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Development and control of scald on wonderful pomegranates during long-term storage

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Abstract

Scald of the husk surface is an important factor limiting long-term storage of pomegranates and little information is available about its cause and methods of control. We evaluated the efficacy of prestorage treatment with diphenylamine and/or 1-methylcyclopropene and of atmospheric modification during storage on scald incidence and severity on Wonderful pomegranates.

Scald incidence and severity were greater on pomegranates harvested during late season than on those harvested during mid season, indicating that this disorder may be associated with senescence. All pomegranates from both harvests that were kept in air exhibited some scald after 4–6 months at 7 °C. Neither diphenylamine, at 1100 or 2200 μL L^{-1}, nor 1-methylcyclopropene at 1 μL L^{-1}, alone or together reduced scald incidence and severity. In contrast, the three controlled atmosphere (CA) storage conditions tested (1 kPa O_2, 1 kPa O_2 + 15 kPa CO_2 and 5 kPa O_2 + 15 kPa CO_2) significantly reduced scald incidence and severity on pomegranates from both harvest dates for up to 6 months at 7 °C. However, the two CA treatments with 1 kPa O_2 resulted in greater accumulation of fermentative volatiles (acetaldehyde, ethanol, and ethyl acetate) than the CA treatment with 5 kPa O_2, especially in the mid-season-harvested pomegranates. In addition to its fungistatic effects, 15 kPa CO_2 appears to be critical for inhibition of scald development on pomegranates. These results confirm recommendation by Hess-Pierce and Kader (2003) of 5 kPa O_2 + 15 kPa CO_2 (balance N_2) as the optimal CA for pomegranates at 7 °C and 90–95% relative humidity. Since very little if any α-farnesene or its conjugated trienol oxidation products were found in the peel of pomegranates, it appears that the biochemical basis of scald in pomegranates is different from that in apples. CA storage (5 kPa O_2 + 15 kPa CO_2) decreased or prevented changes in carotenoid, acyl lipid, and phenylpropanoid metabolism that were associated with scald development in stem-end peel tissue of air-stored fruit and are indicative of stress and/or senescence.

Keywords: *Punica granatum*; Physiological disorder; Controlled atmosphere; 1-MCP; DPA

1. Introduction

Appearance, especially red color, is an important quality factor for marketing fresh pomegranates. Many factors affect appearance, including bruising, water loss, decay, and the development of physiological disorders during storage (Elyatem and Kader, 1984). In general, the major cause limiting the storage potential of pomegranates is the development of decay, which is often caused by the presence of fungal inoculum in the blossom end of the fruit (Hess-Pierce and Kader, 2003). This problem is aggravated at temperatures higher than 5 °C, which are recommended for pomegranates to avoid chilling injury (internal tissue browning). For long-term storage, scald of the husk surface is another factor limiting storage life (Ben-Arie and Or, 1986). Scald symptoms appear as a superficial (skin) browning, similar to superficial scald of apples, and generally develop from the stem end of the fruit, spreading toward the blossom end as the severity increases. Moreover, husk scald increases the susceptibility of the fruit to decay.

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Several postharvest conditions have been evaluated for long-term storage of pomegranates, including low temperature, delayed harvest (Ben-Arie and Or, 1986), intermittent warming (Artés et al., 1998) and controlled atmosphere (CA) (Ben-Arie and Or, 1986; Artés et al., 1996; Hess-Pierce and Kader, 2003). Among these procedures, the most successful in reducing decay and physiological disorders is the use of CA storage, which, with a combination of 5 kPa O_2 and 15 kPa CO_2, has been shown to extend pomegranate postharvest life for up to 5 months at 7 °C (Hess-Pierce and Kader, 2003). This combination also avoids the accumulation of high levels of ethanol, observed under CA conditions with lower levels of oxygen, which limits the marketability of the fruit (Ben-Arie and Or, 1986).

