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Research Article

Effects of *Sporidiobolus pararoseus* Y16 on Postharvest Blue Mold Decay and the Defense Response of Apples

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The efficacy of *Sporidiobolus pararoseus* Y16 in controlling postharvest blue mold caused by *Penicillium expansum* on apples and the defense response involved were evaluated. The results suggested that the decay incidence of blue mold of apples treated by *S. pararoseus* Y16 was significantly reduced compared with the control. *In vitro* testing indicated that germination of spores and germ tube length of *P. expansum* were markedly inhibited by *S. pararoseus* Y16. Meanwhile, polyphenol oxidase (PPO), peroxidase (POD), phenylalanine ammonia lyase (PAL), and catalase (CAT) activities and several pathogenesis-related (PR) gene expression levels (including *PR3, PR4, PR5,* and *PR9*) were determined. In apples, the activities of PPO, POD, CAT, and PAL were significantly induced by *S. pararoseus* Y16 treatment compared with the control fruits. The relative expression levels of *PR3* and *PR4* were significantly induced at 4 and 6 d, while *PR5* was significantly induced at 4 and 6 d and *PR9* was significantly induced at 4 d. Therefore, the reduction in apple fruit decay by *S. pararoseus* Y16 treatment could be related to the increased activities of related enzymes and proteins involved in the defense against pathogens, which suggest that *S. pararoseus* Y16 is a potential antagonistic yeast.

1. Introduction

In general, postharvest losses of fruits and vegetables pose enormous problem worldwide [1], ranging from 10 to 30% in developed countries and even more losses in developing countries [2]. Apples are among the most commonly consumed fruits, which provided fresh ones throughout the year [3] and are one of the most important fruits produced in China and other countries. A significant proportion of postharvest losses are attributed to microbiological diseases caused by fungal pathogens limiting the storage life of apples. Blue mold decay caused by *Penicillium expansum* and grey mold decay caused by *Botrytis cinerea* are two of the most important postharvest diseases of apples [4, 5], which lead to serious economic losses in storage and transportation, especially, blue mold decay caused by *P. expansum*, which may lead to patulin accumulation in apples.

There are many methods to control the postharvest diseases and increase the shelf life of fruits. Nowadays, the use of synthetic fungicides can effectively control pathogens of postharvest fruits and vegetables as the primary strategy. However, there is an increased concern about the potential harmful effects on human health and environment by fungicide residues [6]. Therefore, under the current circumstances, it is necessary to develop alternative methods for synthetic chemicals.

Biological control with antagonistic yeasts has emerged as a promising way to reduce synthetic fungicide usage [7]. Many microbial antagonists have been reported to control several pathogens on different fruits and vegetables [8]. In

this regard, the use of antagonistic yeasts was reported to have a significant effect on blue mold decay in apples, including *Pichia caribbica* [4], *Pantoea agglomerans* [9], *Rhodotorula mucilaginosa* [10], and *Rhodosporidium paludigenum* [11]. Although several antagonistic yeasts were reported to have significant effect on blue mold decay of apples, the effectiveness of biological control also needs to be further improved. *Sporidiobolus pararoseus* Y16, which was isolated by our laboratory from the surfaces of grape leaves picked in unsprayed orchards [12], could significantly inhibit *Aspergillus niger* decay of table grapes [13], while there is no information regarding studying biocontrol of postharvest diseases of apple fruits by *S. pararoseus* Y16, and the mechanism of *S. pararoseus* controlling of postharvest diseases is not yet clear.

In this paper, *S. pararoseus* Y16 which was isolated by our laboratory from the surfaces of grape leaves picked in unsprayed orchards was chosen as the study subject. The object of this study was to evaluate the efficacy of *S. pararoseus* against *P. expansum* infection in apples and determine (1) the efficacy of *S. pararoseus* Y16 in controlling of blue mold on apples, (2) the population dynamics of *S. pararoseus* Y16 in apple wounds, (3) the effectiveness of *S. pararoseus* Y16 against pathogens *in vitro*, and (4) the effect of *S. pararoseus* Y16 on activities of defense-related enzymes and related gene expressions levels.

2. Materials and Methods

2.1. Antagonist. *S. pararoseus* Y16 was isolated by our laboratory from the surfaces of grape leaves picked in unsprayed orchards, Zhenjiang, China, and maintained at 4°C on nutrient yeast dextrose agar (NYDA: 8 g/L nutrient broth, 5 g/L yeast extract, 10 g/L dextrose, and 20 g/L agar) [14]. The yeast strain was preserved in the China General Microbiological Culture Collection Center, and the number was CGMCC 2.5351. The yeast was grown in 250 mL Erlenmeyer flasks containing 50 mL of nutrient yeast dextrose broth (NYDB: 8 g/L nutrient broth, 5 g/L yeast extract, and 10 g/L dextrose). Flasks were incubated on a rotary shaker at 180 rpm for 20 h at 28°C. Following incubation, cells were centrifuged at 7500 ×g for 10 min and washed twice with sterile distilled water in order to remove the growth medium. Cell pellets were resuspended in sterilized distilled water and adjusted to the required concentration by a hemocytometer (XB-K-250, Jianling Medical Device Company, Danyang, China). Cell concentration was then adjusted as needed for different experiments.

