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Application of Certain Compounds to Manage Postharvest Gray Mold Caused by *Botrytis cinerea* and Enhancing Strawberry Fruits Quality

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Abstract

Effects of pre-and postharvest treatments with potassium phosphite, potassium phosphate, and salicylic acid against the severity of gray mold disease caused by *Botrytis cinerea* in strawberry fruits were investigated under ambient conditions. Seven *B. cinerea* isolates were collected from naturally infected strawberry plants. The treatment with potassium phosphite at concentration of 500 mg/L significantly reduced the fungal growth compared to other treatments *in vitro*. The treatments with potassium phosphite at concentrations of 250 or 500 mg/L resulted in the highest disease reduction, followed by the treatment with salicylic acid. Additionally, effects of postharvest treatments with these compounds on disease reduction and biochemical attributes of strawberry fruits were evaluated during storage for 9 days at ambient conditions. The highest disease reduction percentage was found with potassium phosphite. Besides, the phenolics content and peroxidase activity of potassium phosphate were found to be greater than those of potassium phosphite or salicylic acid. However, a reduction in the total soluble solids, titratable acids, and ascorbic acid contents of fruits was found for all treatment groups at the end of storage period. Based on the obtained results, potassium phosphite and salicylic acid can be recommended as fungicide alternatives for extending postharvest shelf life of strawberry fruits.

Keywords: *Strawberry; Botrytis cinerea; Postharvest; Gray mold; Peroxidase; Ascorbic acid.*

Introduction

Strawberry fruits (*Fragaria ananassa* Duch.) are rich in nutrients such as minerals and vitamins, as well as other bioactive substances that may have health advantages (Coles, L. 2013; Giampieri, *et al.*, 2015). Egypt is the world's leading exporter of frozen strawberries, accounting for 20% of global exports in 2019 (Anonymous, 2019). Strawberry fruits are naturally infected with *B. cinerea*, which is the most common strawberry postharvest disease in Egypt and around the world, known as the gray mold disease (Yang *et al.,* 2010; El-Ghanam, 2015; Petrasch *et al.,* 2019 and El-fawy *et al.,* 2020). Furthermore, the gray disease causes significant economic loss in strawberry production around the world (Hahn, M. 2014).

Because of the favorable conditions that exist throughout the postharvest handling chain, such as injuries, high humidity, sensitive plant tissue, and high sugar content, *B. cinerea* is a significant postharvest pathogen. Mostly, the postharvest infection by *B. cinerea* occurs in differ-

ent types of fruit such as strawberry and grapes can sometimes spoil entire lots in field and during storage. Romanazzi and Feliziani (2014) found that *B. cinerea* influences fruits in the field, during storage, during transportation, and in the market. Also, it was reported that the gray mold disease is the most often cause for rejection of fruit shipping and exportation (Petrasch *et al.*, 2019). During the growing season of the strawberry, the gray mold or *B. cinerea* prefers moderate temperatures and high humidity, and strawberry fruits may be contaminated with higher amounts in marketplaces and during shipment (Elad and Stewart 2007 and Choquer *et al.,* 2007).

Synthetic fungicides are now employed in combination with natural or chemical treatments to control the gray mold disease because of the significant risk of fungus resistance (Romanazzi *et al.,* 2016). Several compounds and strategies, including promotion of plant defense levels of resistance, can help strawberry fruits fight the gray mold diseases (Fu and Dong, 2013; Walters *et al.*, 2013; Zhou and Wang, 2018). For example, in strawberry tissues, treatments with chitosan and a calcium-organic acid mixture reduced pathogen development and increased expression of enzymes connected to defensive mechanisms (Landi *et al.*, 2014). Salicylic acid (SA) one of the compounds that gave good results to suppress diseases caused by *B. cinerea* on different hosts (Terry and Joyce, 2004). Plant defense mechanisms were activated by SA in response to a variety of abiotic and biotic physiological, biochemical, and morphological alterations (War *et al.*, 2011). Phosphite also known to has an impact on severity of the plant pathogens (Ribeiro Junior *et al.*, 2006). Effects of tomato-juice and KH2PO4 on the infection of tomato gave noticeable results to control *B. cinerea* (Hyun, *et al.*, 2011). The gray mold severity can be determined by biochemical changes in infected strawberry plants or fruits. The polyphenol oxidase (PPO) and peroxidase (PO) activity in strawberry fruits infected with *B. cinerea* were found to be enhanced by a mixture of chemicals (El-Ghanam *et al.*, 2015). Furthermore, treatment with SA enhanced PO and PPO activities as well as phenols induction (War *et al.*, 2011).

As mentioned above, the excessive usage of chemical fungicide to control *B. cinerea* causal pathogen in strawberry and other fruits develops fungal resistance, environmental problems, and health hazards (Hauschild, 2012; Leroch *et al.*, 2013). Therefore, finding safe and eco-friendly fungicide alternatives is very important (Sylla *et al.*, 2015). The aim of this investigation was to evaluate efficiency of treatment with potassium phosphite, potassium phosphate, and SA as fungicide alternatives to control *B. cinerea* the causal pathogen of gray mold and preserve postharvest quality of strawberry fruits.

Materials and Methods

Materials

Strawberry fruits of Fortuna cultivar were harvested at mature-green stage in March 2020 from Fortuna cultivar, cultivated in Plant Pathology farm of Faculty of Agriculture, Assiut university, Assiut, Egypt.

Fruits were uniform in shape and size, and free of injuries, wounds, scratches, insect infestation, fungal infection, and mechanical harms. Fruits packaged randomly in sterilized polypropylene punnets and stored at 25°C for subsequent analyses at 0, 3, 6 and 9 days of storage periods. Treated fruits surface was disinfected with 70% ethanol. Chemicals and reagents used in this study were of analytical grade and purchased from El Nasr Co. Egypt.

Fungal Isolation and identification

Fungi were harvested from naturally infected fruits and grown on potato dextrose agar (PDA) for 3 to 9 days at 22 to 25°C. Using hyphal tip and single spore isolation techniques, a pure culture was generated. Isolates were identified based on their morphological and cultural characters as described by Khazaeli *et al.* (2010) and Dowling *et al.* (2017). Each plate received ten mL of sterilized distilled water, and the colonies were scraped using a sterile needle. The suspension was determined with a hemocytometer and adjusted as required with sterilized distilled water to approximately 2×10^5 CFU/mL the conidial suspension mixed with carborundum as described by Mansfield *et al.* (1974).

