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Effects of *Phragmites australis* (Cav.) Steud. root extracts on the storage quality of Valencia oranges

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Abstract

Synthetic agrochemicals have been losing their acceptability by the consumers throughout the earth, because of the scientific confirmation of their negative effects on ecosystem and human health. However, both the production and postharvest storability of fresh horticultural products relies on the use of agrochemicals, especially for controlling the pathogenic decay. Numerous studies have reported success for several different plant derived products in preserving the storability of fruits. Therefore, present research was conducted to study the effects of *Phragmites australis* (Cav.) Steud. root extracts on the storage quality of Valencia oranges. Three different concentrations of *P. australis* root extracts (1%, 5% and 10%), and control treatment were tested in present study. Results of present study are novel for the preservative effects of *P. australis* root extracts. It was found that all concentrations of *P. australis* root extracts were effective in preventing weight loss, but the higher efficacy was noted from the median dose (5%). Similarly, *P. australis* root extracts (5%) provided the highest efficacy in maintaining fruit firmness. All doses of *P. australis* root extracts have been found to prevent decay incidence, protect fruit quality, delay the reduction in titratable acidity, increase ascorbic acid content, and reduce the respiration rate of the Valencia oranges.

Key words: plant extracts; postharvest storability; respiration rate; visual quality; weight loss

Introduction

Valencia oranges (*Citrus sinensis* L. Osbeck) contain high amount of ascorbic acid (vitamin C), diverse bioactive compounds, and nutrients (Albertini et al., 2006). Orange production covered about 54.4% of the total *Citrus* genus in 2018 and the *Citrus* genus has been noted to be the leader fruit crop in terms of total production in the world (FAO, 2020). *Citrus* fruits have also been the leader in world trade among the fruits; however, it has been reported as sensitive to prolong storage durations (more than 3 months). The main problems for postharvest storage of orange fruits are fungal decay (*Penicillium digitatum* and *Penicillium italicum*), changes in biochemical composition, and weight loss (Alhassan et al., 2020). Losses due to fungal decay were noted to be higher than 50% under unfavourable conditions (Feliziani et al., 2013). Control of postharvest pathogens has been reported to be utilized mainly by the application of synthetic agrochemicals, i.e. thiabendazole, imazalil, and propiconazole (Kinay et al., 2007). However, agrochemicals have been losing their acceptability by the consumers throughout the earth, because of the scientific confirmation of their negative effects on ecosystem and human health (Sharma et al. 2009; Suleria et al., 2015). The recommended storage conditions for orange fruits are between 5-8 °C (Kader, 1985; Wan et al., 2020). Prolonged storage at low temperatures causes ROS (reactive oxygen species) production at the fruits and it negatively affects the cell membranes. Furthermore, this causes chilling injuries at the orange fruits (Lado et al., 2016).

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Numerous studies (Ncama et al., 2018; Chen et al., 2019; Kahramanoğlu 2019; Xin et al., 2019; Riva et al., 2020; Khetabi et al., 2020; Poveda, 2020) have been reported that different plant-derived biomaterials/extracts (*Aloe vera* gel, basil-seen gum, lemongrass oil, guar gum, cassava starch, starch-based coatings, etc.) have high ability to maintain postharvest quality of fruits and help to control fungal pathogens. Similar success has also been noted by several researchers (Saberi et al., 2018; Chen et al., 2019; Moraes Bazioli et al., 2019) for different citrus species. The high acceptability of the plant biomaterials is generally due to their biodegradability and low toxicity (Tomazoni et al., 2016). The two main mechanisms of the plant biomaterials are 1) controlling the fungal decay (either by improving fruits' tolerance or direct influence on pathogens) (Ncama et al., 2019) and 2) reduction of respiration rate and transpiration of the fruits (by restricting the movement of gaseous and water through the fruits skin) (Kahramanoğlu 2017; Riva et al., 2020). Although there are numerous studies about the effects of different plant biomaterials, according to authors' knowledge, there is not any published literature about the efficacy of common reed (*Phragmites australis* (Cav.) Steud.) root extracts. *P. australis* plants cover a wide range from 70 °N to the tropics (Cronk and Fennessy, 2016) and are widely used in Northern Cyprus as a border between the citrus orchards. It is an aggressive and vigorous plant and becoming dominant in the suitable habitats. It is typically an erect perennial grass, aquatic or subaquatic plant, growing to nearly 400-600 cm high, with an extensive rhizome system. The stems of the plant are rigid and many-noded. The leaves are alternate with ligule of hairs up to nearly 70 cm long (Cronk and Fennessy, 2016). In Cyprus, the plant materials *P. australis* have also been used for baskets, roofs, and fences. It grows both by seed and vegetatively and is a long-lived perennial plant. It has important roles in wastewater management, by its characteristics such as reducing nitrogen and demand for biological oxygen; and it is a clean-up agent for removal of pollutants from water (CABI, 2020; Lv et al., 2020; Ohlsson et al., 2020). It was also noted that the *P. australis* is a good source of cellulose microfibrils and has a high capacity to adsorb methylene blue from industrial wastes (Kankılıç et al., 2020). *P. australis* was also noted to have allelopathic effects on the germination and growth of *Lactuca sativa*, *Melaleuca ericifolia*, and *Poa labillardierei* and to have significant impacts on the fungus growth (Uddin et al., 2017). According to the authors' current knowledge, there is not any published study about the postharvest efficacy of *P. australis*. Therefore, this study was aimed to experience the postharvest efficacy of *P. australis* root extracts on the Valencia oranges.