2.2. Fungal Pathogen. *P. expansum* (preserved in the CGMCC, number 3.3703) was isolated from decayed apples and inoculated on potato dextrose agar medium (PDA: 200 mL of extract from boiled potatoes, 20 g dextrose, 20 g agar, and 800 mL distilled water). PDA plates were incubated at 25°C for 7 days and then transferred to 4°C before use. Spore suspensions were prepared by removing the spores from the sporulating edges of PDA culture with inoculating loop and suspended in sterile distilled water. Spore concentrations were adjusted as required to 5×10^4 spores/mL in sterile distilled water by a hemocytometer (XB-K-250, Jianling Medical Device Co., Danyang, China).

2.3. Fruits. Apples (*M. domestica* Borkh, cv. Fuji) were harvested at commercial maturity from an orchard in Yantai, Shandong province, and selected for uniformity of size, ripeness, and absence of apparent injury or infection. Fruits were selected randomly and sterilized with 0.1% sodium hypochlorite for 1 min, washed with tap water, and allowed to air-dry at room temperature.

2.4. Effect of S. pararoseus on Blue Mold of Apple Fruit. Three uniform wounds (5 mm diameter and 3 mm depth) were made at the equator of each apple fruit using a sterile borer. 30 μL of cell suspensions of *S. pararoseus* Y16 at 10^6, 10^7, 10^8, and 10^9 cells/mL were pipetted into each wound site, respectively, and sterile distilled water was used as the control. Two hours later, 30 μL of suspension of *P. expansum* (5×10^4 spores/mL) was inoculated into each wound. The apples were stored in enclosed plastic trays at 20°C with 95% RH. The decay incidence and lesion diameter of apples were recorded after 6 days of incubation. There were three replicates of twelve fruits for each treatment. All treatments were arranged in a randomized complete block design, and the experiment was conducted twice.

2.5. Population Dynamics of S. pararoseus in Apple Wounds. Apples were prepared and wounded as described above. The method to evaluate the population studies of *S. pararoseus* Y16 in apple wounds was according to [15] with some modifications. Each wound on apple was inoculated with 30 μL of *S. pararoseus* Y16 (10^8 cells/mL), and then apples were stored at 20°C and 4°C, respectively. The tissue of apple wound was removed with a sterile knife and macerated in 50 mL of sterile 0.85% sodium chloride solution and quartz sand in a mortar. The amount of *S. pararoseus* Y16 was recovered from the wounds after incubation at 20°C for 0 (1 h after treatment), 1, 2, 3, 4, 5, 6, 7, and 8 days and at 4°C for 0 (1 h after treatment), 3, 6, 9, 12, 15, 18, 21, and 23 days, respectively. 10-fold serial dilutions were made and 100 μL of each dilution was spread by coated rod on the NYDA plates, stored in incubator at 28°C for 48 hours, and then expressed as the $\log_{10}$CFU per wound. There were three replications of each treatment, and the entire experiment was repeated twice.

2.6. Effects of S. pararoseus Y16 on Spore Germination and Germ Tube Length of P. expansum In Vitro. Spores of *P. expansum* and *S. pararoseus* suspensions were prepared as described above. 100 mL Erlenmeyer flasks with 20 mL PDB were prepared with the treatment of 1 mL suspension of *S. pararoseus* Y16 (10^8 cells/mL) and 1 mL of sterile distilled water was added as the control; 1 mL *P. expansum* spore suspension (adjusted to the final concentration of 10^6 spores/mL) was added to each PDB flask, respectively. All flasks were incubated in rotary shaker at 75 rpm and cultured at 28°C for 12 h. The effects of *S. pararoseus* Y16 on spore germination and germ tube length of *P. expansum* were measured according to the method described by [14]. There were three replicates per treatment and the experiment was conducted twice.

Table 1: Primer design of pathogenesis-related genes in apples.

