Postharvest Biology and Technology 96 (2014) 7–13

Contents lists available at ScienceDirect

Postharvest Biology and Technology

journal homepage: www.elsevier.com/locate/postharvbio

Potassium sorbate effects on citrus weight loss and decay control

Javier Parra*, Gabriela Ripoll, Benito Orihuel-Iranzo*

Department of Postharvest Technology, Productos Citrosol S.A., Partida Alameda parcela C, 46721 Potries, Valencia, Spain

ARTICLE INFO

Article history:
Received 7 February 2014
Accepted 26 April 2014

Keywords:
Potassium sorbate
Penicillium digitatum
Citrus fruit
Wax
Weight loss
Decay control

ABSTRACT

Potassium sorbate (PS) is a well-known and widely used food preservative. Among other applications, it is used as a GRAS fungistatic postharvest treatment for citrus, although its use is not free of significant adverse effects. In this paper, we study in detail the efficacy of wax containing increasing concentrations of PS to control *Penicillium digitatum* decay in citrus fruit, and its effect on fruit weight loss. Decay control and weight loss increased with the concentration of PS in the wax. Wax with typical amounts of 2–5% PS showed poor decay reduction indices (DRI), between 26% and 32%, whereas fruit weight loss increased compared with non-waxed controls. Waxing of fruit reduced weight loss by up to 40%, depending on wax formulation, but the addition of just 2% PS to the wax caused an increase in fruit weight loss of up to 65% compared with the waxed fruit. Similar results were observed for all the types of wax formulations tested. The hygroscopic effects of PS are even more damaging for citrus fruit with leaves. The leaves lose weight very rapidly when PS is added to the wax and they become desiccated in 24 h.

We also present the results of a similar study where PS was applied to citrus as an aqueous treatment. When applied in water, PS was far more effective for decay control than when applied in wax, but there was also a considerable increase in fruit weight loss. A treatment combining aqueous PS with Fortisol® Ca Plus biostimulant completely solved the problem of weight loss, these mixtures being commercially feasible treatments.

1. Introduction

Citrus fruit are prone to postharvest decay, and although transport and storage conditions of fresh citrus have improved, mainly because of the use of refrigerated transport and cold rooms (Korsten, 2006), fungal diseases still produce significant economic losses (Smilanick et al., 2006). As a result of the big increase in citrus sold in pre-packings, i.e. in nets that sometimes contain up to 35 fruit, where just one decayed fruit can contaminate or cause decay in the whole package, citrus decay control has now become a harder task than in the past. In this scenario, the postharvest use of synthetic fungicides such as imazalil, ortho-phenylphenol, thiabendazole, or pyrimethanil, among others, is still the most effective way to achieve mold control in citrus fruit (Ismail and Zhang, 2004).

Green mold, *Penicillium digitatum*, and blue mold, *P. italicum*, are the major fungal pathogens that cause decay in citrus fruit in Spanish citrus shipments (Tuset, 1987), and in all citrus when grown in low summer rainfall areas (Palou et al., 2008b). It is well known that the highest efficacy in postharvest citrus decay control is achieved when the treatment is applied promptly after harvest (Chitzanidis, 1986; Wild and Spohr, 1989; Brown, 1999), usually as an aqueous treatment applied by drenching or water tank dipping. This first treatment is usually complemented by a second treatment on the packing line, commonly with wax containing fungicides.

However, because of reports about the deleterious effects of some synthetic chemicals on the environment and even on the health of consumers, there is a demand for the commercialization of chemical-free fruit. Fungicide-free decay control methods are needed, and treatments based on low-toxicity compounds could be a suitable alternative. These chemicals should have high decay control efficacy with minimal toxicity and environmental impact (Palou et al., 2008b).

