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Impact of pre and post-harvest treatment with chemicals preservatives on Botrytis gray rot disease and fruit quality of strawberry

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Abstract

This study focuses on the evaluation of some chemical food preservatives to control gray mold disease in strawberry fruits. Six compounds, *i.e.* acetic acid, sodium benzoate, benzoic acid, sodium citrate, citric acid and potassium citrate were tested at concentrations 10, 20, 40 and 80 mM for inhibiting mycelial growth of the pathogen. *In vitro* studies, data obtained showed that all treatments significantly ($P \leq 0.05$) inhibited the mycelial growth of the pathogen. Sodium benzoate especially at concentration of 80 mM caused complete mycelial growth inhibition of the pathogen. Under laboratory conditions, dipping the strawberry fruits in solutions of these compounds were effective in reducing the disease severity. Also, applications of these compounds as fruits spraying gave a significant reduction of the disease. Sodium benzoate had a better effect on the disease *in vitro* and *in vivo*. Laboratory estimates showed that treated fruits with the tested compounds contained a high percentage of total soluble solids (TSS) compared to untreated fruits and healthy control. Also, titratable acidity (TA) increased in treated fruits compared to the healthy fruits; as a result, TSS/TA ratio was increased. Furthermore, treated fruits contained a high level of total phenol contents (TPC) compared to untreated fruits. All studied treatments improved the quality attributes of strawberry fruits, *i.e.* T.S.S, TA%, TSS/TA ratio and TPC. It is concluded that these compounds were effective on the disease, so they can be used as safe alternatives to fungicides in treating fruits to protect them from the fungal decay during storing or marketing.

Keywords: strawberry, *Botrytis cinerea*, gray mold disease, food preservatives, fruits quality.

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1. Introduction

Strawberry fruit (*Fragaria ananassa* L.) is very susceptible to fruit rot or gray mold disease caused by *Botrytis cinerea* Pers. (Yao and Tian, 2005). This disease is one of the most important diseases of strawberry pre- or post-harvest in all production areas in Egypt and the worldwide (El-Ghanam, 2015; Petrasch *et al.*, 2019; Stromeng *et al.*, 2009). This disease is an important problem not only in the field, but also during storage, transport and marketing strawberry. It can cause significant losses if not recognized early and controlled. The pathogen can infect all aboveground parts of the plant, but it is the flower blight (Xu *et al.*, 2000) and fruit rot phases of the disease that are the most damaging. The roles of food additives are protecting the product from microbial contamination and prolong the shelf life of the product; to ensure the safety of products. Benzoic acid, sodium benzoate, citric acid, sodium citrate and potassium citrate are used as chemical preservatives to enhance the shelf life of food, because they have a high ability to inhibit a wide range of microorganisms (Blaszyk and Holley, 1998; El-Fawy, 2018). Some mechanisms have been suggested to explain the inhibitory effect of these chemicals on microorganisms. For example, a lowered pH resulting from this acid may influence the growth by acidifying the cell, which will consume a great amount of energy to maintain the intracellular pH homeostasis (Bracey *et al.*, 1998). There are also other theories explaining the effect of acids on microorganisms, such as disruption the membrane (Stratford and Anslow, 1998), the interruption of metabolic reactions (Krebs *et al.*, 1983), and the accumulation of toxic anions (Eklund, 1985). Citric acid inhibits the growth of proteolytic *Clostridium botulinum* due to its Ca+2 chelating activity (Graham and Lund 1986). Several studies also mentioned the role of citrate in control of many plant diseases (Abdel-Monaim and Ismail, 2010; El-Fawy, 2018; Mohamed *et al.*, 2015). The food additives such as potassium sorbate and sodium benzoate had antifungal activities against postharvest decaying fungi (Al-Zaemey *et al.*, 1993; Olivier *et al.*, 1999). Also, application of these compounds had a similar fungicidal activity on citrus fruits inoculated with *Penicillium digitatum* for controlling citrus fruit decay (Hall, 1992). Acetic acid at concentration 50 mM in a medium inhibited the growth of the fungus *Colletotrichum gloeosporioides* (Penz.) Sacc. in a nutrient medium (Kang *et al.*, 2003). El-Fawy and Abo-Elyousr (2016) found that benzoic acid was effective on urediniospores germination percentage of common bean rust disease. Several theories have been presented to explain the antifungal activity of weak acids, including acidification of the cytoplasm, anion accumulation, membrane perturbation, and ATP depletion (Bracey *et al.*, 1998; Mollapour *et al.*, 2008). This study aimed to evaluate the efficacy of certain chemicals food preservatives for controlling Botrytis fruit rot disease and their effect on some quality attributes of strawberry fruits.

