cell wall components associated with fruit softening is precisely regulated by the relevant cell wall hydrolases [37].

In the present study, the protopectin and cellulose contents of panzao continuously decreased, and the soluble pectin content gradually increased with storage. These observations indicate that the degradation of cell wall components such as protopectin and cellulose had an important effect on the softening of panzao during storage. Salicylic acid treatment significantly inhibited the degradation of protopectin, cellulose, and related enzymes in panzao, effectively delaying the softening of the fruit during storage. Several similar studies have shown that salicylic acid treatment delays the softening of pear [38], apricot [39], and tomato [22] fruit during storage. Principal component analysis showed that foliar fertilizer spray treatment improved the quality of panzao at harvest, whereas salicylic acid treatment delayed the quality decline of panzao during storage. Both foliar fertilizer spray and salicylic acid treatments were effective in maintaining fruit quality during panzao storage compared with that of the control group, and the combination of both treatments was more effective. Yang et al. (2022) [28] were also able to preserve the freshness of winter jujube using a low-concentration of salicylic acid (3 mmol L^{-1}). However, since the experimental setup of this study was different (i.e., the jujube varieties used, sample treatment time, storage conditions, etc.,), the effectiveness of low-concentration salicylic acid treatment remains to be investigated in the context of preserving panzao.

5. Conclusions

Preharvest foliar fertilization increased the accumulation of nutrients during the growth of panzao and improved the quality of panzao, while delaying the decline in quality during storage. Postharvest salicylic acid treatment inhibited the reddening of panzao and maintained sugar and organic acid content. Salicylic acid maintained the antioxidant content of ascorbic acid, total phenols, and other antioxidant substances to delay the oxidative aging of panzao and reduced the degradation of starch, cellulose, pectin, and other macromolecules by regulating the activity of starch and cell wall-degrading enzymes to delay the softening process of panzao. The combination of the two treatments had a synergistic effect. In conclusion, preharvest foliar fertilizer spraying combined with postharvest salicylic acid treatment has the potential to maintain the quality of panzao. The application of this preservation technology can not only effectively extend the storage and preservation period of panzao and drive local economic development but is also of great significance in enriching research on other fresh fruit preservation systems.

Author Contributions: Conceptualization, Y.T. and X.Z.; Methodology, Y.G. and B.L.; Resources, X.Z.; Data curation, Y.G., B.L. and P.Z.; Writing—original draft, Y.G., L.Y. and B.L.; Writing —review and editing, P.Z., X.Z. and Y.T.; Supervision, P.Z.; Funding acquisition, X.Z.; Y.G. and B.L. contributed equally to this work. All authors have read and agreed to the published version of the manuscript.

Funding: This research was provided for by Special project for basic scientific activities of non-profit institutes supported the government of Xinjiang Uyghur Autonomous Region (KY2022027) and the Earmarked Fund of Xinjiang Jujube Industrial Technology System (XJCYTX-01).

Data Availability Statement: The datasets used and/or analyzed in the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest: Author Binbin Li was employed by the company Beijing Weishiyuan Food Technology Co. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. Geng, Y.; Zhao, X.M.; Tan, Y.P.; Bao, L.W.; Xie, N.B.; Zhang, T.; Meng, Y.N. Effect of salicylic acid combined with microporous plastic bag on quality of *Ziziphus jujube* Mill. cv. 'Jingcang1' during storage. *Sci. Technol. Food Ind.* **2023**, *44*, 338–346.
2. Zhang, W.L.; Pan, Y.G.; Jiang, Y.M.; Zhang, Z.K. Advances in gas fumigation technologies for postharvest fruit preservation. *Crit. Rev. Food Sci. Nutr.* **2023**, 1–20. [CrossRef] [PubMed]
3. Reche, J.; García-Pastor, M.E.; Valero, D.; Hernández, F.; Almansa, M.S.; Legua, P.; Amorós, A. Effect of modified atmosphere packaging on the physiological and functional characteristics of Spanish jujube (*Ziziphus jujuba* Mill.) cv 'Phoenix' during cold storage. *Sci. Hortic.* **2019**, *258*, 108743. [CrossRef]
4. Lu, X.G.; Meng, G.L.; Jin, W.G.; Gao, H. Effects of 1-MCP in combination with Ca application on aroma volatiles production and softening of 'Fuji' apple fruit. *Sci. Hortic.* **2018**, *229*, 91–98. [CrossRef]

