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Activity of salts incorporated in wax in controlling postharvest diseases of citrus fruit

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ABSTRACT

The role of some salts applied in combination with wax on the development of postharvest rots was examined on 'Tarocco' and 'Valencia late' oranges and 'Comune' Clementines. Sodium carbonate and bicarbonate, potassium carbonate and bicarbonate, ammonium bicarbonate, and potassium sorbate, at 6% concentration (w/v), in combination with a commercial wax, were evaluated for their activity against naturally occurring postharvest decay. Fruit were stored for one month at 4 °C ('Tarocco' and 'Valencia late' oranges) or 6 °C ('Comune' Clementine), followed by one week of shelf life at 20 ± 2 °C and high RH.

Most decay was from green and blue moulds, caused by *Penicillium digitatum* and *P. italicum*, respectively, with an average incidence of 11% for 'Comune' Clementines and 5% for both 'Tarocco' and 'Valencia late' oranges. Decay caused by *Botrytis cinerea* and *Alternaria* spp. was also observed. The incidence of postharvest rots on fruit treated with wax alone (11%) was higher than on those treated with water (7%), whereas in fruit treated with wax combined with different salts, decay incidence was significantly lower than with wax and water controls. In particular, potassium sorbate incorporated in wax significantly reduced the incidence of postharvest decay in all tested cultivars. The incidence of decay on fruit treated with imazalil was low, not exceeding 1%. Salts, except ammonium bicarbonate, interfered with the action of the wax to retard weight loss. The results indicate that the addition of the salts to wax may be an easy and effective mode of their application, since no additional equipment is needed.

1. Introduction

Green and blue moulds, caused by *Penicillium digitatum* (Pers.:Fr.) Sacc. and *P. italicum* Wehmer, respectively, are the most important postharvest diseases of citrus fruit. Currently, another species of *Penicillium*, *P. ulaiense* H.M. Hsieh, H.J. Su & Tzean, causing whisker mould, has been reported in several citrus producing areas (Holmes et al., 1993; Youssef et al., 2010), but its low level of virulence and late appearance in mixed infections make this decay of minor importance (Holmes et al., 1994).

The use of chemical fungicides remains the major means of control for managing citrus postharvest diseases (Eckert and Ogawa, 1988). However, their use is no longer recommended because of concerns regarding the potential impact on human health, environmental pollution, and lack of activity due to the development of fungicide resistant strains. Therefore, safe alternative treatments have become an essential requirement for the management of postharvest decay of fruit. In this perspective, aqueous solutions of some of the most common food additives, GRAS compounds, and low toxicity compounds have been widely tested, also in commercial trials for controlling postharvest diseases of fruit and vegetables (Youssef et al., 2008a; El-Mougy et al., 2008; Janisiewicz and Conway, 2010). The most important requirement of alternative antifungal postharvest treatments is that they must be cost-effective, provide consistent disease control under commercial conditions, and must be accepted by public opinion. However, constraints and obstacles associated with the use of alternative control means, including inconsistent activity, lack of preventive effect, limited persistence, risk of fruit injury, and issues in disposal of exhausted salt solutions (high pH, high salt content, etc.) can make their commercial application more difficult (Larrigaudiere et al., 2002; Palou et al., 2002; Smilanick et al., 2008). In addition, using some alternatives that utilize heated aqueous drenches or tanks require added costs of fabrication and the energy to operate them.

Combinations of alternative means to control postharvest diseases of fresh fruit and vegetables have recently been recommended by several authors (Palou et al., 2008; Sanzani et al., 2009; Janisiewicz and Conway, 2010) in order to overcome the problems related to their application as stand-alone treatments, and to attain commercially acceptable performance.

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The application of wax coatings is a critical operation in citrus fruit packinghouses, since it accomplishes a triple objective: (i) providing the required gloss on which aesthetic value or cosmetic appearance of fruit depends; (ii) protecting the fruit from water loss as the coating replaces natural wax which is removed to some extent during washing operations; (iii) acting as a carrier for fungicides, plant growth regulators such as 2,4-D, and biocontrol agents (Ladaniya, 2008). The effect of waxing on the incidence of postharvest rots apparently is not unique. An increase of stem-end rot and internal core rot caused by *Alternaria citri*, *Diplodia natalensis*, and *Fusarium* spp. was observed on citrus fruit treated with different commercial waxes, whereas a waxing treatment was found to reduce postharvest development of citrus black spot (Wild, 1981) and green and blue mould (Waks et al., 1985). In addition, higher concentrations of water waxes contribute to increased incidence of anthracnose (Ladaniya, 2008). In artificial inoculation experiments, El-Mougy et al. (2008) investigated the efficacy of different organic acids (ascorbic, benzoic, citric, and sorbic) and salts (potassium sorbate and sodium benzoate) mixed with wax, to determine their compatibility. The results showed various levels of either protective or curative effects on lemon fruit against sour rot, green, and blue mould infections.