2. Materials and Methods

2.1 Fungal isolates

A pathogenic isolate of *B. cinerea* was isolated from strawberry fruits showing typical symptoms of gray mold disease and was maintained on Potato Dextrose Agar (PDA) slants at 4°C until further use. Two-week-old culture grown on PDA plates was used to prepare spore suspension for the *in vitro* studies.

2.2 Preparation of the pathogen inoculum

The inoculum of *B. cinerea*, isolated from diseased strawberry fruits was prepared from stock cultures on PDA stored at 4°C. It was inoculated onto PDA medium in a 9-cm-diameter Petri dish and incubated at 20°C for 15 days. Ten milliliters of sterile distilled water were added to each plate, and the colonies were scraped with a sterile needle. The obtained conidial suspension was determined with a hemocytometer and adjusted as required with sterile distilled water to approximately 2×10^5 CFU/ml as mentioned by Bhaskara Reddy (2000). The conidial suspension was sprayed onto strawberry fruits using an atomizer until runoff.

2.3 Evaluation of the inhibitory effect of the chemical preservatives on the growth of B. cinerea in vitro

The chemical preservatives were tested to study their effect on the mycelial growth of the pathogen *in vitro*. These compounds were added to PDA medium at different concentrations, i.e. 0, 10, 20, 40 and 80 mM according to the method described by Gregori et al, (2008). The stock medium (PDA) for each concentration was poured into Petri dishes. The plates were inoculated in the center with equal discs (6 mm) taken from 7-days-old culture of *B. cinerea*. Each treatment was represented by four plates as replicates. Petri dishes without compounds were served as control. All treatments were incubated at 20◦C. The mycelial growth diameter was determined after 7 days period of incubation at 20◦C in darkness. Inhibition of mycelial growth percentage was calculated as follows: [(control radial growth - radial growth in the treatment) / control radial growth] × 100.

2.4 Effect of some chemical food preservatives as spraying pre-harvest treatment on gray mold disease of strawberry fruits under field conditions

Under filed conditions, these compounds at concentration 80 mM (showed the highest effect on the pathogen *in vitro*) were tested as spraying treatments on strawberry fruits Fortuna cultivar was studied. This experiment was carried out in El-dear village, Kaluobeia governorate, Egypt for two successive seasons 2017/2018 and 2018/2019. Strawberry seedlings were transplanted in plots of 3×3.5 m^2 arranged in a completely randomized design, with three plots for each treatment as replicates. The plants were left to natural infection and sprayed with the tested compounds after appearance of the first symptoms of the disease. The control plants were sprayed with distilled water. All tested treatments were applied once spray before harvest. The fungicide Teldor® 50% SC was applied at concentration of 0.5 ml/L water as a comparison treatment. Disease severity was scored on a 1-5 scale, where: 1= intact fruit, 2= more than 5 % Decay, 3= between 5-20 % decay, 4= between 20-50 % decay, 5= more than 50% decay (Ayala-Zavala *et al*., 2005).