Unigenes	Forward primer(5′to 3′) Reverse primer(5′to 3′)	Gene description
LOC 103419198	F: TGACACATACTGCGATACAAG R: ACAGGACGGACATTGGTTAT	Chitinase 4-like *(PR-3)*
LOC 103434169	F: GCCACATACCACCTCTAC R: ATTCTCACCGTTGCTTGA	Pathogenesis-related protein *(PR-4)*
LOC 103426173	F: ATGGTCTGGTCGCTTCTG R: GTCAACAAGGCTAACATCGTA	Thaumatin-like protein 1a *(PR-5)*
LOC 103403867	F:TTGTCAGAGATGCGGTCACTAAGAA R: AACTGCGTCAACGGCTGCTT	Peroxidase 51-like *(*PR-9*)*
MdActin	F: CCCAAAGGCTAATCGGGAGAAA R: ACCACTGGCGTAGAGGGAAAGA	Actin

2.7. Effects of S. pararoseus on Activities of Defense-Related Enzymes of Apples

Fruit Treatment. Fruit samples were treated as described above. The wounds were then treated with 30 μL suspension of *S. pararoseus* Y16 (10^8 cells/mL) or sterile distilled water as the control. After air drying, the apple fruits were stored in enclosed plastic trays at 20°C with 95% RH. In order to measure the activities of defense-related enzymes, the tissue surrounding each apple wound was collected at 0 (1 h after treatment), 1, 2, 3, 4, 5, and 6 days after treatment. There were three replicates per treatment and the experiment was conducted twice.

Supernatant Extract. Two grams of tissue sample was ground with 10 mL of cold (4°C) sodium phosphate buffer (50 mmol/L, pH 7.8) containing 1.33 mmol/L EDTA and 1% polyvinyl pyrrolidone (PVP) for peroxidase (POD), polyphenol oxidase (PPO), and catalase (CAT). The homogenates were then centrifuged at 12000 rpm for 15 min at 4°C and the supernatants were assayed. Extraction procedures were conducted at 4°C.

Analysis of Enzyme Activities of Apple Fruits. POD activity was assayed according to the method described by [1], and one unit was defined as an increase in A_{470} of 0.01 per minute. PPO activity was measured following the method described by [16], and one unit of the PPO activity was defined as the amount of the enzyme extracts producing an increase of A_{398} by 0.01 in 1 min. CAT activity was determined following the method of [17], and one unit was defined as the change of A_{240} in 0.01 absorbance units per minute. The PAL activity was assayed as the method described by [18], and one unit of the PAL activity was defined as the formation of 1 μg of cinnamic acid equivalents per hour. The POD, PPO, CAT, and PAL activities were expressed as U per g fresh tissue weight (U/g FW).

2.8. RNA Extraction and Real-Time-Quantitative Polymerase Chain Reaction (RT-qPCR). Apples were prepared and wounded as described above to evaluate the effect of *S. pararoseus* Y16 on activities of defense-related enzymes of apples. The apple tissue samples were removed by cold sterile knife without *S. pararoseus* Y16; three grams of tissue sample was milled using liquid nitrogen; RNA was extracted using UNlQ-10 Column Trizol Total RNA Extraction Reagent (Sangon Biotech (Shanghai, China) Co., Ltd.) according to the instruction of the manufacturer. About 1000 ng of mRNA was used for cDNA synthesis. RT-qPCR was performed using the cDNA as template, and the gene-specific primers used were presented in Table 1.

RT-qPCR was conducted with Bio-Rad CFX-96 Real-Time PCR System (Bio-Rad, USA) according to the method described by [6]. The PCR conditions were as follows: 95°C for 30 s, 95°C for 5 s, 62°C for 30 s, and 72°C for 27 s, followed by 40 cycles. Melting curve analyses of amplification products were performed at the end of the PCR reaction. The melting cycle was 95°C for 15 s, 60°C for 1 min, 95°C for 15 s, and 62°C for 15 s. The expression level was normalized to level of *actin*, and the results were expressed as relative expression levels; the data were quantified by the method of $2^{-\Delta\Delta CT}$ [6].

2.9. Statistical Analyses. A statistical analysis of the obtained data was carried out using SPSS 16.0 for Windows (SPSS Inc., Chicago, IL). The mean values and the standard error of the mean were calculated from the data obtained from two independent experiments. The differences between the means of the test were evaluated by Student's t-test and $P < 0.05$ was considered significantly different.

3. Results

3.1. Effect of S. pararoseus at Different Concentrations on Blue Mold Incidence and Lesion Diameter of Apples. Efficacy of *S. pararoseus* Y16 at different concentrations against blue mold incidence and lesion diameter of apples were examined. Figure 1(A) showed that different concentrations of *S. pararoseus* Y16 significantly inhibited the decay incidence of apples compared with the control, and the higher the concentration of *S. pararoseus* Y16, the lower the decay rate. When the concentrations of *S. pararoseus* Y16 were 10^8 and 10^9 cells/mL, the decay rate of apples was 21.5% and 10.3%, respectively. Meanwhile the decay rate of the control was 100%, which indicated that *S. pararoseus* Y16 can significantly inhibit the occurrence of blue mold decay caused by *P. expansum* in apples. For lesion diameter, the same trend was observed. The