5. Nhi, T.T.Y.; Phat, D.T.; Truong, L.D.; Tri Nhut, P.; Long, H.B.; Quyen, T.N.; Giang, B.L. Antimicrobial activities of flavedo peel extract and its feasibility in the development of bio-based pectin coating film for fruit preservation. *J. Food Saf.* **2022**, *42*, e13013. [CrossRef]
6. Khurshid, T.; McNeil, D.L.; Trought, M.C.T. Effect of foliar-applied gibberellins and soil-applied paclobutrazol on fruit quality at harvest and during storage of 'Braebum' apples growing under a high-density planting system. *N. Z. J. Crop Hortic. Sci.* **1997**, *25*, 59–65. [CrossRef]
7. Yin, N.; Mu, L.; Liang, Y.L.; Hao, W.L.; Yin, H.F.; Zhu, S.M.; An, X.J. Effects of foliar selenium fertilizer on fruit yield, quality and selenium content of three varieties of *Vitis vinifera*. *Yingyong Shengtai Xuebao* **2020**, *31*, 953–958. [CrossRef]
8. Kumar, A.; Singh, N.; Misra, K.K.; Nirgude, V. Effect of foliar spray of calcium chloride and boric acid on shelf-life of guava. *Indian J. Hortic.* **2017**, *74*, 586–590. [CrossRef]
9. Ali, I.; Abbasi, N.A.; Hafiz, I. Application of calcium chloride at different phenological stages alleviates chilling injury and delays climacteric ripening in peach fruit during low-temperature storage. *Int. J. Fruit Sci.* **2021**, *21*, 1040–1058. [CrossRef]
10. Zydlik, Z.; Zydlik, P.; Kafkas, N.E.; Yesil, B.; Cieśliński, S. Foliar application of some macronutrients and micronutrients improves yield and fruit quality of Highbush Blueberry (*Vaccinium corymbosum* L.). *Horticulturae* **2022**, *8*, 664. [CrossRef]
11. Prakash, R.; Jokhan, A.D.; Singh, R. Effects of foliar application of gibberellic acid, boric acid and sucrose on noni (*M. citrifolia* L.) fruit growth and quality. *Sci. Hortic.* **2022**, *301*, 111098. [CrossRef]
12. Moale, C.; Ghiurea, M.; Sîrbu, C.E.; Somoghi, R.; Cioroianu, T.M.; Faraon, V.A.; Lupu, C.; Trică, B.; Constantinescu-Aruxandei, D.; Oancea, F. Effects of siliceous natural nanomaterials applied in combination with foliar fertilizers on physiology, yield and fruit quality of the apricot and peach trees. *Plants* **2021**, *10*, 2395. [CrossRef] [PubMed]
13. Koo, Y.M.; Heo, A.Y.; Choi, H.W. Salicylic acid as a safe plant protector and growth regulator. *Plant Pathol. J.* **2020**, *36*, 1–10. [CrossRef] [PubMed]
14. Chen, C.J.; Sun, C.C.; Wang, Y.H.; Gong, H.S.; Zhang, A.D.; Yang, Y.Q.; Guo, F.J.; Cui, K.B.; Fan, X.G.; Li, X.L. The preharvest and postharvest application of salicylic acid and its derivatives on storage of fruit and vegetables: A review. *Sci. Hortic.* **2023**, *312*, 111858. [CrossRef]
15. Geng, Y.; Zhao, X.M.; Tan, Y.P.; Wang, Y.H.; Lin, J.; Fan, D.Y. Effects of Different Foliar Fertilizer Treatments on the Growth and Storability of *Ziziphus Jujube* Mill. cv. 'Jingcang1'. *Soil Fertil. Sci. China* **2023**, *2*, 186–194.
16. Geng, Y.; Zhao, X.M.; Tan, Y.P.; Fan, D.Y.; Li, B.B.; Ma, S.J. Effects of harvest maturity on storage quality and antioxidative capacity of *Ziziphus jujube* Mill. cv. 'Jingcang1'. *Food Ferment. Ind.* **2023**, *49*, 269–275. [CrossRef]