***In vitro* treatments**

Effect of treatments by SA, potassium diphosphate and potassium phosphite at concentrations of 125, 250, 500 ppm on mycelial growth of *B. cinerea* were performed on PDA medium. The plates were inoculated with 5 mm in diameter mycelia discs of 7 days old of *B. cinerea*, four petri dishes were used for each replicate, incubated at 25°C and compared with the control. Mycelial growth diameter length was taken and the reduction in growth diameter was measured as follows:

% Reduction= (A – B/A) 100

Where A is the control radial growth and B is the treatment radial growth

***In vivo* treatments**

For *in vivo* artificial infection, strawberry fruits were sprayed with spore suspension of *B. cinerea* at about $2x10^5$ cfu/mL, packed in polypropylene Punit, and stored at 25 °C and 85-95% relative humidity for 24 hours and tested at 0, 3, 6 and 9 days of storage period. Disease severity measured as Romanazzi *et al.* (2000)

Where d is the category of rot intensity scored on the fruit, f is the frequency, N is the total number of examined fruits (uninfected and infected), and D is the highest category of decay intensity present on the empirical scale, using scale 0-4, where 0 = healthy fruit, 1 = decayed area of the fruit ranging from 1 to 25%, 2 = decayed area of fruit ranging from 26 to 50%, 3 = decayed area of fruit ranging from 51 to 75% and 4 = decayed area of fruit ranging from 76 to 100%. and used the followed equation

Disease Severity (%) = ($\sum$ (d × f)/ (N × D)) 100

The experiment was randomly designed, and each treatment group was sprayed with compounds immediately after harvesting. The control plants were sprayed with distilled water. The fungicide switch was applied at concentration of one mL/L.

Total phenolics content (TPC)

One gram of treated and untreated strawberry fruits was cut into small pieces and extracted with 95%

ethanol alcohol for 10 min. The total phenolic content was measured according to Folin-Ciocalteau method, and the absorbance of measured at 765 nm using a spectrophotometer as described by Ough and Amerine (1988). Measurements were performed in duplicate and the mean values were expressed as g of gallic acid per kg of the sample using a standard gallic acid curve.

Peroxidase (POD) activity assay

The POD activity was assessed according to Vicente *et al.* (2006). In a total volume of 3.0 mL, the reaction mixture contains 100 µL of extract, 0.024 mol H2O2, 0.1 mol phosphate-buffered saline and 0.008 mol guaiacol was prepared. At wavelength of 460 nm and 30°C, the enzyme activity was measured with guaiacol as substrate, the results were reported as U/g min.

Measurement of total soluble solids

Tissues (50 g) from 4-8 fruits were homogenized and centrifuged for 20 min at 10000 x g. The supernatant was collected, and a refractometer was used to determine the total soluble solids concentration.

Determination of ascorbic acid content

The content of ascorbic acid (AA) in strawberry was determined according to 2, 6- dichlorophenolindophenol titration method. Briefly, tissue from fruits was homogenized in 50 mL of 0.02 g/mL oxalic acid solution. The mixture was centrifuged for 15 min at 15000 × g and 4 ˚C. A total of 10 mL supernatant was titrated with 0.1 percent 2,6-dichlorophenolindophenol to get a persistent pink color. The AA concentration was estimated using the titration volume and the results were reported as mg per 100 g of fresh weight.

Measurement of titratable acidity (TA)

Using phenolphthalein indicator, the TA % of the treated and untreated strawberry fruits was measured by titrating 10 mL of clear strawberry juice 0.1 N NaOH. The TA% was calculated as malic acid according to the following equation of AOAC (1980)

Statistical analysis

The obtained data were statistically analyzed using MSTAT-C version 2.10 (1991) software. The least significant difference (L.S.D.) was used for the comparison between means as described by Gomez and Gomez (1984).

Results and Discussion

Fungal isolates sources

Data in Table 1 shown that isolates were collected from Naturally infected strawberry, Fortuna strawberry cultivar grown in El Behira governorate (El Nubaria and Badr territories) with symptoms of gray mold. *B. cinerea* 1, 2, and 3 were collected from El Behira-El Nubaria, while *B. cinerea* 4, 5, 6, and 7 were collected from El Behira-Badr. These results are consistent with those reported by Wagih *et al.* (2019), who investigated the pathological diversity related to 51 *B. cinerea* isolates those infected grapes and strawberry in Egypt. In another study, fifteen *B. cinerea* isolates were obtained from different vegetables cultivated in various Egyptian locations and identified by Gaber *et al.* (2020). Furthermore, four isolates of *B. cinerea were* col-

lected and tested for fenhexamid- regardless of host plant, location, and plant organ by Wahab (2015).

Pathogenicity

The isolated and identified fungi isolates used to conduct pathogenicity test and the results are shown in Table 1. The pathogenicity test was conducted using 7 isolates of *B. cinerea* on strawberry plants of the Fortuna cultivar, eighty days after planting in the first stage of maturity and the start of red discoloration on the fruits next to the uninfected control. The infection with *B. cinerea* 1 isolate resulted in incidence of 75% and disease severity of 58.40%, which were the highest percentages among the seven isolates, followed by *B. cinerea* 2, while the lowest percentages of disease severity and incidence were found for *B. cinerea* 6. On the other hand, no disease symptoms were found are the infection with the isolate *B. cinerea* 7. The *B. cinerea* infection was found to take place very rapidly on strawberry fruits, the germination starts within 90 min of infection (Hennebert and Gilles, 1958) and the penetration occurs after 20 h of inoculation. Additionally, it was reported that the first symptom can appear in two days of strawberry fruit ripening (Guillon, 1906). Furthermore, Jarvis (1968) found that only about 1% of infections of ripened intact strawberry with *B. cinerea* occurred conidia germinated in a persistent drop of water. Valiuskaite *et al.* (2010) investigated pathogenicity traits of *B. cinerea* isolates on strawberry fruits and found different degrees of virulence on strawberry by the three isolates of *B. cinerea*. Reddy *et. al*. (2000) tested the pre-harvest and post-harvest infection by *B. cinerea* decay incidence under storage period and temperature that recorded increasing in disease incidence by time over 10 days.

