Browning Inhibition of Fresh-cut 'Anjou', 'Bartlett', and 'Bosc' Pears

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Abstract. Treatments to inhibit browning and maintain quality of fresh-cut 'Anjou', 'Bartlett', and 'Bosc' pears (*Pyrus communis* L.) were developed. Slices of 'Anjou', 'Bartlett', and 'Bosc' pears (firmness 22, 36, and 22 N, respectively) were dipped in solutions of 4-hexylresorcinol, isoascorbic acid, N-acetylcysteine, and potassium sorbate prior to storage in air for up to 14 days at 5 °C. Inhibition of browning without loss of firmness and with no microbial growth was achieved for the three cultivars for 14 d. Inhibition of browning during 14 d storage at 5 °C was not affected by initial firmness (21–52 N) of 'Anjou' pear slices.

While fresh-cut vegetables are an important part of the produce industry, fresh-cut fruits are not (Schlimme, 1995). Difficulties in controlling the very rapid onset of enzymatic browning, as well as textural changes associated with deterioration, have limited the shelf-life of fruits that might be used as fresh-cut products (Brecht, 1995). Enzymatic browning of apple (*Malus × domestica* Borkh.) slices can be eliminated by use of modified atmosphere packaging (MAP) in which oxygen levels are very low (Gorny, 1997), but such levels can result in anaerobic respiration and flavor deterioration (Luo and Barbosa-Canovas, 1996). Browning can also be controlled by application of chemicals although use of sulfites was prohibited on fresh-cut fruit (Food and Drug Administration, 1986). Sulfite substitutes, including commercial products containing ascorbic or isoascorbic acids (reducing agents), citric acid, or other complexing agents, have been intensively investigated. A more recent approach has been to employ inhibitors of polyphenol oxidase (PPO), such as 4-hexylresorcinol, derived from natural products and classified by the Food and Drug Administration as generally regarded as safe (GRAS) (McEvily et al., 1992), as components of anti-browning treatments. Cysteine and its derivatives were found to be very effective inhibitors of pear PPO (Siddiq et al., 1994). Using 4-hexylresorcinol in combination with N-acetylcysteine (a dietary supplement),

isoascorbic acid, and calcium propionate (an inhibitor of microbial growth) extended the shelf-life of fresh-cut 'Delicious' apple slices in cold storage for several weeks without use of MAP (Buta et al., 1999).

Recently, interest has been expressed in the marketing of fresh-cut pear slices, especially of the Anjou cultivar, which can be stored for long periods during the year. As with apples, the control of enzymatic browning has been the major obstacle to introduction of fresh-cut pears. Many of the treatments used on apple slices were tested on pear slices without great success. Browning of the cut surfaces of 'Bartlett' pears occurred in an atmosphere of 0.25% O₂ and treatment with calcium chloride was necessary to prevent browning during 9 d at 5 °C (Gorny et al., 1998). Other effective treatments were found to be combinations of 4-hexylresorcinol, sodium isoascorbate, and calcium chloride and subsequent cold storage under MAP conditions (Sapers and Miller, 1998). However, browning was controlled only in 'Anjou' and 'Bartlett' but not in 'Bosc' pears.

This study was undertaken to investigate the inhibition of browning and textural changes in slices of three pear cultivars using the natural products and derivatives that prevented browning of apple slices without the use of MAP conditions. In addition, a more detailed investigation evaluated the effectiveness of the treatments on 'Anjou' pears with different degrees of initial firmness.

Materials and Methods

'Anjou', 'Bartlett', and 'Bosc' pears were obtained from local food stores during their seasons of availability for the initial experiments on inhibition of browning. The effects of processing manipulations, such as blotting or centrifugation to remove excess treatment solutions, were also studied using the same fruit.

The intact fruit were surface-sterilized by immersion in a 5% v/v solution of Clorox®

(sodium hypochlorite 5.25%) containing 0.5% w/v Tween 20® surfactant for 30 s. The air-dried pears were sliced transversely to 5 mm thickness using an electric slicer, and the slices were cored and halved. Each replicate contained two halves of slices from different pears. The slices were dipped in several combinations of solutions of N-acetylcysteine, calcium propionate, 4-hexylresorcinol, isoascorbic acid, potassium sorbate (inhibitor of microbial growth), and propyl gallate for 30 s. They were then placed in petri dishes which were wrapped loosely with Parafilm® to minimize moisture loss and stored at 5 °C. Visual observations of anti-browning effectiveness were made.

Expt. 1. After preliminary determination of the most effective anti-browning solutions, slices of 'Anjou', 'Bartlett', and 'Bosc' (with initial slice firmness of 22, 36, and 22 N, respectively—averages of single measurements on 12 slices) were dipped for 30 s into the following test solutions adjusted to pH 5.5 with KOH: RA = 4-hexylresorcinol (0.001 M) + isoascorbic acid (0.5 M); RAS = same as RA + potassium sorbate (0.05 M); RASC = same as RAS + N-acetyl-cysteine (0.025 M). Control slices were dipped in water. Two replicates of two slices per treatment were used; each slice in a treatment was obtained from a different pear. After dipping, the slices were immediately placed in petri dishes, or blotted on white absorbent tissue, or manually centrifuged for 1 min in a salad spinner before placement in storage at 5 °C. The experiment was repeated three times. The extent of browning was measured with a CR-300 Chroma Meter (Minolta Instrument Systems, Ramsey, N.J.). Color measurements were made through the bottom of the petri dish at 0, 7 and 14 d with L* (lightness) and a* (green to red) values being recorded. A decrease in the value of L* indicates darkening; increase in the value of a* was visually related to increased browning.