2.5 In vitro investigation of the effects of some chemical preservatives as dipping post-harvest treatment on gray mold disease of strawberry

Fresh harvested healthy of strawberry fruits cv. Fortuna were obtained from El-dear village, Kaluobeia Governorate, Egypt and then washed thoroughly with tap water, surface sterilized by dipping in 70% ethyl alcohol solution for 5 minutes and left for drying at the laminar bench. Strawberry fruits were inoculated with spore suspension (2×10^5 CFU/ml) of *B. cinerea* as spraying treatment, then air-dried at room temperature (23-25°C). Inoculated strawberry fruits were dipping in each prepared compound for one minute, then air dried at room temperature and transferred to egg carton trays. Untreated fruits were served as a control treatment. Three trays were used for each treatment. The fungicide Teldor® 50% SC obtained from Bayer Company was applied at concentration 0.5 ml/L water as a comparison treatment. All trays were kept in a cold room (Plant Pathology Laboratory, Faculty of Agriculture Al-Azhar University, Assiut, Egypt) at 10 -15°C for 14 days, with the daily examination (Abd-Alla *et al*., 2011). Disease severity was calculated as mentioned before.

2.6 Effect of chemicals preservatives on some quality attributes of strawberry fruits

2.6.1 Total soluble solids (TSS %)

Strawberry fruits were randomly taken from each treatment and blended in an electrical blender, then filtered to obtain clear juice of homogenate. Total soluble solids (TSS %) of strawberry fruits was measured in the juice of fresh fruits by using a Digital Hand Refractometer at room temperature.

2.6.2 Titratable acidity (TA)

TA in treated and untreated strawberry fruits was determined by titrating 10 ml of clear juice of strawberry against 0.1 N NaOH using phenolphthalein indicator. The percentage of TA was calculated as malic acid according to the following equation of AOAC (1980):

$$Acidity\ (\%) = \frac{ml\ of\ used\ NaOH \times N\ of\ NaOH \times 0.064}{Sample\ volume\ of\ strawberry\ sample\ (ml)} \times 100$$

Also, by knowing TSS and TA the relationship between them (TSS /TA ratio) was estimated.

2.6.3 Total phenol contents (TPC)

One gram of treated and untreated strawberry fruits was cut into small portions, immediately plunged into 95% ethanol alcohol for 10 min, to kill the tissues then extracted for 8-10 h in soxhlet units using 70% ethanol till the percolate was colorless. The combined ethanol extracts were filtered and evaporated on the water path at 70°C to near dryness. The dried residues were re-dissolved in 50% isopropanol. Then, isopropanol extracts were used for determining free, total and conjugated phenols using Folin and Ciocatalteus reagent as described by Snell and Snell (1953). TPC were determined as follows: ten drops of concentration HCl (70%) were added to the samples, heated rapidly to boiling point and placed in a boiling water bath for 10 min. After cooling 1 ml of the reagent and 5 ml of 20 % Na_2CO_3 were added. The mixture was diluted to 10 ml and determination was carried out by spectrophotometer at 520 nm after 30 min. TPC were calculated as milligrams equivalent of catechol/gm fresh weight of fruits using the following formula:

$$\text{Sample conc.(mg)} = ((\text{Reading of sample} \times \text{Total volume of sample (cm}^3)) \ / \ \text{Sample volume (ml)}) \ / \ (\text{Standard curve of catechol} \times \text{Fresh weight (gm)}) \times 100$$

2.7 Statistical analysis

The obtained data were subjected to statistical analysis using the MSTAT-C program version 2.10 (1991). The least significant difference (L.S.D., p = 0.05) has been used for the comparison between means of treatments as stated by Gomez and Gomez (1984).

3. Results

3.1 Inhibitory effect of chemical preservatives on the linear growth of B. cinerea in vitro

This study evaluated the activity of the chemical preservatives against *B. cinerea in vitro* at concentrations 10, 20, 40 and 80 mM. The results are shown in Table (1) and Figure (1) indicate that all these compounds, *i.e.* acetic acid, sodium benzoate, benzoic acid, sodium citrate, citric acid and potassium citrate significantly ($P \leq 0.05$) inhibited the mycelial growth of *B. cinerea* compared to the control. In general, addition of these compounds separately to the medium significantly inhibited the growth of the pathogen at all the tested concentrations. The reduction of mycelial growth was increased by increasing the concentration of these compounds in the medium and reached its maximum using the concentration of 80 mM. In this concern the pathogen was more sensitive to both sodium benzoate and citric acid than the other compounds. Data also showed that, sodium benzoate especially at concentration of 80 mM caused complete mycelial growth inhibition of the pathogen (100 %), followed by citric acid (73.70%) at 80 mM. There are significant differences among the treatments in reducing the mycelial growth of the pathogen. But the use of acetic acid caused the lowest inhibition of the fungal growth (34.81%) even at the higher concentration (80 mM).