Table 1. Isolates of strawberry gray mold, sources and their pathogenic capability.

Isolates number	Source of isolate	Gray mold	
		Incidence %	Severity %
B. cinerea 1	El Behira-El Nubaria	75.00	58.40
B. cinerea 2	El Behira-El Nubaria	43.75	36.50
B. cinerea 3	El Behira-El Nubaria	37.5	12.25
B. cinerea 4	El Behira-Badr	25.00	10.40
B. cinerea 5	El Behira-Badr	22.60	10.85
B. cinerea 6	El Behira-Badr	18.75	8.25
B. cinerea 7	El Behira-Badr	0.0	0.0
Control	-	0.0	0.0
L.S.D. 0.05		8.85	8

Antifungal effect of chemical concentration *in vitro*

In vitro, the effect of chemical compounds on *B. cinerea* growth was performed with three concentrations of each chemical compound and the results are shown in Table 2. Three compounds were used including potassium phosphite and potassium phosphate at concentrations of 125, 250 and 500 µg/L as well as SA at concentrations of 250, 500, and 1000 µg/L, compared with fungicide (Switch) and control infected with the fungal strain *B. cinerea 1*. The treatment with potassium phosphate did

not reduce the mycelium growth of the fungus as well as the treatment with SA at concentration of 250 µg/L. However, a reduction in the growth of the mycelium was found after treatment with SA at 500 and 1000 µg/L. Growth reductions were also found after the treatment with potassium phosphite at concentrations of 125, 250 and 500 mg/L. Estrada-Ortiz, *et al.* (2013) found that treatment with phosphite enhanced quality of strawberry fruits and plant resistance. Also, phosphite was found to have effect against oomycetes (Orbovic *et al.*, 2008). Volatile substances and plant extracts have been shown to have antifungal effects. For example, benzaldehyde, acetaldehyde, ethanol, benzyl alcohol, ethyl benzoate, methyl salicylate, and isothiocyanates inhibited the *B. cinerea* infection on a laboratory scale (Tripathi and Dubey, 2004).

Table 2. Effect of chemical compounds on *in vitro radial growth*.

Treatments	*B. cinerea* Growth	
	Diameter mm	eduction
K_2HPO_4 500 mg/L	70.0	0.0
K_2HPO_4 250 mg/L	70.0	0.0
K_2HPO_4 125 mg/L	70.0	0.0
KPhi 500 mg/L	22.0	68.57
KPhi 250 mg/L	46.0	34.28
KPhi 125 mg/L	60.0	14.28
SA 1000 mg/L	64.0	8.57
SA 500 mg/L	65.0	7.14
SA 250 mg/L	70.0	0.0
Switch 100 mg/L	0.0	100
Control (untreated)	70.0	0.0
L.S.D. 5	8.2	6.4

Preharvest treatments on strawberry plants

Antifungal effect of chemical treatments

Treatments *in vivo* were carried out on strawberry plants of Fortuna cultivar to investigate the effect of chemical treatments against the fungal strain *B. cinerea* 1 under greenhouse conditions, the results are presented in Table 3. A reduction in severity of the disease and significant differences were found after treatments with potassium phosphite, potassium phosphate, and SA. The lowest reduction percentage in the infection with the causal pathogen were found after treatment with SA at 250 mg/L, potassium di phosphate at 125 and 250 mg/L, and SA at 500 and 1000 mg/L, and potassium di phosphate 500 mg/L. However, the treatment with potassium phosphite at concentrations of 500, 250 and 125 mg/L resulted in the higher diseases reductions than other treatment, but lower that of treatment with fungicide. Estrada-Ortiz *et al.* (2013) reported that adding 20% phosphite to the nutrient solution improved the quality of strawberry fruits. They also found that the addition of 30% phosphite to the nutrient solution triggered defense systems in plants and im-

proved the quality of fruits and anthocyanins accumulation. In another study, Kamal *et al.* (2008) found that treatment with di-potassium phosphate can reduce the infection of onion plants by *Stemphylium vesicarium*.

Table 3. Effect of treatments with chemical compounds at different concentrations against the infection of strawberry with fungal strain *B. cinerea*.

Compaunds	Strawberry gray mold	
	Disease severity (%)	Reduction (%)
K_2HPO_4 500 mg/L	39.2	28.7
K_2HPO_4 250 mg/L	42.4	22.9
K_2HPO_4 125 mg/L	46.8	14.9
KPhi 500 mg/L	10.6	80.7
KPhi 250 mg/L	14.6	73.5
KPhi 125 mg/L	18.8	65.8
SA 1000 mg/L	40.6	26.2
SA 500 mg/L	40.8	25.8
SA 250 mg/L	48.6	11.6
Switch 100 mg/L	2.5	95.5
Control1 (infected)	55.0	0.0
Control 2 (uninfected)	0.0	100.0
L.S.D. 0.05	10.4	9.6

Biochemical changes as response to infection and treatments

Changes in the phenolics content and peroxidase activity of strawberry after 6 days of treatments with different concentrations of chemical compounds are presented in Table 4. Generally, the total phenolics content and peroxidase activity significantly increased in the infected control with chemical treatments as compared to the uninfected control. On the other hand, the phenolics content and peroxidase activity of the uninfected and chemically treated strawberry are lower than those of the infected and chemically treated strawberry. Also, the total phenolics content and peroxidase activity of the infected and chemically treated strawberry are lower than those of the infected control without chemical treatments. These results indicate that the chemical treatments have inhibition effect against *B. cinerea 1*.

Table 4. Effect of different compounds on total phenolic contents and peroxidase activity of the untreated and treated strawberry plants after 6 days of treatments.