17. Cao, J.K.; Jiang, W.B.; Zhao, Y.M. *Guidance of Postharvest Physiological and Biochemical Experiment of Fruits and Vegetables*; China Light Industry Press: Beijing, China, 2007; pp. 78–82,85–88. Available online: https://max.book118.com/html/2019/0824/5242233104002121.shtm (accessed on 1 February 2023).
18. Liu, Y.N.; Wang, Y.; Bi, Y.; Li, S.E.; Jiang, H.; Zhu, Y.; Wang, B. Effect of preharvest acetylsalicylic acid treatments on ripening and softening of harvested muskmelon fruit. *Sci. Agric. Sin.* **2017**, *50*, 1865–1875. [CrossRef]
19. Pritts, M.P.; Reickenberg, R.L. Dynamics of nutrient uptake from foliar fertilizers in red raspberry (*Rubus idaeus* L.). *J. Am. Soc. Hortic. Sci.* **1996**, *121*, 158–163. [CrossRef]
20. Tóth, B.; Moloi, M.J.; Mousavi, S.M.N.; Illés, Á.; Bojtor, C.; Szőke, L.; Nagy, J. The evaluation of the effects of Zn, and amino acid-containing foliar fertilizers on the physiological and biochemical responses of a Hungarian fodder corn hybrid. *Agronomy* **2022**, *12*, 1523. [CrossRef]
21. Fan, X.; Du, Z.; Cui, X.; Ji, W.; Ma, J.; Li, X.; Wang, X.; Zhao, H.; Liu, B.; Guo, F.; et al. Preharvest methyl salicylate treatment enhance the chilling tolerance and improve the postharvest quality of apricot during low temperature storage. *Postharvest Biol. Technol.* **2021**, *177*, 111535. [CrossRef]
22. Kumar, N.; Tokas, J.; Raghavendra, M.; Singal, H.R. Impact of exogenous salicylic acid treatment on the cell wall metabolism and ripening process in postharvest tomato fruit stored at ambient temperature. *Int. J. Food Sci. Technol.* **2021**, *56*, 2961–2972. [CrossRef]
23. Hanif, A.; Ahmad, S.; Shahzad, S.; Liaquat, M.; Anwar, R. Postharvest application of salicylic acid reduced decay and enhanced storage life of papaya fruit during cold storage. *Food Meas.* **2020**, *14*, 3078–3088. [CrossRef]
24. Tang, Y.; Kuang, J.; Wang, F.; Chen, L.; Hong, K.; Xiao, Y.; Xie, H.; Lu, W.; Chen, J. Molecular characterization of *PR* and *WRKY* genes during SA- and MeJA-induced resistance against *Colletotrichum musae* in banana fruit. *Postharvest Biol. Technol.* **2013**, *79*, 62–68. [CrossRef]
25. Gomes, E.P.; Vanz Borges, C.V.; Monteiro, G.C.; Filiol Belin, M.A.; Minatel, I.O.; Pimentel Junior, A.; Tecchio, M.A.; Lima, G.P.P. Preharvest salicylic acid treatments improve phenolic compounds and biogenic amines in 'Niagara Rosada' table grape. *Postharvest Biol. Technol.* **2021**, *176*, 111505. [CrossRef]
26. Wang, L.B.; Li, X.H.; Bai, J.H.; Luo, H.B.; Jin, C.H.; Hui, J.; Yu, Z.F. Residual impact of methyl salicylate fumigation at the breaker stage on C6 volatile biopathway in red tomato fruit. *J. Food Process. Preserv.* **2017**, *41*, 13285. [CrossRef]
27. Wei, Y.; Liu, Z.; Su, Y.; Liu, D.; Ye, X. Effect of salicylic acid treatment on postharvest quality, antioxidant activities, and free polyamines of asparagus. *J. Food Sci.* **2011**, *76*, S126–S132. [CrossRef] [PubMed]
28. Yang, W.T.; Kang, J.W.; Liu, Y.X.; Guo, M.R.; Chen, G.G. Effect of salicylic acid treatment on antioxidant capacity and endogenous hormones in winter jujube during shelf life. *Food Chem.* **2022**, *397*, 133788. [CrossRef]