Materials and Methods

Materials and experimental design

Valencia oranges of this research were collected from a commercial orchard found in Güzelyurt city of Northern Cyprus. Moreover, roots of *P. australis* plants were then collected from the borders of the same orchard. The roots were then chopped into smaller pies (less than 2 cm^3) and were mixed with water at a ratio of 1:100 (w/v). Water + roots were then heated until 100 °C, kept hot at 100 °C for 30 minutes and filtered, and then cooled down to 25 °C. This was used as the 1% concentration of *P. australis* root extracts (Figure 1.). The same procedure was then followed with 5:100 (w/v) and 10:100 (w/v) concentrations of *P. australis* and referred as 5% and 10% doses, respectively.

Figure 1. Collection and preparation of the *P. australis* root extracts.

Hereafter, oranges were randomly separated into four groups, with 125 fruits in each. Each of these groups was then treated with different treatments i) control, ii) *P. australis* root extract (1%), iii) *P. australis* root extract (5%) and iv) *P. australis* root extract (10%). The control oranges were immersed into water and the other fruits were immersed into above described *P. australis* root extract solutions at 25 °C for 1 min. The 125 fruits of each group were then air-dried for 1 h and divided into 25 groups with 5 in each. These 5 fruits were then packed in open box cartoons with violas. The weight of each fruit was measured and noted; and moved to a cold room adjusted to the temperature of 6.0±1.0 °C and 90-95% relative humidity. Experiments were continued for 150 days and quality measurement of the fruits was performed with 30 days interval. At each measurement point, a total of 5 boxes (25 fruits) for each group of treatment were taken out the following quality parameters were measured.

Data collection and analysis

At the above-mentioned points, fruit weight (for the determination of weight loss), fruit firmness, decay incidence, visual quality, soluble solids concentration (SSC), titratable acidity (TA), ascorbic acid (AsA) content, and respiration rate (RR) were measured according to the following methods.

Fruit weights were measured with a digital balance (±0.01 g). Then, before cutting the fruits, the RR was determined as ml CO_2 kg^{-1} h^{-1} according to the formula of Fonseca et al. (2002). The 0-3 scale of Cao et al. (2011) was then used to determine decay incidence as %. Hereafter, visual quality was assessed with the 0-5 scale of Silvia et al. (2015).

The fruit firmness, as kg cm^{-2}, was then determined with a hand penetrometer. The fruits were then half-cut and squeezed to obtain juice, and the juice was used in hand refractometer to determine fruit SSC.

The fruits' TA (g 100 g^{-1} citric acid) was then determined by titrating the juice with 0.1 N NaOH, by following the standard method. Finally, the titrating method by 2,6-dichlorophenol indophenol was used to determine AsA contents of each fruits.

After collecting all data, Microsoft excel was used to organize the data and to calculate the means, standard deviations and figures. The comparison of the treatments was then carried out by subjected the data to the ANOVA by SPSS 22.0.