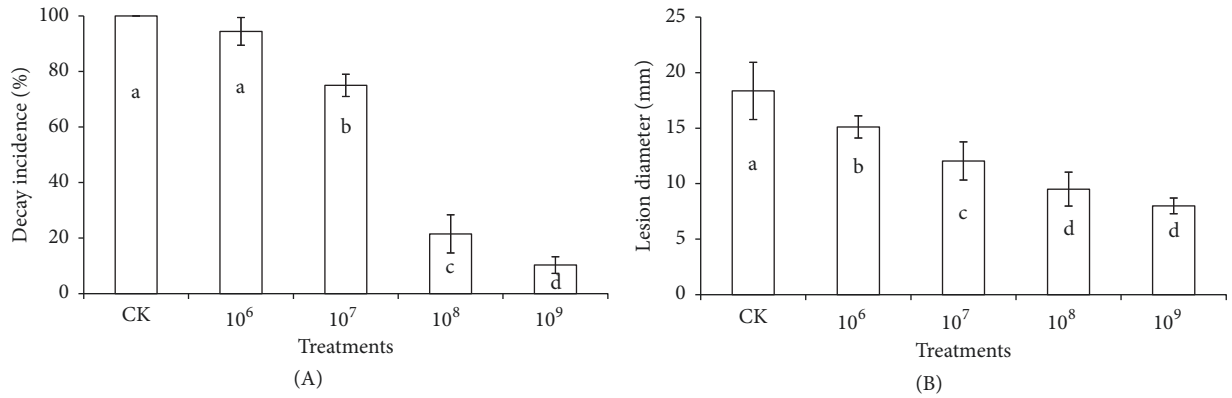

Figure 1: Efficacy of *S. pararoseus* Y16 in inhibiting blue mold decay of apples. Disease incidence (A) and lesion diameter (B) were measured after 6 days of *(P. expansum)* incubation at 20°C. CK means control; the letters of 10^6, 10^7, 10^8, and 10^9 represent the concentrations of *S. pararoseus* Y16 at 10^6, 10^7, 10^8, and 10^9 cells/mL, respectively. Each value is the mean of two experiments. Bars represent the standard error of the mean. Data in columns with the different letters are significantly different according to Duncan's multiple range test at $P < 0.05$.

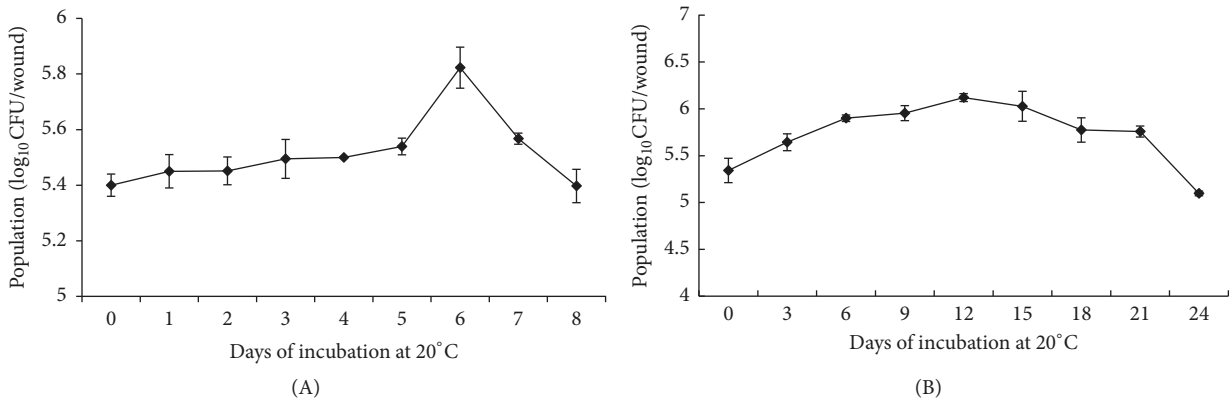

Figure 2: Population dynamics of *S. pararoseus* Y16 in apple wounds at 20°C (A) and 4°C (B). Bars represented standard errors.

lesion diameters of apple wounds treated with *S. pararoseus* Y16 at different concentrations (10^6, 10^7, 10^8, and 10^9 cells/mL) were 15.11 mm, 12.45 mm, 9.51 mm, and 8.03 mm, respectively, which were significantly lower than those of the control (18.35 mm), and the higher concentration of *S. pararoseus* Y16, the smaller lesion diameter of the apple wounds. When the concentration of *S. pararoseus* Y16 was 10^8 cells/mL or 10^9 cells/mL, the decay diameter of apple recorded the least value (Figure 1(B)).

3.2. Population Dynamics of S. pararoseus in Apple Wounds. Population dynamics of *S. pararoseus* Y16 in apple wounds at 20°C and 4°C were tested. The results showed that the population of *S. pararoseus* Y16, incubated at 20°C, increased slowly from 1 d to 4 d and then grew quickly, from 4 d to 6 d; the number of yeast in apple wounds increased by 1.09 times. The population of *S. pararoseus* Y16 reached the maximum at days 6 (Figure 2(A)). However, *S. pararoseus* Y16 in wounds of apple fruits stored at 4°C grew more slowly than those stored at 20°C; the yeast could colonize during 0–12 d and then the population of the yeast decreased after 12 d. Although the population of the yeast decreased from the 12 d to 24 d, the population did not fall below 10^5 CFU/wound during all times points at 4°C (Figure 2(B)).