The main low-toxicity chemical alternatives for citrus decay control are food additives (Palou et al., 2002b), inorganic salts (Palou et al., 2002a; Deliopoulos et al., 2010; Youssef et al., 2012b; Cerioni et al., 2013a,b), essential oils (Plaza et al., 2004; du Plooy et al., 2009; Combrinck et al., 2011; Perez-Alfonso et al., 2012; Castillo et al., 2014) and phytochemicals (Hao et al., 2010). Among the food additives, potassium sorbate (E-202), PS, is a widely used broad spectrum food preservative (Sofos, 1989; Stopforth et al., 2005). In 1978, it was first proposed to be used in citrus decay control of *P. digitatum* (Smoot and McCornack, 1978). Since then, aqueous PS has been described many times as an alternative

---

* Corresponding authors. Tel.: +34 96 280 05 12; fax: +34 96 280 08 21.
E-mail addresses: jparra@citrosol.com (J. Parra), borihuel@citrosol.com (B. Orihuel-Iranzo).

http://dx.doi.org/10.1016/j.postharvbio.2014.04.011
0925-5214/

postharvest treatment for citrus decay, often combined with synthetic fungicides and/or with heat, with the aim of increasing the efficacy of the treatment (Kitagawa and Tani, 1984; Palou et al., 2008a; Smilanick et al., 2008; Montesinos-Herrero et al., 2009; D'Aquino et al., 2013). Currently, aqueous PS is widely used in Spain and in other citrus exporting countries for the drenching of citrus fruit, and is incorporated into commercial waxes as an alternative method for decay control. PS is considered a GRAS substance (*Generally Recognized As Safe*) by the FDA (FDA, 1975) and it was approved by the EFSA as a food additive for surface treatment of citrus fruit (EFSA, 2010).

Wax coatings create a protective barrier that essentially has four expected properties: appearance improvement (providing shine and gloss), weight loss reduction, aging retardation, and, very frequently, additional decay control by the addition of chemically compatible fungicides to the wax (Kaplan, 1986; Eckert and Eaks, 1989; Hall and Sorenson, 2006). Recently, it has been reported that PS and sodium and potassium carbonate salts decrease the weight loss reduction capacity of waxes (Youssef et al., 2012a). When PS is added to the wax, equivalent weight loss is observed for waxed and non-waxed fruit. If weight loss reduction capacity disappears, then one of the most important properties of the wax is lost. For many citrus fruit shipments, weight loss can have more implications than just the economic loss in terms of weight and size (Hagenmaier and Shaw, 1992). Several authors link an excess of weight loss and peel water status to the advent of various rind disorders (Eckert and Eaks, 1989; Lafuente and Zacarias, 2006). Fruit firmness is also affected (Hagenmaier and Shaw, 1992), and, in general, 5–7% weight loss is considered by several authors a threshold for the fruit to become shriveled, soft, and unmarketable (Hagenmaier, 1998; Grierson and Miller, 2006).

The purpose of the present paper is to study in detail the advantages and disadvantages of using PS as an alternative chemical for citrus decay control, exploring its limitations, both in aqueous treatments and when incorporated into the wax, and paying special attention to weight loss and decay control. Studies on the effects of PS on citrus leaves are also reported. The results obtained allow us to envisage an appropriate use of PS, as well as provide a solution to overcome the adverse effects of this molecule when used as an aqueous treatment.

2. Materials and methods

2.1. Fruit samples

The citrus fruit ('Nova' mandarins, 'Valencia' and 'Navel' oranges) used in all the experiments were obtained directly from packing houses located in the Comunidad Valenciana (Spain) and they had not received any postharvest treatment. Citrus leaves (from 'Nova' mandarins) were collected from the tree in a nearby grove on the same day of the experiment.