Table (1): Effect of chemical preservatives on the linear growth of *B. cinerea in vitro*.

Treatments	Inhibition of the mycelial growth (%)					
	0	10	20	40	80	Mean
Acetic acid	0.00	12.96	19.63	22.96	34.81	18.73
Sodium benzoate	0.00	52.59	64.81	75.19	100.00	58.52
Benzoic acid	0.00	21.11	33.33	33.33	48.89	27.33
Sodium citrate	0.00	20.74	27.04	32.22	46.30	25.26
Citric acid	0.00	49.26	57.41	65.93	73.70	49.26
Potassium citrate	0.00	10.37	22.22	27.41	40.00	20.00
Mean	0.00	27.84	37.41	42.84	57.28	-

L.S.D. at 5% for: Treatments (T) = 1.21, Concentrations (C) = 0.90, Interaction (T×C) = 2.20.

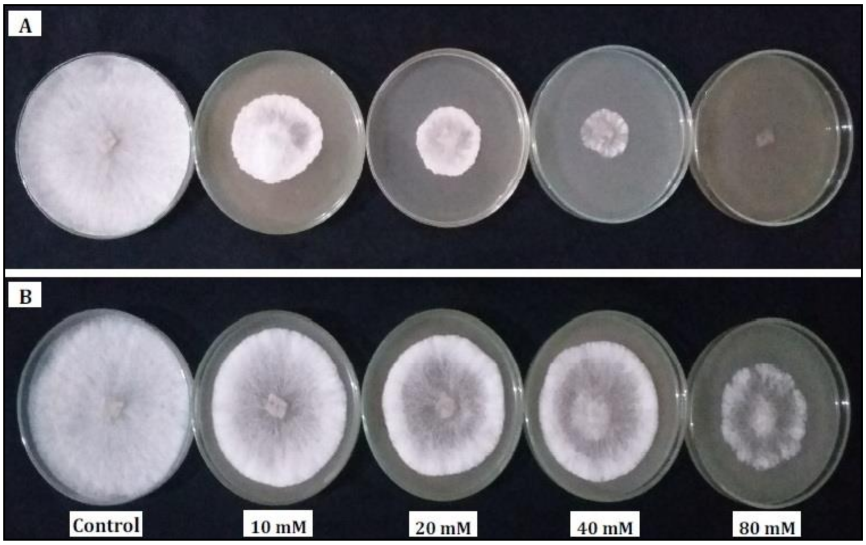

Figure (1): Effect of sodium benzoate (A) and citric acid (B) on mycelial growth of *B. cinerea in vitro*.

3.2 Effect of application of chemical preservatives as spraying fruits treatment on gray mold disease of strawberry under field conditions

Data presented in Table (2) showed that fruits spraying with the tested compounds caused significant reduction in the disease severity of gray mold disease on strawberry fruits compared to the control. Generally, Teldor fungicide was the more effective in reducing the disease severity than the other treatments (8.89 and 6.29%) in both seasons 2017/2018 and 2018/2019 respectively. Data also indicate that application of these chemicals reduced the disease severity in both tested seasons except in case of acetic acid treatment. The highest reduction in disease severity was observed in case of sodium benzoate where the recorded percentages of disease severity in 2017/2018 and 2018/2019 seasons were 11.11 and 8.52 % respectively followed by citric acid (15.93 and 17.41 %).

Table (2): Effect of pre-harvest treatment of strawberry fruits with chemical preservatives on gray mold disease of under field conditions during 2017/2018 and 2018/2019 growing seasons.

