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Postharvest Biology and Technology 39 (2006) 247–253

Postharvest Biology and Technology

www.elsevier.com/locate/postharvbio

Effect of calcium dips and chitosan coatings on postharvest life of strawberries (*Fragaria* x *ananassa*)

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Received 7 July 2005; accepted 22 November 2005

Abstract

Strawberries (*Fragaria* x *ananassa* Duch.) were treated either with 1% calcium gluconate dips, 1.5% chitosan coatings or with a coating formulation containing 1.5% chitosan + 1% calcium gluconate and stored at 20 °C for up to 4 days. The effectiveness of the treatments was assessed by evaluating their impact on the following parameters: fungal decay incidence, loss of weight, firmness, external color, pH, titratable acidity and soluble solids content. Calcium dips were effective in decreasing surface damage and delaying both fungal decay and loss of firmness compared to untreated fruit. No sign of fungal decay was observed in fruit coated with 1.5% chitosan which also reduced fruit weight loss. Chitosan coatings markedly slowed the ripening of strawberries as shown by their retention of firmness and delayed changes in their external color. To a lesser extent titratable acidity and pH were also affected by coatings. Whilst addition of calcium gluconate to the chitosan coating formulation did not further extend the shelf-life of the fruit, the amount of calcium retained by strawberries was greater than that obtained with calcium dips alone, thus resulting in increased nutritional value of the strawberries.

Keywords: Strawberry; Chitosan coating; Calcium gluconate; Fungal decay; Quality

1. Introduction

Strawberry is a non-climacteric fruit with a very short postharvest life. Loss of quality in this fruit is mostly due to its relatively high metabolic activity and sensitivity to fungal decay, mainly gray mold (*Botrytis cinerea*). Strawberries are also susceptible to water loss, bruising and mechanical injuries due to their soft texture and lack of a protective rind.

Refrigeration is widely used to reduce spoilage and extend the shelf-life of fresh fruit and vegetables. In order to slow down metabolism and reduce deterioration prior to transport or storage strawberries are cooled to 0 °C after harvest. The postharvest life of strawberries can be extended by several techniques combined with refrigeration. The beneficial effect of heat treatment on storage and the inhibition of fungal decay in strawberries have been reported by several authors (García et al., 1995; Civello et al., 1997; Vicente et al., 2002). Recently, biologically active natural products have become an effective alternative to synthetic fungicides as a means to control fungal decay (Spadaro and Gullino, 2004; Tripathi and Dubey, 2004). Modified atmospheres of low O_2 concentration and high CO_2 concentration have been shown to be very effective at inhibiting microbial growth and reducing the decay of fresh produce, among them strawberries (Kader et al., 1989; Agar et al., 1990; Smith and Skog, 1992; Harker et al., 2000). Modified atmosphere storage can, however, adversely affect strawberry color (Holcroft and Kader, 1999) and its influence on flavor preservation in this fruit is not clear (Pelayo et al., 2003). Other authors have also reported that prolonged exposure of strawberries to high CO_2 concentrations can cause off-flavor development (Li and Kader, 1989; Ke et al., 1994).

It is well known that calcium plays a major role in maintaining the quality of fruit and vegetables. Increasing the calcium content in the cell wall of fruit tissue can help to delay softening and mold growth and decrease the incidence of physiological disorders (Poovaiah, 1986). Dipping and

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0925-5214/$ – see front matter
doi:10.1016/j.postharvbio.2005.11.006

vacuum or pressure infiltrations are common techniques used to increase cell wall calcium content of fruit tissue after harvest. The firming effect can be explained by the formation of crosslinks between the carboxyl groups of polyuronide chains found in the middle lamella of the cell wall; calcium also increases cell turgor pressure (Mignani et al., 1995; Mastrangelo et al., 2000) and stabilizes the cell membrane (Picchioni et al., 1995). Calcium dips have been employed to improve firmness and extend the postharvest shelf-life of a wide range of fruit and vegetables. With regard to strawberries, several authors have reported that $CaCl_2$ dips in combination with heat treatment or modified atmosphere storage and refrigeration increase calcium content and fruit firmness and delay postharvest decay (Rosen and Kader, 1989; Garcia et al., 1996; Bitencourt de Souza et al., 1999). Although $CaCl_2$ exerts a beneficial effect on fruit texture it has been reported to impart bitterness (Monsalve-Gonzalez et al., 1993). Organic calcium salts are an alternative calcium source and calcium lactate has been described in the literature as a firming agent for several fruit (LaCerda et al., 1999). According to Lawless et al. (2003), the bitter and salty tastes associated with calcium chloride are largely suppressed when calcium is combined with larger organic ions such as lactate, gluconate or glycerophosphate. In addition, organic acid salts of calcium such as citrate, lactate and gluconate are more bioavailable than the inorganic salts and enhance the nutritional value of foods (LabinGoldscher and Edelstein, 1996).