Compaunds	Phenolics (mg galic acid equivalent/g)	Peroxidase (U/g. min)
K_2HPO_4 500 mg/L+B	6.55	1.40
K_2HPO_4 500 mg/L	2.45	0.84
K_2HPO_4 250 mg/L+B	7.35	1.48
$K_2HPO_{4\ 250}$ mg/L	2.24	0.80
K_2HPO_4 125 mg/L+B	8.24	1.64
K_2HPO_4 125 mg/L	2.24	0.80
KPhi 500 mg/L+B	4.35	0.62
KPhi 500 mg/L	2.34	0.32
KPhi 250 mg/L+B	4.68	0.75
KPhi 250 mg/L	2.46	0.58
KPhi 125 mg/L+B	4.98	0.88
KPhi 125 mg/L	2.65	0.68
SA 1000 mg/L+B	6.98	0.90
SA 1000 mg/L	3.48	0.72
SA 500 mg/L+B	5.95	0.88
SA 500 mg/L	3.22	0.70
SA 250 mg/L+B	5.65	0.95
SA 250 mg/L	2.98	0.70
Switch 100 mg/L+B	3.46	0.68
Switch 100 mg/L	3.20	0.42
Control1 (infected)	8.94	1.84
Control 2 (uninfected)	2.31	0.16
L.S.D. 0.05	0.32	0.18

Postharvest treatments and changes in biochemical attributes of strawberry fruits

Antifungal effect of treatments

The antifungal effect of treatments of harvested strawberry fruits with different concentrations of potassium phosphite, potassium phosphate, and SA was investigated, and the results are presented in Table 6. The untreated and treated strawberry fruits were stored at room temperature for 9 days, and samples were taken for analysis every 3 days of storage period, It can be seen that the treatment of strawberry fruits with potassium phosphite at concentration of 500 mg/L resulted in the highest disease reduction, followed by treatment with SA at concentration of 1000 mg/L, while the treatment with potassium phosphate resulted in the lowest disease reduction percentage after storage to up to 9 days compared with infected control. Additionally, the obtained results indicate that the treatment with potassium phosphite is the best and comparable to the treatment with the recommended fungicide. These results match previous studies for other researchers, Rebollar-Alviter and Ellis (2005) mentioned that potassium phosphite reduced the leather rot in strawberry fruits. In another study, to minimize botrytis and anthracnose rot, potassium phosphite was recommended as a supplemental ingredient to strawberry in the field during prolonged wetness conditions (Rebollar-Alviter *et al.*, 2010).

Table 5. Effect of different compounds and storage periods on strawberry gray mold disease severity *caused by B. cinerea* under ambient conditions.

Compounds	Concentration	Storage periods					
		3 days		6 days		9 days	
		DS (%)	reduction (%)	DS (%)	reduction (%)	DS (%)	reduction (%)
K_2HPO_4	500 mg/L	6.8	59.0	22.2	36.2	52.4	22.9
KPhi	500 mg/L	4.2	74.7	12.0	65.5	18.6	72.6
SA	1000 mg/L	10.2	38.6	19.4	44.3	26.8	60.6
Switch	100 mg/L	2.6	84.3	8.2	76.4	10.0	85.3
Control1 (infected)	-	16.6	0.0	34.8	0.0	68.0	0.0
Control 2 (uninfected)	-	0.0	100.0	0.0	100.0	0.0	100.0
L.S.D. 0.05		2.24	6.41	2.61	4.78	7.20	6.62

Total phenolic content

Changes in the content of total phenolics in the untreated and treated strawberry fruits during storage at room temperature for 9 days are presented in Table 7. The total phenolic content of the untreated strawberry fruits significantly decreased as the storage time extended to up to 9 days. However, the total phenolic content of the postharvest *B. cinerea 1* infected and chemical compounds or fungicide treated strawberry fruits significantly increased as storage prolonged, especially during the first 3 days of storage. Also, a significant increase was found in the total phenolic content of *B. cinerea 1* infected strawberry fruits without potassium phosphate, potassium phosphite, and SA treatments. The increase in the total phenolic content of the infected strawberry fruit during storage may be attributed to stress effects caused infection (Coltro *et al.*, 2014). The pathogen infection stress may lead to physiological disturbances and activation of certain phenylpropanoid metabolism proteins, increasing the phenolic compounds accumulation. Additionally, the damage of cells by pathogen may be contributed to the increased phenolics, which released from vacuoles and oxidized to quinones (Thipyapong *et al.*, 2004). Kamal *et al.* (2008) found that treatment with di-potassium phosphate enhances peroxidase and total phenol contents when fungal infection occurs on onion plants by fungal strain of *Stemphylium vesicarium*. On the other hand, slight changes were found in the total phenolics content of uninfected and potassium phosphate, potassium phosphite, and SA treated strawberry fruits. Recently, it was found that calcium chloride and SA treated strawberry fruits showed an increased phenolic content during cold storage, while the phenolic content of the untreated fruits decreased as storage prolonged (Shahzad *et al.*, 2020). Nguyen & Nguyen (2021) found a reduction in the total content of phenolics in strawberry fruits stored at different temperatures (2, 5, 10, and 25C). The decrease in the total phenolic content can be attributed to oxidation of polyphenols by polyphenoloxidase and partial degradation of anthocyanins during storage.

Table 6. Effect of different compounds and storage periods on total phenolic contents of strawberry fruits infected with *B. cinerea* under ambient conditions.

Compaunds	Concentation (mg/L)	Storage periods			
		Total phenolics contents (mg galic acid equivalent/g)			
		0 days	3 days	6 days	9 days
K_2HPO_4 +B	500	1.25	4.26	5.84	5.82
K_2HPO_4	500	1.23	1.32	1.30	1.40
KPhi +B	500	1.24	3.14	2.08	1.42
KPhi	500	1.22	1.25	1.25	1.39
SA +B	1000	1.20	4.26	3.44	2.64
SA	1000	1.14	1.85	2.18	2.24
Switch +B	100	1.26	2.42	1.90	1.22
Switch	100	1.23	1.34	1.34	1.22
Controll (infected)		1.24	4.62	6.20	5.06
Control 2 (uninfected)	-	1.22	1.02	0.81	0.42
LSD 0.05	-	-	0.48	0.62	0.31

Peroxidase activity

Peroxidase activity was measured for the untreated and treated strawberry fruits and the results are presented in Table 8. Peroxidase activity of the uninfected and untreated strawberry fruits significantly decreased as the storage time prolonged. However, the postharvest *B. cinerea 1* infected strawberry fruits without chemical compounds treatment showed increased peroxidase activity as storage time extended to up to 6 days. A significant increase was also found in peroxidase activity of *B. cinerea 1* infected and chemical compounds or fungicide treated strawberry fruits during 6 days of storage. On the other hand, slight changes were found in the peroxidase activity of chemical compounds and fungicide treated strawberry fruits without *B. cinerea 1* postharvest infection. Asghari and Hasanlooe (2016) found that treatment by methyl jasmonate enhanced peroxidase and some other defense enzymes activities as well as the total antioxidant content of harvested strawberry fruits during storage. In another study, Shahzad *et al.* (2020) found an increase in the catalase and peroxidase activities of calcium chloride and SA treated strawberry fruits during the cold storage compared to the untreated ones, especially during the first days of storage.