3.3. Effects of S. pararoseus on Spore Germination and Germ Tube Length of P. expansum In Vitro. As shown in Figure 3, *S. pararoseus* Y16 significantly decreased spore germination and germ tube length of *P. expansum in vitro*, and the higher the concentration of *S. pararoseus* Y16, the lower the spore germination rate and the germ tube length. As the concentration of yeast is 10^8 cells/mL, *S. pararoseus* Y16 can inhibit spore germination totally. When treated by *S. pararoseus* Y16 of 10^7 cells/mL, germ tube length of *P. expansum* is from 60.2 μm to 8.11 μm compared with the control.

3.4. Effects of S. pararoseus on PPO, POD, PAL, and CAT Activities of Apples. As indicated in Figure 4(A), treatment with *S. pararoseus* Y16 resulted in a significant increase in the PPO activity of apples compared with the control during the most storage time. At 2 days after inoculation, PPO activity of apples treated with *S. pararoseus* Y16 peaked at 1.78 times of the control. The POD activity in apples treated

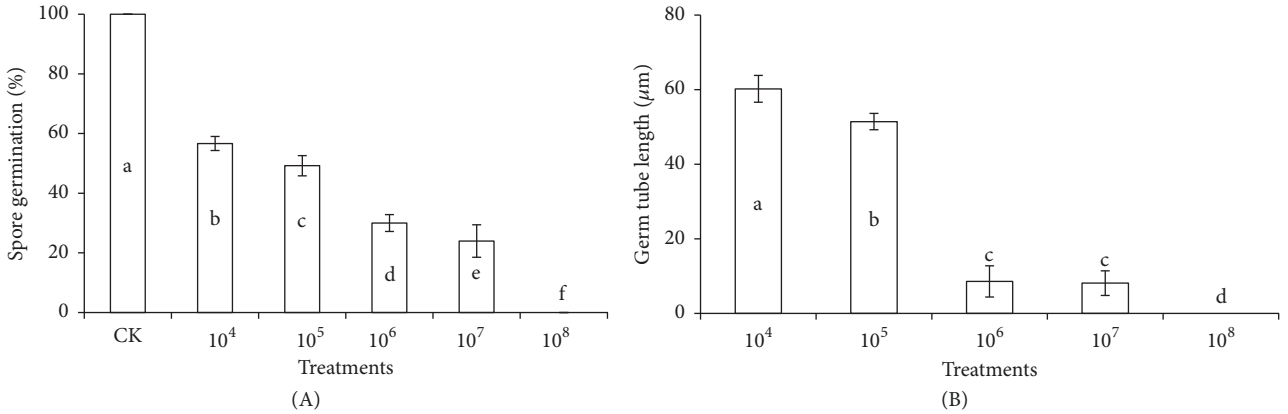

Figure 3: Effects of *S. pararoseus* Y16 on spore germination (A) and germ tube length (B) of *P. expansum*. CK means control; the letters of 10^4, 10^5, 10^6, 10^7, and 10^8 represent the concentrations of *S. pararoseus* Y16 at 10^4, 10^5, 10^6, 10^7, and 10^8 cells/mL, respectively. Germination rate and germ tube length were measured by microscope and micrometer after 12 h incubation at 28°C in PDB. Bars represent standard errors. Data in columns with different letters are statistically different according to Duncan's multiple range test at $P < 0.05$.

with *S. pararoseus* Y16 increased gradually at first 3 days and reached a peak on the third day and then began to decrease. However, the POD activity in samples treated with *S. pararoseus* Y16 was still higher than the control on the whole time (Figure 4(B)). Figure 4(C) shows the CAT activity in apples for treatment with *S. pararoseus* Y16 and the control. The changes of CAT activity of apple fruits treated with *S. pararoseus* Y16 were similar to those of the control. However, the CAT activity of *S. pararoseus* Y16 was higher than that of the control at first 3 days, and then the difference became very small. As was shown in Figure 4(D), PAL activity of apple treated with *S. pararoseus* Y16 was higher than that of the control in the whole storage period, especially on the third day; the PAL activity of apple fruit treated with *S. pararoseus* Y16 was 2.31 times more than the control, reaching 4.88 U/g FW.