In recent years, much attention has been paid to the potential of natural polymers such as polysaccharides and proteins in food packaging applications. Most of these macromolecules can be processed into films or applied as fruit surface coatings to reduce respiration and transpiration rates due to their high permselectivity (CO_2/O_2) coefficient and partial moisture barrier. They also improve the mechanical handling properties of the produce and help maintain its structural integrity (Baldwin, 1994).

Chitosan (poly β-(1, 4)*N*-acetyl-D-glucosamine) is a polycationic biopolymer industrially produced by chemical deacetylation of chitin which is found in arthropod exoskeletons although it can also be obtained directly from the cell walls of some plant-pathogenic fungi. Chitosan and its derivatives have been shown to inhibit the growth of a wide range of fungi (Allan and Hadwiger, 1979). They can also trigger defensive mechanisms in plants and fruit against infections caused by several pathogens (El Ghaouth et al., 1994). Preharvest chitosan sprays on strawberries have been effective in inhibiting fungal growth and maintaining fruit quality (Bhaskara Reddy et al., 2000). Several authors have reported beneficial effects of this biopolymer as a coating on products including bell pepper (El Ghaouth et al., 1997), strawberry fruit (El Ghaouth et al., 1991, 1992a; Zhang and Quantick, 1998; Han et al., 2004; Devlieghere et al., 2004), papaya fruit (Bautista-Banos et al., 2003) and tomatoes (El Ghaouth et al., 1992b). Recent studies on the sensory evaluation of chitosan-coated strawberries have reported that chitosan solution prepared at a low acid concentration did not change astringency of the fruit. Chitosan coatings did not change consumer acceptance of strawberries stored for one week at 2 °C (Han et al., 2005).

Edible coatings have been reported to be more effective at delaying the ripening of fruit and vegetables at room temperature than under cold storage (Amarante and Banks, 2001). However, there are few studies regarding the effect of edible coatings on strawberry quality during storage under unrefrigerated conditions. In the current work the effects of several treatments comprising postharvest calcium gluconate (CaGl) dips, chitosan coating or the incorporation of CaGl into the coating formulation are studied on fungal decay and the fruit quality attributes of strawberries stored at 20 °C for up to 4 days.

2. Materials and methods

2.1. Fruit material

Strawberries (*Fragaria ananassa* Duch. cv Camarosa) were purchased from a local market. Fruit was harvested and shipped from Palos de la Frontera (Huelva, Spain) in a refrigerated truck the previous day and stored at 2 °C until use in experiments. Strawberries were sorted to select those with 2/3 of their red color, being of uniform size and free of physical damage and fungal infection. A total of 725 berries were used for each treatment as specified below.

2.2. Edible coating formulations

Acetic acid, CaGl and crab-shell chitosan were purchased from Sigma Chemical Co. (St. Louis, MO, USA). Coating solutions were prepared by dissolving 1.5% chitosan in 0.5% acetic acid solution. Chitosan coatings containing CaGl were prepared by dissolving the calcium salt at 1% in water prior to the incorporation of the acetic acid and 1.5% chitosan.

2.3. Sample treatment

Strawberries were randomly distributed into four groups and each group was assigned to one of four treatments. Strawberries were immersed for 5 min in 1.5% chitosan solution; chitosan–CaGl solution (1.5–1%); CaGl 1% or in a water control and individually removed. Strawberries were allowed to dry for 2 h at room temperature and 50% relative humidity. After drying, fruit was stored at 20 °C and 70% relative humidity.

2.4. Loss of visual quality

The loss of fruit due to fungal decay was established by visual inspection on alternating days during the storage period. Strawberry fruit showing surface mycelial