Results and Discussions

The fruit weight was found to increase during the cold storage. According to the findings measured, the *P. australis* root extract was effective in reducing weight loss (Figure 2A). The untreated control oranges were found to have a 16.83% weight loss in 150 days of cold storage, while the weight loss of the oranges treated with the *P. australis* root extract (5%) was only 8.62%. This was about half the weight loss as compared with the control fruits. The findings of current study are in conjunction with the reports of several previous studies, which recommended that the different biomaterials reduce the weight loss of stored fruits (Ncama et al., 2018; Chen et al., 2019; Kahramanoğlu 2019; Xin et al., 2019; Riva et al., 2020; Khetabi et al., 2020; Poveda, 2020). The other doses of the *P. australis* root extract were also effective in reducing weight loss. Similar results were obtained for the fruit firmness. The lowest fruit firmness (0.55 kg cm^{-2}) was noted from the control oranges at the end of the studies, where the medium dose of *P. australis* root extract had the highest fruit firmness (0.70 kg cm^{-2}) (Figure 2B). One of the most valuable findings of this study might be the efficacy of *P. australis* root extracts on the decay incidence. The control oranges were noted to have an increasing decay incidence during cold storage, which increased to 48.0% in 150 days (Figure 2C). At that time, the DI was noted as 6.67%, 9.33%, and 10.67 for the 10%, 5%, and 1%, respectively, concentrations of *P. australis* root extracts. Further studies have to be carried out to determine the exact mechanism, but as referenced to Kahramanoğlu et al. (2020), it was thought to be due to increasing the resistance of oranges or direct prevention of the decay. To do so, it is recommended for further studies to determine the changes in the enzymatic activities of peroxidise (POD), polyphenol oxidase (PPO), superoxide dismutase (SOD), catalase (CAT) and/or ascorbate peroxidase (APX) enzymes are activated or not. Moreover, it is also important to perform genetic studies to identify which genes are activated. Similar studies with different plant-derived biomaterials, hot water treatment, light, peach-gum, or salicylic acid (Hu et al., 2014; Bouaziz et al., 2016; Kahramanoğlu et al., 2020; Wan et al., 2020) had recommended that these treatments induce pathogenesis-related proteins and help to develop tolerance to the decay.