2.2. Preparation of aqueous solutions and wax formulations

Citrosol A UE and Citrosol AS UE (both are emulsions of polyethylene oxide, E914, and shellac, E904), Citrosol AK UE (emulsion of carnauba, E903, and shellac, E904), and Citrosol A (emulsion of polyethylene oxide, E914, and rosin) water waxes (Citrosol A wax complies with US and Canadian legislation and waxes with the UE acronym also comply with European Union legislation), Essasol biodegradable detergent (4% sodium dodecylbenzenesulfonate), Citrosol 500 (50% emulsionable imazalil), Citrosol 7.5 LS (7.5% imazalil sulfate), and Fortisol® Ca Plus biostimulant (proprietary formulation of phosphorous, calcium, and potassium salts) were from Productos Citrosol S.A. (Potries, Valencia, Spain). PS was purchased from Ter Hell & Co. GmbH (Hamburg, Germany).

PS samples were prepared by dissolving the appropriate amount of PS directly, with mechanical stirring, either in water or in the various waxes, at room temperature. Similarly, imazalil formulations were prepared by dissolving the appropriate amount of Citrosol 500 or Citrosol 7.5 LS in waxes or water, respectively.

2.3. Fruit treatments and determination of decay reduction index (DRI) and weight loss control (WLC)

Fruit were randomized, cleaned with 6% (v/v) Essasol, rinsed with tap water, and dried at room temperature before use in the waxing experiments. In the case of water dipping experiments, fruit were randomized before application of treatments.

Citrus fruit decay experiments were performed with 4 replications of 25 fruit per treatment. Fruit were artificially inoculated by wounding each fruit with a steel rod (1 mm diameter wide and 2 mm long) previously immersed in a conidial suspension of *P. digitatum* (7×10^6 cfu/mL). After 17 h, fruit were either waxed (1 L wax/1000 kg of fruit) in a commercial waxing unit or dipped in the aqueous treatment 15 L tank for 30 s. After the treatments, waxed fruit were dried with hot air whereas water-dipped fruit were allowed to dry at room temperature, simulating industrial operations. Dried fruit were placed in trays, stored for 1 week at 20 °C and 85% relative humidity (RH), and then decayed fruit were counted and expressed as a percentage. Decay reduction indices (DRIs) were calculated as follows: 100 × (no. of decayed fruit in the control – no. of decayed fruit in the treatment)/no. of decayed fruit in the control.

Citrus fruit weight loss experiments were carried out with 4 replicates of 5 fruit per treatment. Fruit were selected with absence of defects or injuries, numbered, and treated as previously described with the different waxes or aqueous solutions. In order to study both decay control and weight loss with the same fruit and in the same conditions, each set of non-inoculated fruit was randomly mixed with a set of inoculated fruit and the whole set of fruit was treated at the same time. Treated non-inoculated fruit were placed into trays and stored for 1 week at 20 °C and 60% RH. Weight of individual fruit was recorded just after the treatment, and then after 2, 5, and 7 days. Weight loss for each day was calculated for each individual fruit as % weight loss referenced to the initial weight of the fruit, immediately after treatment [100 × (initial weight – weight)/initial weight]. Weight loss rate was expressed as % weight loss/day and was obtained from the slope of the % weight loss vs. time (days) plot. Weight loss control (WLC) was calculated as: 100 × (weight loss rate in the control – weight loss rate in the treatment)/weight loss rate in the control.

Additionally, two industrial PS wax samples from other manufacturers were given to us by packing house managers, analyzed for PS content by HPLC-DAD, and used as described above to determine DRI and WLC.

2.4. Leaf resistance and weight loss measurements

Citrus leaves were randomized, cleaned with 6% (v/v) Essasol, rinsed with tap water, and dried at room temperature before use in the waxing experiments. Experiments were carried out with sets of 15 leaves per treatment. Leaves were waxed manually, using the same dose as in the waxing line, dried with hot air, simulating an industrial operation, and stored for 4 days at 20 °C and 60% RH.

The weight of 10 individual leaves was recorded just after waxing, and then after 1, 2, 3, and 4 days. Weight loss for each day was calculated for each single leaf as % weight loss referenced to the initial weight of the leaf, immediately after waxing [100 × (initial weight – weight)/initial weight]. In addition, photographs of the