Table 7. Effect of different compounds and storage periods on peroxidase activity (U/g. min) of the untreated and treated strawberry fruits at ambient conditions.

Treatments	Concentration (mg/L)	Storage periods			
		0 days	3 days	6 days	9 days
K_2HPO_4 +B	500	0.32	1.47	1.22	0.80
K_2HPO_4	500	0.30	0.38	0.42	0.42
KPhi +B	500	0.36	0.46	0.58	0.50
KPhi	500	0.30	0.32	0.48	0.46
SA +B	1000	0.32	1.25	1.56	1.42
SA	1000	0.32	0.42	0.70	0.62
Switch +B	100	0.36	0.56	0.62	0.60
Switch	100	0.40	0.42	0.44	0.42
Control 1 (infected)	-	0.38	1.82	1.86	1.42
Control 2 (uninfected)	-	0.35	0.30	0.23	0.15
LSD 0.05	-	-	0.11	0.09	0.12

Total soluble solids

Total soluble solids contents of the untreated and treated strawberry fruits during storage at room temperature for 9 days are shown in Table 9. Generally, a reduction in the total soluble solids content of the postharvest *B. cinerea 1* infected and chemical compounds or fungicide treated strawberry fruits was found as the storage time extended to up to 9 days. The highest reduction rates in the total soluble solids were found for the *B. cinerea 1* infected straw berry fruits without chemical compounds treatments. Also, the decrease rate in total soluble solids content was greater for the potassium phosphate treated strawberry fruits than other treatments. Mandour *et al.* (2019) found a reduction in the total soluble solids contents untreated and chemically treated strawberry fruits during cold storage for 15 days. However, in another study, it was found that treatment with different concentrations of calcium chloride and SA effectively maintained the total soluble solids contents of strawberry during cold storage (Shahzad *et al.*, 2020). Recently, a reduction in the total soluble solids content of strawberry fruits during storage at 25ºC was reported by Nguyen and Nguyen (2021). The decrease in the total soluble solids content can be attributed the higher respiration rate and the metabolic utilization of sugars during storage at room temperature (Yang *et al.*, 2010; and Nguyen and Nguyen, 2021).

Table 8. Effect of different compounds and storage periods on total soluble solids content (%) of the untreated and treated strawberry fruit at ambient conditions.

Treatments	Concentration (mg/L)	Storage periods			
		0 days	3 days	6 days	9 days
K_2HPO_4	500	9.2	7.6	7.0	6.4
KPhi	500	9.2	8.8	8.4	8.0
SA	1000	9.1	8.8	7.8	7.4
Switch	100	9.2	9.1	7.9	7.2
Control1 (infected)	-	9.5	8.0	6.2	6.0
Control 2 (uninfected)	-	9.4	9.2	7.4	7.2
LSD 0.05	-	-	0.92	0.55	0.61

Titratable acids

The titratable acids contents of the untreated and treated strawberry fruits are presented in Table 10. The titratable acids significantly decreased as the storage time extended to up to 9 days for all samples. The uninfected and chemical compounds untreated strawberry fruits (Control) showed the greatest titratable acids decrease rate, followed by the infected and SA treated strawberry fruits. Shahzad *et al.* (2020) found a reduction in titratable acids percentage in the untreated and calcium chloride and SA treated fruits stored for 15 days at 4ºC, which was attributed to conversion of acids into sugars. Additionally, they found that treatment with 5 mM SA was effective in maintaining strawberry content of acids compared with other treatments. Nunes *et al.* (2002) found a decrease in the content of titratable acids in strawberry fruits stored at 20ºC. Also, Rahman *et al.* (2016) found a decrease in the content of titratable acids in strawberry fruits stored at ambient temperature (25 ºC). The reduction in the acidity of stored strawberry may be due to oxidative metabolism of organic acids.

Table 9. Effect of different compounds and storage periods on titratable acids content (%) of the untreated and treated strawberry fruits at ambient conditions.

Treatments	Concentration (mg/L)	Storage periods			
		0 days	3 days	6 days	9 days
K_2HPO_4	500	0.83	0.81	0.54	0.46
KPhi	500	0.82	0.73	0.68	0.62
SA	1000	0.81	0.62	0.52	0.49
Switch	100	0.81	0.80	0.62	0.58
Control1 (infected)	-	0.83	0.80	0.63	0.42
Control 2 (uninfected)	-	0.82	0.76	0.58	0.40
LSD 0.05	-	-	0.19	0.06	0.05

Ascorbic acid content

The Ascorbic Acid content AA content is important factor for determining the quality of stored strawberry fruits (Cordenunsi *et al.*, 2003). Changes in the content of AA in strawberry fruits during storage at room temperature for 9 days were measured, and the results are shown in Table 11. The AA content significantly decreased as the storage time extended to up to 9 days for all samples. The lowest AA content was found for the postharvest infected strawberry fruit without chemical compounds treatment, followed by fungicide treated sample. However, the potassium phosphite and SA treated strawberry fruits showed higher AA content at 9 days of storage than that of other samples. Moor *et al.* (2009) found an enhancement in synthesis of anthocyanins and AA after fertilizing with phosphite. However, the reduction in the AA content of strawberry fruits is mainly attributed to the increase in level of the oxygen or storage temperature (Sogvar *et al.*, 2016). Additionally, Pavlovska *et al.* (2015) found a major reduction in the AA content during storage of strawberry fruits for 16 days at room temperature compared to cold and freezing storages. In another study, Rahman *et al.* (2016) found that the ascorbic content of strawberry fruits

decreased as storage at room temperature prolonged. Also, Mandour *et al.* (2019) found a reduction in the AA content of the untreated and chemically treated strawberry fruits during cold storage for 15 days. Also, Khodaei *et al.* (2021) found a reduction in the AA content during cold storage of strawberry fruits for 16 days. They also found that edible coatings provided protective effect against degradation of AA by reduction of oxygen diffusion and respiration rate. The decrease in the content of AA content can be attributed to oxidation reaction and degradation during storage (Zeb *et al.*, 2015).