3.5. Effect of S. pararoseus on Defense-Related Genes of Apples. It can be seen from Figures 5(A) and 5(B) that the expression levels of *PR-3* and *PR-4* were induced by *S. pararoseus* Y16 at 0 d, 2 d, 4 d, and 6 d, respectively. Meanwhile *PR-3*, *PR-4*, and *PR-5* expression levels were significantly induced at 4 and 6 d and *PR9* was significantly induced at 4 d. The expression of *PR-4* and *PR-5* reached the maximum at 6 d, while *PR-3* and *PR-9* reached the maximum at 4 d. The expression levels of pathogenesis-related genes were significantly upregulated, induced by *S. pararoseus* Y16.

4. Discussion

The use of biocontrol agents to manage postharvest diseases of fruits and vegetables has been explored as an alternative to the use of synthetic fungicides [10]. *S. pararoseus* Y16 proved to be a potential biological control agent for the control of postharvest blue mold decay of apples caused by *P. expansum* in the text. However, there is no information concerning the effect of *S. pararoseus* Y16 on postharvest blue mold of apples and its mechanism involved. The object of this study was to evaluate the biocontrol efficacy of *S. pararoseus* against *P. expansum* infection in apples. This is the first report of *S. pararoseus* Y16 as an antagonist of blue mold of apples.

S. pararoseus Y16 at different concentrations significantly inhibited blue mold of apples compared with the control. The higher the concentration, the better the efficacy. This finding is in agreement with [11, 19] that indicated that the biological control efficacy of antagonistic yeasts is dependent on the biocontrol agent's concentration and the pathogen inoculum concentration. To further understand the mechanisms of *S. pararoseus* Y16 controlled postharvest diseases of apples, we found that *S. pararoseus* could significantly inhibit the spore germination and germ tube length of *P. expansum* in *in vitro* experiments. Moreover, *S. pararoseus* Y16 could quickly adapt to the environment in apple wounds stored at 20°C or 4°C and kept the amount of yeast at a high level, which proved that *S. pararoseus* Y16 could quickly utilize the nutrients at the wounds and compete with the pathogen for space and nutrition, which explained that the disease resistance of apples was enhanced by *S. pararoseus* Y16. It can be seen that competition of space and nutrition between *S. pararoseus* Y16 and pathogen is an important reason for controlling postharvest blue mold decay of apples. Similar results for other antagonist yeasts have been reported by [20, 21] who described this phenomenon as an advantage to microbial antagonists in competing for nutrients and space, which plays a major role in its biocontrol efficacy.

Furthermore, the results of our study showed that *S. pararoseus* Y16 induced higher levels of PPO, POD, CAT, and PAL activities, activating the defense mechanism of apples. Studies showed that PPO and POD are important catalytic enzymes that not only accelerate the oxidation of phenolic compounds, but also participate in the synthesis of certain hormones, while enhancing the disease resistance [22]. POD is a multifunctional enzyme, and it can be used as a good regulator of fruit aging and physiological changes. PPO activity changes the disease resistance of fruits and vegetables, which is closely related to the direct role of pathogens, and PPO also plays a protective role in the plant. CAT, which is known to control reactive oxygen scavengers (ROS) [23],