29. Sayyari, M.; Esna-Ashari, M.; Tarighi, T.H. Impacts of salicylic acid, chitosan, and salicyloyl chitosan on quality preservation and microbial load reduction in strawberry fruits during cold storage. *J. Food Process. Preserv.* **2022**, *46*, e16710. [CrossRef]
30. Luo, Z.; Chen, C.; Xie, J. Effect of salicylic acid treatment on alleviating postharvest chilling injury of 'Qingnai' plum fruit. *Postharvest Biol. Technol.* **2011**, *62*, 115–120. [CrossRef]
31. Cai, H.; Yuan, X.; Pan, J.; Li, H.; Wu, Z.; Wang, Y. Biochemical and proteomic analysis of grape berries (*Vitis labruscana*) during cold storage upon postharvest salicylic acid treatment. *J. Agric. Food Chem.* **2014**, *62*, 10118–10125. [CrossRef]
32. Li, J.Z.; Min, D.D.; Li, Z.L.; Fu, X.D.; Zhao, X.M.; Wang, J.H.; Zhang, X.H.; Li, F.J.; Li, X.A.; Guo, Y.Y. Regulation of sugar metabolism by methyl jasmonate to improve the postharvest quality of tomato fruit. *J. Plant Growth Regul.* **2022**, *41*, 1615–1626. [CrossRef]
33. Gabioud Rebeaud, S.; Cioli, L.; Cotter, P.-Y.; Christen, D. Cultivar, maturity at harvest and postharvest treatments influence softening of apricots. *Postharvest Biol. Technol.* **2023**, *195*, 112134. [CrossRef]
34. Ren, Y.Y.; Sun, P.P.; Wang, X.X.; Zhu, Z.Y. Degradation of cell wall polysaccharides and change of related enzyme activities with fruit softening in *Annona squamosa* during storage. *Postharvest Biol. Technol.* **2020**, *166*, 111203. [CrossRef]
35. Zhao, Y.T.; Zhu, X.; Hou, Y.Y.; Wang, X.Y.; Li, X.H. Effects of nitric oxide fumigation treatment on retarding cell wall degradation and delaying softening of winter jujube (*Ziziphus jujuba* Mill. cv. cv. Dongzao) fruit during storage. *Postharvest Biol. Technol.* **2019**, *156*, 110954. [CrossRef]
36. Shi, Z.J.; Yang, H.Y.; Jiao, J.Y.; Wang, F.; Lu, Y.Y.; Deng, J. Effects of graft copolymer of chitosan and salicylic acid on reducing rot of postharvest fruit and retarding cell wall degradation in grapefruit during storage. *Food Chem.* **2019**, *283*, 92–100. [CrossRef]
37. Brummell, D.A. Cell wall disassembly in ripening fruit. *Funct. Plant Biol.* **2006**, *33*, 103–119. [CrossRef]
38. Sinha, A.; Gill, P.P.S.; Jawandha, S.K.; Grewal, S.K. Composite coating of chitosan with salicylic acid retards pear fruit softening under cold and supermarket storage. *Food Res. Int.* **2022**, *160*, 111724. [CrossRef]
39. Li, Y.L.; He, H.; Hou, Y.Y.; Kelimu, A.; Wu, F.; Zhao, Y.T.; Shi, L.; Zhu, X. Salicylic acid treatment delays apricot (*Prunus armeniaca* L.) fruit softening by inhibiting ethylene biosynthesis and cell wall degradation. *Sci. Hortic.* **2022**, *300*, 111061. [CrossRef]