Treatments	Season 2017/2018		Season 2018/2019	
	Disease severity (%)	Disease reduction (%)	Disease severity (%)	Disease reduction (%)
Acetic acid	40.37	6.03	45.56	14.57
Sodium benzoate	11.11	74.14	8.52	84.02
Benzoic acid	30.37	29.31	34.81	34.73
Sodium citrate	38.89	9.47	41.11	22.91
Citric acid	15.93	62.92	17.41	67.35
Potassium citrate	36.67	14.64	36.30	31.93
Teildor® 50%	8.89	79.31	6.29	88.21
Untreated control	42.96	0.00	53.33	0.00
Mean	28.15	-	30.42	-
L.S.D.	5.41		4.76	

Data also revealed that there were significant differences among all treatments at both seasons. On the other hand, acetic acid gave the lowest effect on controlling the disease at both seasons.

3.3 Effect of chemical preservatives strawberry as fruits dipping on gray mold disease under artificial infection in vitro

Results of this study presented in Tables (3) and Figure (2) show that dipping of strawberry fruits in solutions of these compounds at concentrations 80 mM and Teildor fungicide at 0.5 ml/L after harvesting influenced significantly ($P \leq 0.05$) decreased the disease severity of strawberry fruit rots compared to the control. Data also indicate that all tested chemicals were effective in reducing the disease in both seasons (2017/2018 and 2018/2019). Generally, sodium benzoate caused the highest effect on the disease severity and gave the best control of the disease, followed by citric acid. While, acetic acid gave the lowest effect on controlling the disease. Sodium benzoate suppressed disease severity of fruits rot to 11.11 and 8.52% at seasons 2017/2018 and 2018/2019, respectively.

Table (3): Effect of chemical preservatives as dipping treatments on Botrytis fruit rot of strawberry under laboratory conditions.

Treatments	Season 2017/2018		Season 2018/2019	
	Disease severity (%)	Disease reduction (%)	Disease severity (%)	Disease reduction (%)
Acetic acid	44.35	9.03	44.77	13.72
Sodium benzoate	13.66	71.88	16.67	67.87
Benzoic acid	32.18	33.99	33.08	36.25
Sodium citrate	41.14	15.61	42.85	17.42
Citric acid	16.67	65.81	20.24	60.99
Potassium citrate	38.89	20.23	38.16	26.46
Teildor® 50%	11.11	77.21	13.33	74.31
Untreated control	48.75	0.00	51.89	0.00
Mean	30.84	-	32.62	-
L.S.D.	2.17		2.56	

Figure (2): Effect of dipping strawberry fruits in chemical preservatives on Botrytis fruit rot *in vitro*: (C) non-infection as a control, (1) infected and untreated fruits as a control, (2) acetic acid, (3) sodium citrate, (4) potassium citrate, (5) benzoic acid, (6) citric acid and (7) sodium benzoate and (8) Teildor fungicide.

3.4 Effect of chemical preservatives on some quality attributes of strawberry fruits

3.4.1 Total soluble solids (TSS %)

The results of this experiment in Figure (3) showed that treated strawberry fruits with chemicals preservatives contained a high percent of total soluble solids (TSS) percentage in treated strawberry fruits. Data also, showed that the maximum total soluble solids were recorded in sodium benzoate treatment (10.86%) followed by Teldor fungicide (10.42%). While a minimum total soluble solids percent was recorded in infected and untreated control (7.30%) followed by acetic acid treatment (7.73%). The results show that there are significant differences among the treatments in increasing percentage of total soluble solids percentage in strawberry fruits.

3.4.2 Titratable acidity (TA)

Data in Figure (4) showed that treatments with chemical preservatives increased TA in treated strawberry fruits compared to the healthy and untreated fruits. While, infected fruits with rot and untreated were contained a high percentage of TA compared to the healthy and untreated fruits. Furthermore, there was a significant increase of TA in treated strawberry fruits with chemical preservatives and infected with *B. cinerea*.