Table 10. Effect of different compounds and storage periods on ascorbic acid (mg/100 g fresh weight) of the untreated and treated strawberry fruits at ambient conditions.

Treatments	Concentration (mg/L)	Storage periods			
		0 days	3 days	6 days	9 days
K_2HPO_4	500	70	62	42	34
KPhi	500	76	72	55	46
SA	1000	74	70	45	39
Switch	100	69	65	40	25
Control1 (infected)	-	70	50	35	22
Control 2 (uninfected)	-	68	61	53	35
LSD 0.05	-	2.76	1.25	3.94	2.84

Conclusion

Under green house and ambient conditions, the protective effects of pre- and postharvest treatments with potassium phosphite, potassium phosphate, and SA on strawberry fruits inoculated with B. cinerea were examined. The treatment with potassium phosphite at concentration of 500 mg/L significantly reduced the fungal growth compared with other treatments *in vitro*. In addition, treating strawberry plants with potassium phosphite at concentrations of 250 or 500 mg/L led to the greatest disease reduction, followed by SA treatment. On the other hand, strawberry fruits were treated with these chemical compounds immediately after harvesting and effects treatments on disease reduction and biochemical characteristics of strawberry fruits were evaluated during storage at room temperature for 9 days. The gray mold disease was significantly reduced in strawberry fruits during storage for 9 days. Furthermore, at the end storage period, the infected and potassium phosphate treated strawberry fruits had higher phenolic content and peroxidase activity than the infected and potassium phosphite or SA treated ones. However, the total soluble solids, titratable acids, and AA contents of strawberry fruits significantly reduced at the end of storage periods for all treatment groups. The obtained results indicate that potassium phosphite and SA can be used as fungicide alternatives for preserving quality of strawberry fruits. Further studies are needed to comprehensively characterize the chemically treated strawberry fruits and its postharvest microbial and chemical safety.

References

Anonymous FAOSTAT, F. (2019). FAOSTAT statistics database.

AOAC, (1980). Official methods of analysis association of official Agricultural chemists, 13th Edition, The Association of Official Analytical Chemists, Washington, D.C., USA.

Asghari, M., & Hasanlooe, A. R. (2016). Methyl jasmonate effectively enhanced some defense enzymes activity and Total Antioxidant content in harvested "Sabrosa" strawberry fruit. Food science & nutrition, 4(3), 377-383.

Choquer, M., Fournier, E., Kunz, C., Levis, C., Pradier, J. M., Simon, A., & Viaud, M. (2007). Botrytis cinerea virulence factors: new insights into a necrotrophic and polyphageous pathogen. FEMS microbiology letters, 277(1), 1-10.

Coles, L. (2013). Vitamin C in Human Health and Disease is Still a Mystery? An Overview. Functional Foods, 179-202.

Coltro, S., Broetto, L., Rotilli, M. C. C., Moraes, A. J. D., Barp, F. K., & Braga, G. C. (2014). Heat shock and salicylic acid on postharvest preservation of organic strawberries. Revista Ceres, 61, 306-312.

Cordenunsi, B. R., Nascimento, J. D., & Lajolo, F. M. (2003). Physico-chemical changes related to quality of five strawberry fruit cultivars during cool-storage. Food Chemistry, 83(2), 167-173.

Dowling, M. E., Hu, M. J., & Schnabel, G. (2017). Identification and characterization of Botrytis fragariae isolates on strawberry in the United States. Plant disease, 101(10), 1769-1773.

Elad, Y., & Stewart, A. (2007). Microbial control of Botrytis spp. Botrytis: biology, pathology and control, 223-241.

El-fawy, M. M., El-Sharkawy, R. M. I., & Ahmed, M. M. (2020). Impact of pre and post-harvest treatment with chemicals preservatives on Botrytis gray rot disease and fruit quality of strawberry. Archives of Agriculture Sciences Journal, 3(2), 178-194.

El-Ghanam, A. A., Farfour, S. A., & Ragab, S. S. (2015). Bio-suppression of strawberry fruit rot disease caused by Botrytis cinerea. Journal of Plant Pathology and Microbiology, 6(Special Issue 3).

Estrada-Ortiz, E., Trejo-Téllez, L. I., Gómez-Merino, F. C., Núñez-Escobar, R., & Sandoval-Villa, M. (2013). The effects of phosphite on strawberry yield and fruit quality. Journal of soil science and plant nutrition, 13(3), 612-620.

Fu, Z. Q., & Dong, X. (2013). Systemic acquired resistance: turning local infection into global defense. Annual review of plant biology, 64, 839-863.

Gaber, M. A., Wagih, E. E., Shehata, M. R., Fahmy, M. M., & Wahab, H. A. (2020). Detection and Characterization of Botrytis cinerea Isolates from Vegetable Crops in Egypt. International Journal of Phytopathology, 8(3), 77-85.

Giampieri, F., Forbes-Hernandez, T. Y., Gasparrini, M., Alvarez-Suarez, J. M., Afrin, S., Bompadre, S., ... & Battino, M. (2015). Strawberry as a health promoter: an evidence based review. Food & function, 6(5), 1386-1398.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedures for Agriculture Research, 2nd Ed., John Willey. New York, USA, pp. 680.

Guillon, J. M. (1906). Etude de la croissance du Botrytis cinerea. C. R. Hebd. Séanc. Acad. Sci., Paris, 142: 1346-1349.

Hahn, M. (2014). The rising threat of fungicide resistance in plant pathogenic fungi: Botrytis as a case

study. Journal of chemical biology, 7(4), 133-141.

Hauschild, R. (2012). Safety and regulation of microbial pest control agents and microbial plant growth promoters-introduction and overview. Beneficial microorganisms in agriculture, food and the environment: Safety assessment and regulation, 67-71.

Hennebert, G. L., & Gilles, G. L. (1958). Epidemiologie de *Botrytis cinerea* Pers. sur fraisiers. *Meded. Landbouwhogesch. Opzoekingsstn.* Gent, 23, 864-888.

Hyun, T. K., Eom, S. H., Rim, Y., & Kim, J. S. (2011). Alteration of the expression and activation of tomato invertases during Botrytis cinerea infection. Plant Omics, 4(7), 413-417.