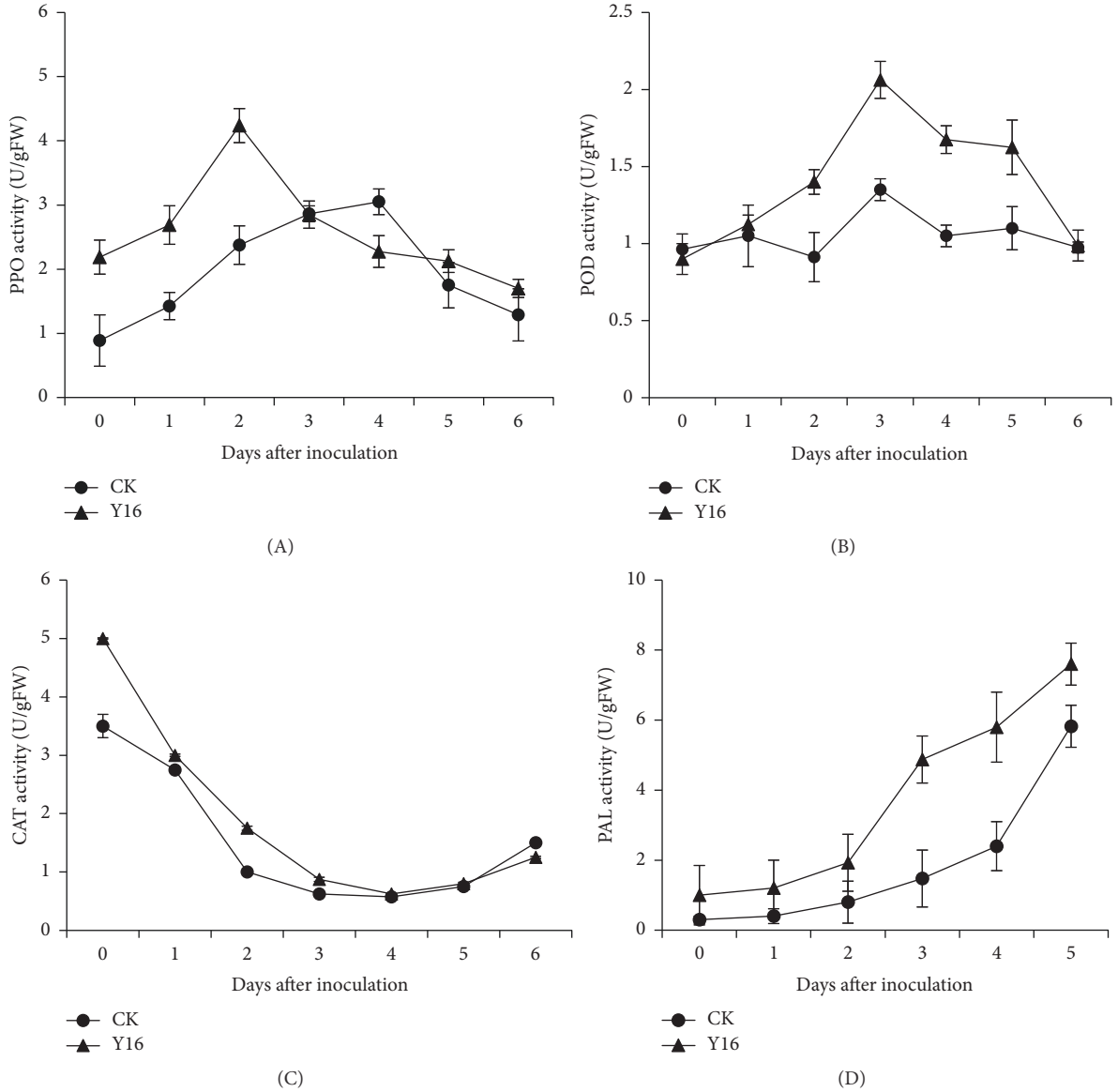

Figure 4: Effects of polyphenol oxidase (PPO) (A), peroxidase (POD) (B), catalase (CAT) (C), and phenylalanine ammonia lyase (PAL) (D) activities in apples treated with *S. pararoseus* Y16. Each value is the mean of two experiments. Bars represent standard errors.

was described as the capacity of the tissues to scavenge excess ROS and maintain ROS concentration at relatively low level [1]. Our results suggested that the CAT activity of apples was induced by *S. pararoseus* Y16 in this study; *S. pararoseus* Y16 improved CAT activity of apples, which may also be one of the reasons for enhancing the resistance ability of apples [24]. PAL is a key rate-limiting enzyme for the pathway of phenylpropanoid metabolites in fruits and vegetables, and it also could be used as a kind of important resistance-related enzymes that contribute to the production of lignin, alkaloids, and other resistant substances. It can be seen from Figure 4(D) that the PAL activity of apple fruit in *S. pararoseus* Y16 treatment group was significantly higher than that of the control during the whole storage period, which indicated that it could induce the PAL activity of apples.

Pathogenesis-related (PR) family of proteins could inhibit the activity of pathogens and improve the disease resistance of fruits. In this article, the relative expression levels of defense-related genes of apples induced by *S. pararoseus* Y16 were studied. The results showed that the expression levels of *PR-3*, *PR-4*, *PR-5,* and *PR-9* on apples were increased when treated with *S. pararoseus* Y16. *PR-3* and *PR-4* encoding chitinase and β-1,3-glucanase, respectively, which had high expression levels of hydration enzymes in plants, could destroy the cell wall of fungi. Meanwhile, *PR-5* belongs to the genes encoded by the sweet protein and has β-1,3-glucan binding activity, antitrypsin activity, kinase activity, and actin binding activity, indicating that its induced expression may be involved in the improvement of disease resistance to apples [25, 26]. *PR-9* is a peroxidase-encoding gene, involved in production of lignin