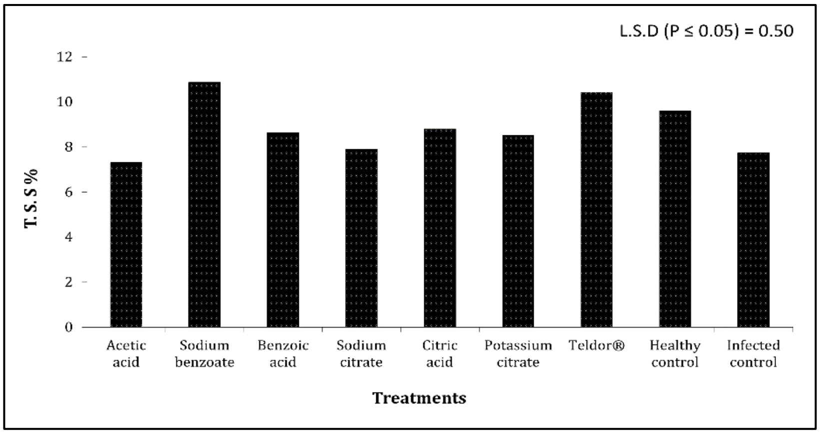

Figure (3): Effect of chemical preservatives treatments on total soluble solids (TSS %) of strawberry fruits.

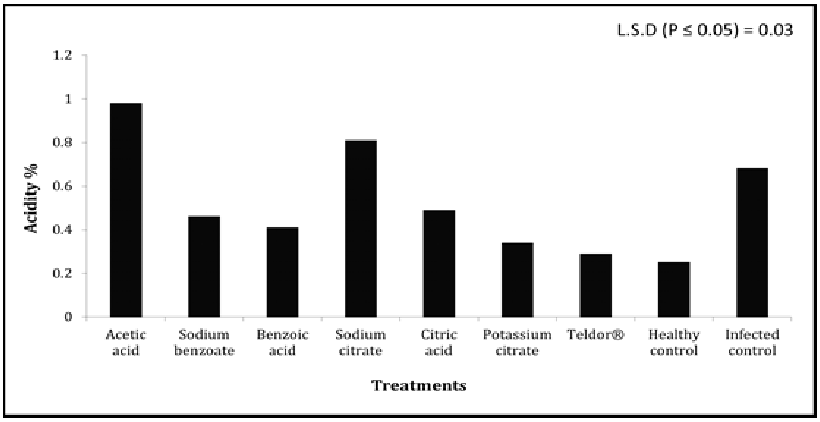

Figure (4): Effect of chemical preservatives treatments on titratable acidity (TA %) of strawberry juice.

Treated fruits with acetic acid have a high TA percentage (0.98%), while Teldor fungicide treatment caused the lowest percentage of TA (0.25%) compared to the other treatments. In general, the treatments had a significant effect on the TA of strawberry fruits treated with these treatments.

3.4.3 Total soluble solids / Titratable acidity (TSS/TA ratio) of strawberry fruits

Data in Figure (5) showed that there was a significant increase of TSS/TA ratio in all treated fruits with chemical preservatives of strawberry fruits and infected with *B. cinerea*. The treatments had significant effect on TSS/TA ratio of strawberry fruits treated. The highest ratio of TSS/ TA was recorded in case of healthy fruits (38.04), followed by Teldore fungicide (35.93). While, sodium benzoate was the caused the highest ratio of TSS/TA (23.61) compared to the other compounds. It's known that, the TSS/ TA ratio of fruit is essentially a measure of the sugar content versus acidity which gives fruits characteristic taste and flavour.

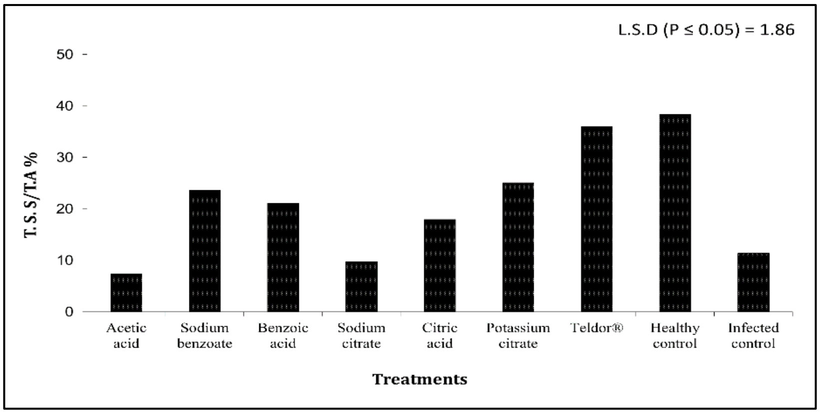

Figure (5): Effect of chemical preservatives on TSS/TA ratio of strawberry fruits.