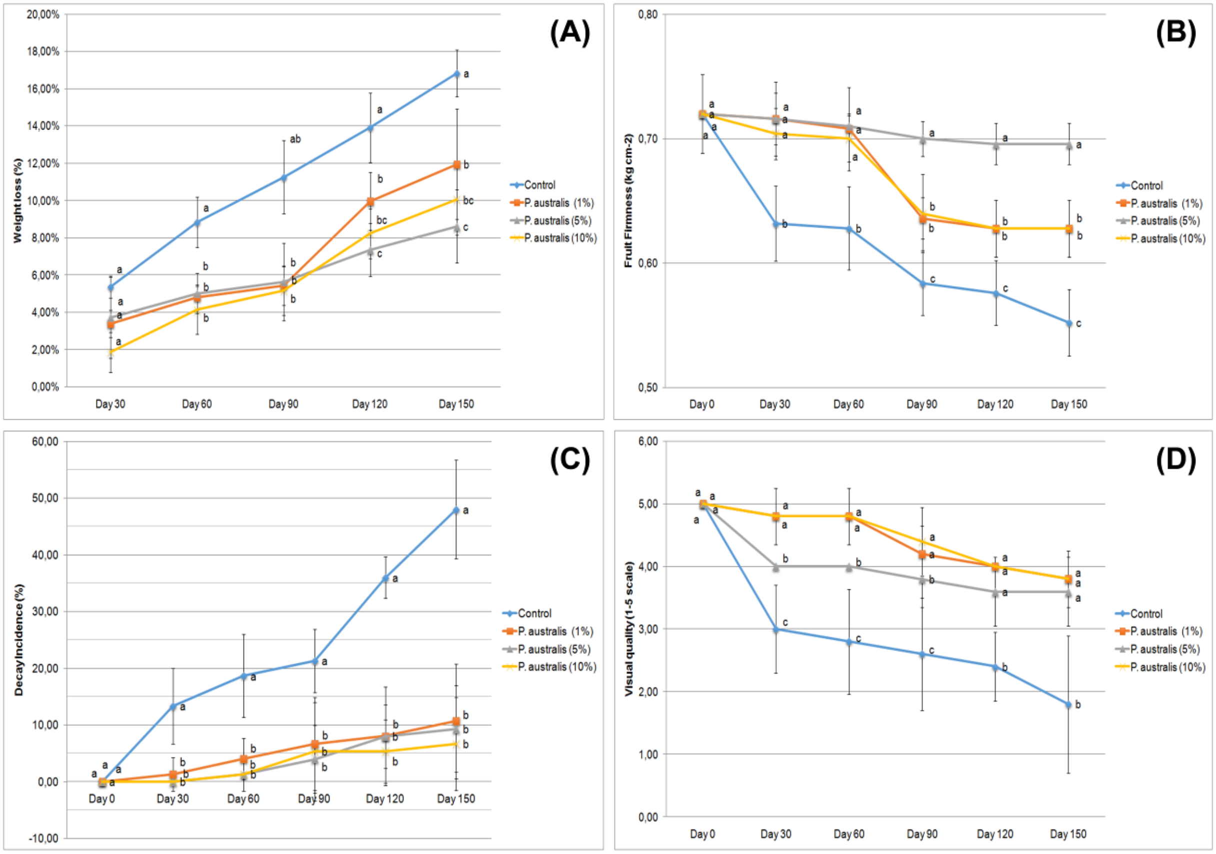

Figure 2. Change in the (A) weight loss, (B) fruit firmness, (C) decay incidence and (D) visual quality of Valencia oranges as affected by the different doses of *P. australis* root extracts. Same letters have been used on the figures to represent no significant difference (at $p \leq 0.05$) at the same storage duration

The changes in the visual quality of oranges were found to be in compatible with those findings (Figure 2D). The untreated control oranges were found to have the lowest quality where the fruits treated with different concentrations of *P. australis* root extracts had higher and acceptable visual quality. This finding is in accordance with the reports of Mohebbi et al. (2014) Sophia et al. (2015) and Supapvanich et al. (2016) who noted that edible coatings with different plant-derived products improve visual fruit quality. The maintenance of visual quality was reported to be related to the biosynthesis or inducement of some enzymes, i.e. polyphenol oxidase (PPO) and peroxidase (POD) (Maqbool et al., 2011; Sharma and Rao, 2015; Murmu and Mishra, 2018). However, it was noted by Gol et al. (2015) that, detailed further study requires identifying the exact mechanism of *P. australis* root extracts on the enzyme activities. Overall results of current research provided better results than the findings of Rehman et al. (2018) where they reported 90 days of acceptable storage quality by the application of methyl jasmonate.

SSC was found to have an increasing trend during the first days of storage and then decreased. However, no significant difference was obtained among the different treatments (Figure 3A). However, the fruit TA had a continuous decrease during storage, and *P. australis* root extracts were all effective in delaying this decrease. The initial TA content of the oranges was measured as 2.75 g 100 g^{-1} citric acid and was decreased to 1.19 g 100 g^{-1} citric acid at the untreated oranges in 150 days of cold storage (Figure 3B).