Jarvis, W. R., and Borecka, H. (1968). The susceptibility of strawberry flowers to infection by Botrytis cinerea. Hortic. Res. 8: 147-154.

Kamal, A. E. A., Mohamed, H., Aly, A. A., & Mohamed, H. A. (2008). Enhanced onion resistance against stemphylium leaf blight disease, caused by Stemphylium vesicarium, by di-potassium phosphate and benzothiadiazole treatments. The Plant Pathology Journal, 24(2), 171-177.

Khazaeli, P., Zamanizadeh, H., Morid, B., & Bayat, H. (2010). Morphological and molecular identification of *Botrytis cinerea* causal agent of gray mold in rose greenhouses in centeral regions of Iran.

Khodaei, D., Hamidi-Esfahani, Z., & Rahmati, E. (2021). Effect of edible coatings on the shelf-life of fresh strawberries: A comparative study using topsis-shannon entropy method. NFS Journal, 23, 17-23.

Landi, L., Feliziani, E., Romanazzi, G., (2014). Expression of defense genes instrawberry fruit treated with different resistance inducers. J. Agric. Food Chem.62, 3047–3056.

Leroch, M., Plesken, C., Weber, R. W. S., Kauff, F., Scalliet, G., & Hahn, M. (2013). Gray mold populations in German strawberry fields are resistant to multiple fungicides and dominated by a novel clade closely related to Botrytis cinerea. Applied and Environmental Microbiology, 79, 159–167.

Mandour, M. A., Metwaly, H. A., & Ali, A. M. (2019). Effect of foliar spray with amino acids, citric acid, some calcium compounds and monopotassium phosphate on productivity, storability and controlling gray mould of strawberry fruits under sandy soil conditions. Zagazig Journal of Agricultural Research, 46(4), 985-997.

Mansfield, J. W., & Deverall, B. J. (1974). The rates of fungal development and lesion formation in leaves of Vicia faba during infection by Botrytis cinerea and Botrytis fabae. Annals of Applied Biology, 76(1), 77-89.

Moor, U., Põldma, P., Tõnutare, T., Karp, K., Starast, M., & Vool, E. (2009). Effect of phosphite fertilization on growth, yield and fruit composition of strawberries. Scientia horticulturae, 119(3), 264-269.

MSTAT-C. (1991). A Software Program for the Design, Management and Analysis of Agronomic Research Experiments, Michigan State University, East Lansing, USA.

Nguyen, D. H. H., & Nguyen, H. V. H. (2021). Effects of storage temperature on postharvest physicochemical attributes of nanochitosan coated strawberry (Fragaria× ananassa Duch.). Journal of Horticulture and Postharvest

Research, 4(1-March 2021), 101-114.

Nunes, M.C.N., Morais, A.M.M.B., (2002). Fruit maturity and storage temperature influence response of strawberry to controlled atmospheres. J. Am. Soc. Hort Sci. 127 (5), 836–842.

Orbovic,V., Syvertsen, J. P., Bright, D., Van Clief, D. L., & Graham, J. H. (2008). Citrus seedling growth and susceptibility to root rot as affected by phosphite and phosphate. Journal of Plant Nutrition, 31(4), 774-787.

Ough, C.S., Amerine, M.A. (1988). Phenolic Compounds. Methods for Analysis of Musts and Wines. John Wiley & Sons, Inc., New York: 196–221.

Pavlovska, G., Dukovska, E., Knights, V. A., & Jankuloska, V. (2015). Influence of temperature and time of storage on amount of vitamin C in strawberries. Journal of Hygienic Engineering and Design, 11, 15-19.

Petrasch, S., Knapp, S. J., Van Kan, J. A., & Blanco- Ulate, B. (2019). Grey mould of strawberry, a devastating disease caused by the ubiquitous necrotrophic fungal pathogen Botrytis cinerea. Molecular Plant Pathology, 20(6), 877-892.

Rahman, M. M., Moniruzzaman, M., Ahmad, M. R., Sarker, B. C., & Alam, M. K. (2016). Maturity stages affect the postharvest quality and shelf-life of fruits of strawberry genotypes growing in subtropical regions. Journal of the Saudi Society of Agricultural Sciences, 15(1), 28-37.

Rebollar-Alviter, A., & Ellis, M. A. (2005). Efficacy of azoxystrobin, pyraclostrobin, potassium phosphite, and mefenoxam for control of strawberry leather rot caused by Phytophthora cactorum. Plant Health Progress, 6(1), 17.

Rebollar-Alviter, A., Wilson, L. L., Madden, L. V., & Ellis, M. A. (2010). A comparative evaluation of post-infection efficacy of mefenoxam and potassium phosphite with protectant efficacy of azoxystrobin and potassium phosphite for controlling leather rot of strawberry caused by Phytophthora cactorum. Crop Protection, 29(4), 349-353.

Reddy, M. B., Belkacemi, K., Corcuff, R., Castaigne, F., & Arul, J. (2000). Effect of pre-harvest chitosan sprays on post-harvest infection by Botrytis cinerea and quality of strawberry fruit. Postharvest Biology and Technology, 20(1), 39-51.

Ribeiro Júnior, P. M., Resende, M. L. V. D., Pereira, R. B., Cavalcanti, F. R., Amaral, D. R., & Pádua, M. A. D. (2006). Effect of potassium phosphite on the induction of resistance in cocoa seedlings (Theobroma cacao L.) against Verticillium dahliae Kleb. Ciência e Agrotecnologia, 30(4), 629-636.

Romanazzi, G., Feliziani, E., (2014). Botrytis cinerea. In: Bautista-Baños, S. (Ed.), Postharvest Decay: Control Strategies. Elsevier, pp. 131–146 ISBN: 9780124115521.

Romanazzi, G., Nigro, F., & Ippolito, A. (2000). Effectiveness of pre and postharvest chitosan treatments on storage decay of strawberries. Rivista di Frutticoltura e di Ortofloricoltura, 62(5), 71-75.

Romanazzi, G., Smilanick, J. L., Feliziani, E., & Droby, S. (2016). Integrated management of postharvest gray mold on fruit crops. Postharvest Biology and Technology, 113, 69-76.