3.4.4 Total phenol contents (TPC)

Data in Figure (6) showed that treated strawberry fruits with chemicals preservatives contained a high level of total phenol contents compared to the healthy control, but the highest increase was obtained when acetic acid was applied. However, fruits treated with acetic acid (12.18) and sodium benzoate (12.67 mg/g fresh weight) gave the highest level of phenolic compounds if compared to the healthy control (5.61). On the converse, all the tested compounds lead to increase of TPC in treated fruits. Also, results indicate that all treatments with these compounds enhanced the accumulation of TPC in the treated strawberry fruits compared to the healthy plants.

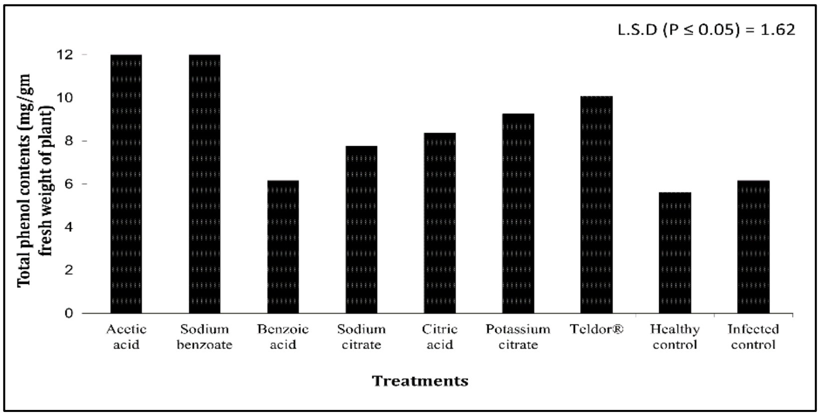

Figure (6): Effect of chemical preservatives treatments on total phenol contents (mg/gm fresh weight) of strawberry juice.