Despite the importance of husk scald, little information is available about its origin and mechanisms of control during long-term storage of pomegranates. Studies performed by Ben-Arie and Or (1986) suggested that scald symptoms may be caused by the enzymatic oxidation of *o*-dihydroxyphenols during storage, but the biochemical changes that conclude with enzymatic browning remain unclear. The similarities between pomegranate scald and apple scald, in terms of symptomatology and occurrence, suggest that the two disorders may be similar in the biochemical causes and mechanism of control. It is generally accepted that apple scald is an oxidative stress disorder involving conjugated triene oxidation products of the sesquiterpene α-farnesene (Whitaker, 2004). The disorder has long been controlled by treatment with the antioxidant diphenylamine (DPA) and/or low oxygen CA storage (Ingle and D'Souza, 1989), and more recently by treatment with the blocker of ethylene action 1-methylcyclopropene (1-MCP) (Watkins et al., 2000; Zanella, 2003).

The development of more sensitive analytical tools and the availability of new products that can control scald in apple (Whitaker et al., 1997; Zanella, 2003) led us to re-examine this disorder in pomegranates. Therefore, the objective of this work was to evaluate the efficacy of DPA, 1-MCP (SmartFresh™, AgroFresh Inc., Spring House, PA), and low oxygen atmospheres in controlling incidence and severity of scald on 'Wonderful' pomegranates during long-term storage.

2. Materials and methods

2.1. Plant material

Freshly harvested, sorted, and packed 'Wonderful' pomegranates from a packinghouse near Fresno, California were brought to the Postharvest Laboratory at the University of California at Davis. Two harvest dates were evaluated; a mid-season harvest on 20 October, and a late-season harvest on 18 November (2003) (Table 1). Before postharvest treatments, the pomegranates were sorted and those with surface blemishes and other defects were discarded.

Table 1
Comparison of maturity indices (soluble solids, pH, titratable acidity and color) between mid- and late-season harvested 'Wonderful' pomegranates

Quality parameters	Harvest time	
	Mid season	Late season
Soluble solids content (%)	15.7 ± 0.3	17.0 ± 0.3
Titratable acidity (%)	1.2 ± 0.1	1.2 ± 0.1
pH	3.2 ± 0.0	3.3 ± 0.1
Aril color		
L value	47.8 ± 1.2	44.7 ± 4.1
Chroma	48.4 ± 1.0	48.6 ± 3.6
Hue angle	27.7 ± 1.1	24.5 ± 2.4

Data shown are means of three replicates ± S.E.

2.2. Treatments tested

The eight treatments tested for scald control are listed in Table 2. For each CA treatment, 6 boxes (30 fruit each) of pomegranates were placed into a 0.3 m^3-stainless steel container that was ventilated with either humidified air or the desired gas mixture for each CA treatment at 7 °C. The ethylene action inhibitor, 1-MCP (SmartFresh™, AgroFresh Inc., Philadelphia, PA), was applied in 0.3 m^3 gas-tight containers at 7 °C for 24 h. 1-MCP was generated with "Light Orange SmartFresh™ Research Tablets" with a Blue Activator Tablet and Activator Solution as suggested by Agrofresh. Pomegranates treated with DPA were dipped in the solution for 3 min and air dried at 20 °C before storage. Pomegranates were evaluated after 2, 3, 4, 5 and 6 months to determine their marketability based on visual external and internal quality. After removal from storage, fruit were kept at 20 °C for 4 days to simulate marketing conditions before final quality evaluations.

2.3. Maturity and quality parameters

At harvest, 3 replicates of 10 fruit each were evaluated for compositional analysis. Arils were squeezed through cheesecloth and pH, titratable acidity (TA) and soluble solids content (SSC) were measured. SSC was measured using a refractometer (Abbe refractometer model 10450, American Optical, Buffalo, NY). Four grams of juice diluted with 20 mL of distilled water were titrated to pH 8.1 with 0.1N NaOH

Table 2
Treatments tested for control of scald on pomegranates

Treatment	Details
Control	No treatment, stored in air
CA-1	1 kPa oxygen + 99 kPa nitrogen
CA-2	1 kPa oxygen + 15 kPa carbon dioxide + 84 kPa nitrogen
CA-3	5 kPa oxygen + 15 kPa carbon dioxide + 80 kPa nitrogen
DPA-1	1100 μL L^{-1} DPA for 3 min, stored in air
DPA-2	2200 μL L^{-1} DPA for 3 min, stored in air
1-MCP	1 μL L^{-1} 1-MCP for 24 h at 7 °C, then stored in air
1-MCP + DPA	1 μL L^{-1} 1-MCP for 24 h at 7 °C and dipped in 1100 μL L^{-1} DPA for 3 min, stored in air