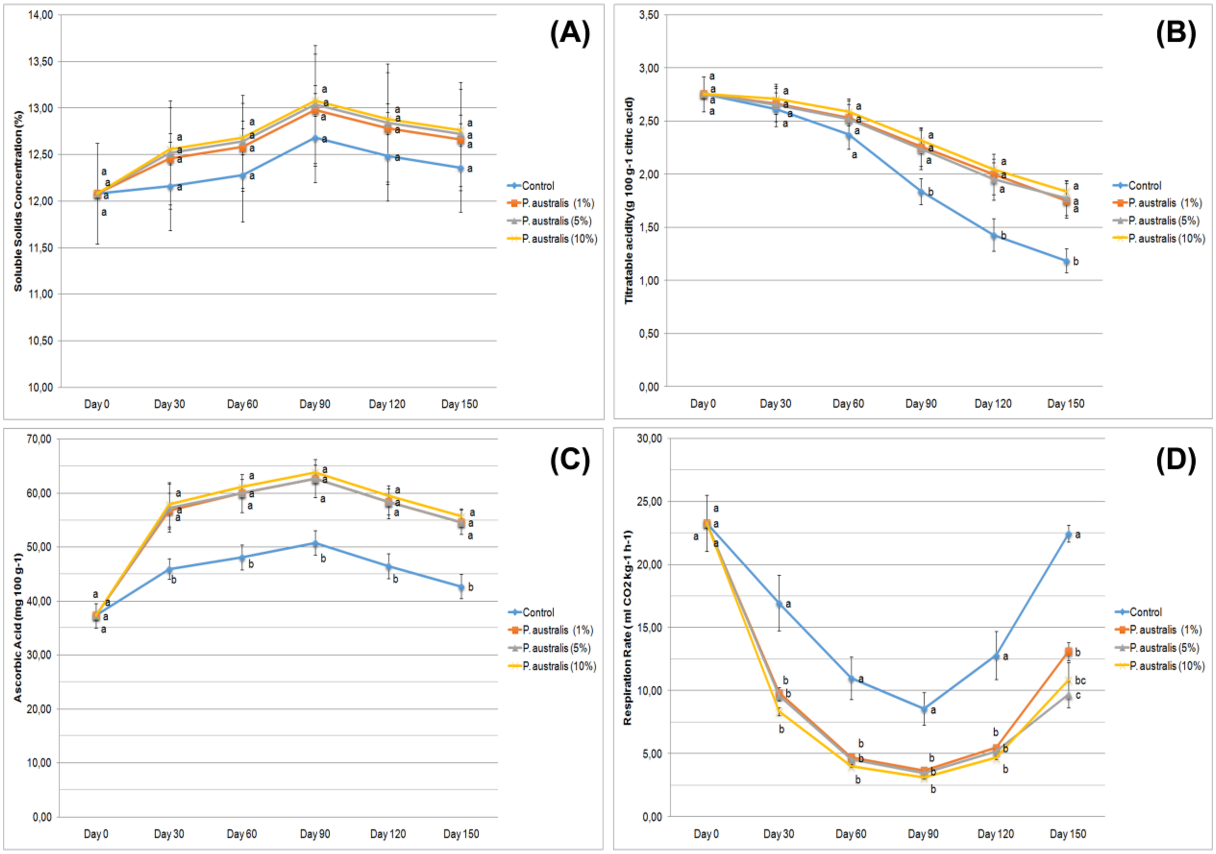

Figure 2. Change in the (A) soluble solids concentration, (B) titratable acidity, (C) ascorbic acid and (D) respiration rate of Valencia oranges as affected by the different doses of *P. australis* root extracts. Same letters have been used on the figures to represent no significant difference (at $p \leq 0.05$) at the same storage duration

On the other hand, the TA of the fruits treated with different concentrations of *P. australis* root extracts had a range from 1.75 to 1.84 g 100 g^{-1} citric acid. Furthermore, the AsA content of the fruits had an increasing trend during the first days of storage and then decreased, similar to the SSC. However, the treatments were now effective in the changes of AsA. The fruits treated with different concentrations of *P. australis* root extracts had higher AsA than control fruits (Figure 3C). One of the most important results of present study was the efficacy of *P. australis* root extracts for reducing the RR during cold storage. The RR of the Valencia oranges decreased during storage until the 90th day of storage and then had an increasing trend (Figure 3D). During this period, the fruits treated with the different concentrations of *P. australis* root extracts were all found to have lower RR than untreated control fruits. This explains the higher efficacy of *P. australis* root extracts for the prevention of weight loss and changes in other quality parameters. This result is in accordance with the general knowledge about the efficacy of plant-derived biomaterials (as edible coatings) for reducing RR of fruits (Kator et al., 2018; Kahramanoğlu et al., 2019). Dhall (2013) recommended that the concentrations of edible coatings play an important role in its efficacy. Similar results were obtained in present study and the different concentrations of the *P. australis* root extracts were found to have different efficacy. Generally, the efficacy was increased, as the concentration increased. However, higher concentrations also caused some reduction in the fruit firmness. Thus, the optimum concentration in present study was noted as 5% of *P. australis* root extracts.

Conclusions

The detailed evaluation of the results showed that the 5% concentration of the *P. australis* root extract had higher efficacy in maintaining the postharvest storability of Valencia oranges. All doses of *P. australis* root extracts were effective in reducing respiration rate of the stored fruits, which lead to the maintenance of fruit weight, fruit firmness, titratable acidity, ascorbic acid content, and visual quality. The extract was also effective in preventing decay incidence but a detailed study is highly necessary to understand the main mechanism behind these valuable results.

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