4. Discussion

Application of the chemical preservatives to the medium significantly inhibited growth of *B. cinerea* at the tested concentrations. The pathogen was more sensitive to both sodium benzoate and citric acid than the other compounds. Sodium benzoate at concentration 80 mM caused complete inhibition of mycelial growth of the pathogen (100 %). These obtained results are in agreement with those mentioned by Yildirm and Yapici (2007) who indicate that food additives and plant activators showed inhibitory effect at different levels on the mycelial growth and conidia germination of *B. cinerea* the causal pathogen gray mold disease on strawberry fruits. On the other hand, El-Fawy (2018) showed that citrate (citric acid and sodium citrate) inhibited the mycelial growth of *Cercospora beticola* at the tested concentrations. The presence of these compounds has been shown by direct actions, including the inhibition of mycelial growth, spore germination and reduction of membrane metabolism in the pathogen (Abdel-Kader *et al*., 2011; El-Fawy and Abo-Elyousr, 2016; El-Mohamedy *et al.*, 2015). Citrate such as citric acid, sodium citrate and potassium citrate could kill bacteria in many ways. The first way it could chelate away specific metals from bacteria and thus stop some enzymes from working as reported by Graham and Lund (1986) who found that citric acid inhibits the growth of proteolytic *Clostridium botulinum* due to its Ca2+ chelating activity. The second way, it could change pH drastically depending on the concentration (Bracey *et al.*, 1998; Cole and Keenan, 1987) and the third way, citric acid is a part of the Krebs cycle (Wills *et al.*, 1981). Under laboratory conditions, dipping of strawberry fruits in solution of the chemicals preservatives at concentration of 80 mM after harvesting influenced significantly decreased strawberry fruits rot compared to the control. Sodium benzoate caused the highest effect on the disease severity and gave the best control of the disease. Furthermore, these compounds caused significant reduction in disease severity of fruit rot as spraying treatments before harvesting at 80 mM under field conditions compared to untreated fruits. All these compounds reduced the disease severity in both seasons except in case of acetic acid treatment. The highest significant reduction in disease severity was observed in case of sodium benzoate *in vitro* and *in vivo*. Our results are in accordance with those obtained by Palou *et al*. (2002) who reported that potassium sorbate, sodium benzoate and ammonium molybdate were superior for the control of post-harvest Penicillium decay of citrus fruit compared to the other tested compounds. Similar findings were reported by Mohamed *et al.* (2015), also who found that citric acid at 2% as a foliar treatment was the most effective treatment against the fungal decay of artificially inoculated snap bean pods with *B. cinerea* as well as naturally infected pods. Potassium sorbate and sodium benzoate have been used in commercial citrus packinghouses to control postharvest diseases of different fruits (Olivier *et al*., 1999; Saleh and Huang, 1997). Organic acids such as citric, benzoic and acetic acids reduce cytoplasmic pH and stop metabolic activities and caused the death by the susceptible organisms act on the plasmic membrane by neutralizing its electrochemical potential and increasing its permeability (Dalie *et al*., 2010). Furthermore, other studies have shown the effect of the chemicals preservatives on the pathogenic plant diseases such as, Hall (1992) reported that the potassium sorbate or sodium benzoate applied to citrus fruits inoculated with *P. digitatum* had a similar fungicidal activity. All treatments significantly increased TSS and TA in treated fruits than the untreated control, but the highest increase was obtained when sodium benzoate and teldore fungicide were applied compared to the healthy and infected plants. On the converse, all the tested compounds lead to increase of TSS. These obtained results are in partial agreement with those mentioned by Yang *et al*. (2019), who reported that CA treatment maintained a slow ripening process after harvest, which tends to decrease TSS and increase TA (Yang *et al*., 2019). Data also, showed that TA of control and treated fruits of strawberry remained unchanged. There is an inverse relationship between TSS and TA percentage in treated fruits. TA values of strawberry fruits varied between 0.25 and 0.98 % at different treatments. The increase in TSS, acidity and TSS/TA ratio contents in grape fruits treated with the tested salts could be attributed to their fungistatic effect on the pathogen and consequently accumulation of TSS, TA and TSS/TA ratio which were not consumed by the pathogen (Soltan *et al*., 2016). Application of chemicals preservatives increased significantly the TPC in treated fruits compared to untreated and healthy fruits. The highest level of TPC was obtained from sodium benzoate treatment. Increase levels of TPC following treatments of strawberry fruits with food preservatives reported herein was previously suggested to be involved in resistant mechanisms of plants to other plants pathogens **(**Abd El-Hai *et al*., 2010; Gogoi *et al*., 2001). Our data indicate that the high infected fruits contained a lot of TPC. The obtained results agree with those obtained by Preciado-Rangel *et al*. (2018) who found that citric acid treatment led to the increase of the TPC in treated wheat plants. In other study, ascorbic acid treatment increases polyphenol retaining in frozen strawberry and raspberry fruits (Turmanidze *et al*., 2017). Gogoi *et al*. (2001) reported that the first step of the plant defense mechanism involves a rapid accumulation of phenols at the infection site, which restricts or slows the growth of the pathogen. Also, the resistance may be increased by change of pH of plant cell cytoplasm, due to the increase in phenolic acid content, resulting in inhibition of pathogen development (Khaledi *et al*., 2015). Diabate *et al*. (2009) showed that oil palm defense reaction to the vascular wilt disease was characterized by the production of phenolic compounds in the roots and pseudo bulbs infected at the pre-incubation stage. In our study, treated fruits with sodium benzoate and infected control untreated gave the highest level of TPC if compared to the healthy control. In conclusion, our results indicate that these compounds could be used as replacements to fungicides in keeping strawberry fruits quality and controlling decay caused by fungi during storage and marketing.

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