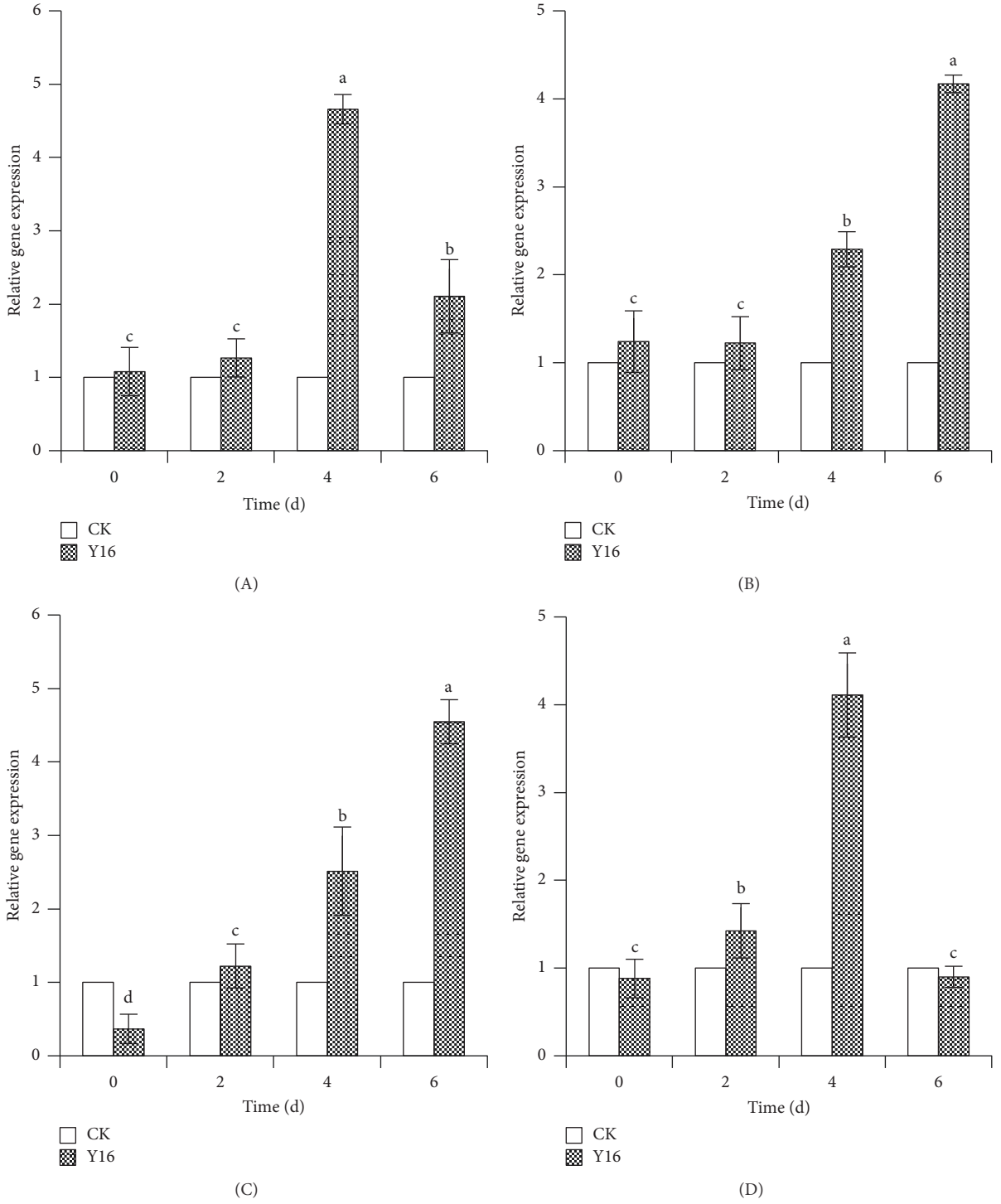

Figure 5: Relative expression levels of (A) *PR-3*, (B) *PR-4*, (C) *PR-5*, and (D) *PR-9* in apples treated with *S. pararoseus* Y16. MdActin was used as the internal control gene. Apples were treated with sterile distilled water as the control. Bars represent the standard error of the mean. Data in columns with the different letters are significantly different according to Duncan's multiple range test at $P < 0.05$.

that enhances resistance to pathogens [27]. These results indicated that *S. pararoseus* Y16 has great biocontrol effects on postharvest blue mold decay of apples, largely because *S. pararoseus* Y16 could induce the expression levels of defense-related genes in apples and improve its resistance, which also explains the mechanism of *S. pararoseus* Y16 inducing the disease resistance of the apples at the transcription levels of the genes.

In conclusion, the involved possible mechanism of *S. pararoseus* Y16 controlling blue mold decay of apples mainly

includes the following: (1) *S. pararoseus* Y16 competed with *P. expansum* for space and nutrition, which is the dominant flora, inhibiting the growth of pathogens; (2) *S. pararoseus* Y16 can significantly induce the activities of PPO, POD, CAT, and PAL in the resistance of apples *in vivo* and improve the disease resistance of apple fruits; (3) *S. pararoseus* Y16 induced the expression levels of defense-related genes in apples and improved the resistance of fruits. Further studies are needed to evaluate the effect of *S. pararoseus* Y16 as biocontrol agent against postharvest diseases of other fruits.

Additional Points

Practical Applications. Biological control with antagonistic yeasts has emerged as a promising way to reduce synthetic fungicide usage. Many microbial antagonists have been reported to control several pathogens on different fruits and vegetables. This study investigated the biocontrol of postharvest diseases of apple fruits by *S. pararoseus* Y16, which was isolated by our laboratory, and the mechanism of *S. pararoseus* controlling of postharvest diseases. It not only enriches the resource library of strains, but also provides theoretical basis for the practical application of using antagonistic yeasts to control the postharvest diseases of fruits.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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