According to the literature, only limited research has been conducted, under natural infection, to elucidate the ability of a mixed application of wax and food additives to retard the development of postharvest diseases of citrus during storage. The purpose of the present research was to test the activity of some salts applied in combination with a commercial wax on the development of postharvest diseases of Clementines and oranges. Trials on naturally infected fruit instead of fruit artificially infected were carried out to simulate actual commercial conditions. The effect of treatments on fruit weight loss was evaluated as well.

2. Materials and methods

2.1. Fruit samples

During 2008 and 2009, Clementines (*Citrus reticulata* Blanco), cv. Comune, and sweet oranges (*Citrus sinensis* [L.] Osbeck) cvs. Tarocco and Valencia late were obtained from different packinghouses located in Castellaneta (TA, Italy), selected for size uniformity, colour and absence of visible symptoms of diseases, disorders, and defects.

2.2. Salt/wax solutions preparation

Salts (Sigma–Aldrich, Milan, Italy) were dissolved manually in Citrashine® (Decco Italia s.r.l., Belpasso, CT, Italy), a commercial wax containing 18% solids, specially formulated with food additives: shellac (E904), polyethylene oxide (E914), coadjuvants and carrier solvents (fatty acids, ammonium hydroxide, casein, dimethyl polysiloxane and deionized water). Sixty grams of each salt was dissolved in 1000 mL of wax, to achieve a final concentration of 6% (Table 1). The pH of all the solutions was measured using Jenway 3510 bench pH-meter (Staffordshire, UK).

2.3. Fruit treatment and storage

Fruit were sprayed manually using plastic sprayers by about 1 mL/fruit on the two sides and allowed to dry for 2 h at room temperature. After drying, fruit were placed in five covered plastic boxes (each containing 40–50 fruit for Clementines and 20–25 fruit for oranges) per each treatment. Fruit were stored for one month at 4 °C (oranges) and 6 °C (Clementines) and 90–95% RH, followed by one week of shelf life at 20 ± 2 °C and high RH. Fungal decay was determined by counting the number of decayed fruit at weekly intervals during cold storage and shelf life. Incidence of decay was expressed as the percentage of infected fruit caused by fungal pathogens. Pathogens were visually identified and in case of doubt, isolations and morphological identification were carried out. Fruit were regularly weighed at the beginning and at the end of cold storage, and after one week of shelf life. The percentage of weight reduction was recorded. Each assay was repeated at least twice.

2.4. Statistical analysis

Data were arcsine transformed prior to analyses of variance (ANOVA). Mean values of treatments were compared using Fisher's protected least significant difference (LSD) and judged at $P \leq 0.05$ level using Statistica 6.0 software. Data in the graphs are untransformed percentage of decayed fruit.

3. Results

3.1. Effect of salts/wax on decay incidence

Major rots at the end of storage were due to *P. digitatum* and *P. italicum*, with an incidence of 11% for 'Comune' Clementines and 5% for both 'Tarocco' and 'Valencia late' oranges. The incidence of *P. ulaiense* infection was negligible and appeared at the end of the storage, especially on Clementines. Rots caused by *Botrytis cinerea* and *Alternaria* spp. showed an incidence, on the whole, lower than 1% on 'Tarocco' oranges and 3% on Clementines. The incidence of postharvest rots on Clementines, 'Tarocco' and 'Valencia late' fruit treated with wax alone was higher (14.0, 5.0, 12.3%, respectively) compared to fruit treated with water (11.0, 3.0, 6.7%, respectively; Fig. 1). On fruit treated with wax combined with some salts, rot incidence was significantly lower than wax and water controls.

In the first trial, conducted on Clementines, rot incidence in wax/sodium bicarbonate and wax/potassium sorbate treated fruit was significantly lower compared to water or wax controls and not different from imazalil in combination with wax (Fig. 1).

In the second trial carried out on 'Tarocco' fruit, sodium bicarbonate, potassium bicarbonate, potassium carbonate and potassium sorbate mixed with wax significantly reduced the incidence of postharvest rots. In particular, the combination wax/potassium carbonate, being the most effective treatment, completely suppressed rot incidence (Fig. 1).

In the third trial carried out on 'Valencia late' fruit, the combination wax/sodium carbonate, wax/ammonium bicarbonate, and wax/potassium sorbate was as effective as wax/imazalil. In particular, the combination wax/potassium sorbate was the best treatment even compared to the wax/imazalil treatment, reducing decay incidence by 100% (Fig. 1).

3.2. Weight reduction

Fig. 2 shows the percentage of weight reduction in the tested citrus fruit, as measured after 30 d of cold storage, followed by one week of shelf-life. Overall, results proved that in Clementines and 'Tarocco' oranges wax alone was significantly effective in reducing weight loss, as compared to the water control. All tested salts, except for ammonium bicarbonate, reduced the efficacy of the wax in limiting the weight loss.

4. Discussion

The aim of this research was to evaluate the efficacy of a mixed application of wax and some salts on the development of postharvest diseases during storage on three citrus cultivars, 'Comune'