Shahzad, S., Ahmad, S., Anwar, R., & Ahmad, R. (2020). Pre-storage ap-

plication of calcium chloride and salicylic acid maintain the quality and extend the shelf life of strawberry. Pakistan Journal of Agricultural Sciences, 57 (2).

Sogvar, O. B., Saba, M. K., & Emamifar, A. (2016). Aloe vera and ascorbic acid coatings maintain postharvest quality and reduce microbial load of strawberry fruit. Postharvest biology and Technology, 114, 29-35.

Sylla, J., Alsanius, B. W., Krüger, E., & Wohanka, W. (2015). Control of Botrytis cinerea in strawberries by biological control agents applied as single or combined treatments. European journal of plant pathology, 143(3), 461-471.

Terry, L. A., & Joyce, D. C. (2004). Elicitors of induced disease resistance in postharvest horticultural crops: a brief review. Postharvest Biology and Technology, 32(1), 1-13.

Thipyapong, P., Hunt, M. D. & Steffens, J. C. (2004). Antisense down regulation of polyphenol oxidase results in enhanced disease susceptibility. Planta, 220:105-117.

Tripathi, P., & Dubey, N. K. (2004). Exploitation of natural products as an alternative strategy to control postharvest fungal rotting of fruit and vegetables. Postharvest biology and Technology, 32(3), 235-245.

Valiuskaite, A., Survilienė, E., & Baniulis, D. (2010). Genetic diversity and pathogenicity traits of Botrytis spp. isolated from horticultural hosts. Žemdir Agric, 97(4), 85-90.

Vicente, A. R., Martínez, G. A., Chaves, A. R., & Civello, P. M. (2006). Effect of heat treatment on strawberry fruit damage and oxidative metabolism during storage. Postharvest Biology and Technology, 40(2), 116-122.

Wagih, E. E., Wahab, H. A., Shehata, M. R., Fahmy, M. M., & Gaber, M. A. (2019). Molecular and pathological variability associated with transposable elements of Botrytis Cinerea isolates infecting grape and strawberry in Egypt. International Journal of Phytopathology, 8(2), 37-51.

Wahab, H. A. (2015). Characterization of Egyptian Botrytis cinerea isolates from different host plants. Advances in Microbiology, 5(03), 177.

Walters, D. R., Ratsep, J., & Havis, N. D. (2013). Controlling crop diseases using induced resistance: challenges for the future. Journal of experimental botany, 64(5), 1263-1280.

War, A. R., Paulraj, M. G., War, M. Y., & Ignacimuthu, S. (2011). Role of salicylic acid in induction of plant defense system in chickpea (Cicer arietinum L.). Plant signaling & behavior, 6(11), 1787-1792.

Yang, F., Li, H., Li, F., Xin, Z., Zhao, L., Zheng, Y., & Hu, Q. (2010). Effect of nano□packing on preservation quality of fresh strawberry (*Fragaria ananassa* Duch. cv Fengxiang) during Storage at 4°C. Journal of Food Science, *75*(3), 236-240.

Zeb, A, Amin NU, Shah S, Ayub M, khan A, *et al.* (2015). Post-Harvest Evaluation of Strawberry Fruit Preserves in Different Concentration of Sucrose Solution and Potash Alum Stored at Ambient Temperature. J Nutr Food Sci S13: 001. doi:10.4172/2155-9600.S13-001.

Zhou, M., & Wang, W. (2018). Recent advances in synthetic chemical inducers of plant immunity. Frontiers in plant science, 9, 1613.

استخدام بعض المركبات لمكافحة مرض العفن الرمادي المتسبب عن الفطر بوتريتس و تحسين جودة ثمار الفراولة

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الملخص

أجريت هذه الدراسة بهدف التعرف على تأثير المعاملة بفوسفيت البوتاسيوم، وفوسفات البوتاسيوم، وحامض الساليسيليك على مرض العفن الرمادي في الفراولة، والذي يسببه فطر *Botrytis cinerea*، فى مرحلتي ما قبل وبعد الحصاد، وذلك تحت الظروف المناخية الطبيعية. تم جمع سبعة عزلات من الفطر المسبب من نباتات الفراولة المصابة طبيعيًا، واستُخدمت العزلة الأكبر قدرة على إحداث المرض لإجراء الدراسات المختبرية والحيوية. أظهرت النتائج أن المعاملة بفوسفيت البوتاسيوم بتركيز ٥٠٠ ملجم/ لتر أدت إلى خفض نمو الفطريات بشكل معنوي مقارنة بالمعاملات الأخرى في المختبر. كما أدت معاملة نباتات الفراولة بفوسفيت البوتاسيوم بتركيزات ٢٥٠ أو ٥٠٠ ملجم / لتر إلى الحد من المرض بدرجة كبيرة، تلتها المعاملة بحمض الساليسيليك. إضافة إلى ذلك، تم تقييم تأثير المعاملة بتلك المركبات للحد من شدة المرض بعد الحصاد، وذلك عن طريق تقييم التغير في الخصائص الكيموحيوية لثمار الفراولة أثناء التخزين لمدة ٩ أيام على درجة حرارة الغرفة، وقد أوضحت النتائج أن أكبر نسبة خفض في إصابة ثمار الفروالة بالمرض كانت بالمعاملة بفوسفيت البوتاسيوم، وذلك عند نهاية فترة التخزين. إلى جانب ذلك، وجد أن محتوى الفينولات ونشاط البيروكسيداز في نهاية فترة التخزين لثمار الفراولة المصابة والمعاملة بفوسفات البوتاسيوم أعلى من تلك المصابة والمعاملة بفوسفيت البوتاسيوم أو بحامض الساليسيليك. وفي نهاية فترة التخزين، وجد انخفاض في المحتوى الإجمالي للمواد الصلبة الذائبة، والأحماض القابلة للمعايرة، ومحتوى حامض الأسكوربيك في ثمار الفراولة لجميع المعاملات. بناءً على النتائج المتحصل عليها، يمكن التوصية باستخدام فوسفيت البوتاسيوم وحمض الساليسيليك كبدائل للمبيدات الاكثر ضررًا لإطالة عمر ثمار الفراولة بعد الحصاد والحفاظ على جودتها.

الكلمات الدالة: الفراولة؛ بوتريتيس سينيريا، ،العفن الرمادي، البيروكسيداز، حامض الأسكوربيك.