Slice firmness was measured as maximum force required to puncture the approximate center of the slice to a depth of 3 mm with a 4-mm diameter cylindrical probe loaded at 1 mm·s⁻¹ in a universal testing (force/deformation) instrument (Stable Microsystems Texture Analyzer, Surrey, U.K.).

Expt. 2. The effects of the treatments in inhibiting browning of fresh-cut slices of pears varying in initial firmness (ripeness) were investigated using 'Anjou' pears that were available commercially. The fruit had been stored by the wholesale merchant at 4 to 5 °C and were placed in 0 °C storage prior to use. Slices of different degrees of firmness were obtained by ripening fruit at 15 °C and withdrawing fruit daily to be sliced. Several lots of pears were needed to obtain a broad range of fruit firmness, because the rate of fruit softening was rapid even though the fruit had been stored at 0 °C. Initial fruit firmness was determined with a Magness-Taylor tester using an 8-mm probe on two pared surfaces of each of three pears. Browning inhibition was investigated by dipping the slices in a solution of RAS for 30 s before centrifugation for 1 min

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and then wrapping them in petri dishes for storage at 5 °C. Two experiments totaling sixteen treatments were done using pear slices ranging from 21 to 52 N in five replicates of two slices per dish for each daily treatment. Color was measured daily from 0 to 14 d with L^* and a^* values being recorded.

Results and Discussion

Expt. 1. L^* values of the slices of the three cultivars were not affected by anti-browning treatments and centrifugation during 14 d storage at 5 °C (data not shown). Similar effects were found with slices of the three cultivars that were dipped but not centrifuged. Removal of the excess liquid by centrifugation was expected to be beneficial as less free moisture would be available to support microbial growth; however, blotting diminished the effectiveness of the anti-browning treatments (data not shown). Therefore, only the effects on slices that had been centrifuged are considered further.

Anti-browning treatments were effective as indicated by smaller increases in a^* values in all three cultivars during 14 d at 5 °C (Fig. 1). The most effective treatment was RAS, indicating that the addition of cysteine derivatives was unnecessary, unlike the results obtained with apple slices (Buta et al., 1999). The treatments inhibited browning of both the cut flesh and the edges of the skin. The magnitude of inhibition was inversely proportional to the browning susceptibility of the cultivars. Less effect was shown in 'Bartlett' pears, which

had little browning during 14 d at 5 °C. Spanos and Wrolsted (1992) reported that 'Bartlett' contained one-half of the phenolic levels found in the other two cultivars, while no comparison of relative PPO activity was presented. The inhibition attained in 'Bosc' slices contrasted with a previous report of a lack of browning inhibition in this cultivar (Sapers and Miller, 1998), although inhibition in 'Anjou' was achieved using $\approx 1/2$ the concentration of isoascorbic acid and similar concentrations of 4-hexylresorcinol used in our study, together with calcium chloride and subsequent MAP storage.

Slices from the RASC treatment were significantly ($P \leq 0.01$) firmer after 14 d at 5 °C

than control slices, while those from RAS and RA were intermediate for the three cultivars (Table 1). Although 'Bartlett' pears were firmer than 'Anjou' or 'Bosc' ($P \leq 0.01$), cultivar did not affect the response to treatments ($P = 0.20$). Methods of processing (dipping, dipping and blotting, or dipping and centrifugation) did not affect responses ($P = 0.73$).

Senesi et al. (1999) found that respiration of slices continued during 15 d of storage at 3 °C with no change in firmness of slices treated with 0.05 M ascorbic acid; however, the decline in firmness of untreated slices was cultivar-dependent. Gorny et al. (1998) found that storage at 5 °C of fresh-cut 'Bartlett' slices in 5% CO_2 for 9 d increased browning and

Table 1. Effect of chemical treatments on firmness (F_{max})² of pear slices after 14 d at 5 °C following dipping and centrifugation. (Expt. 1).

Treatment ¹	Cultivar			Main effect means separation ³
	Anjou	Bartlett	Bosc	
Water	18.4	30.9	14.8	a
RA	18.9	35.6	18.1	ab
RAS	21.4	30.6	21.5	ab
RASC	21.2	36.2	22.6	b

²Maximum force (F_{max} , in N) required to puncture the slices to a depth of 3 mm with a 4-mm diameter cylindrical probe loaded at 1 mm·s⁻¹ in a universal testing (force/deformation) instrument.

³RA = 4-hexylresorcinol (0.001 M) + isoascorbic acid (0.5 M); RAS = same as RA + potassium sorbate (0.05 M); RASC = same as RAS + N-acetyl-cysteine (0.025 M).

⁴Mean separation for treatment effects (over all cultivars). Means not followed by the same letter are significantly different based on Tukey's HSD test at the 1% level.

Fig. 1. Effect of anti-browning treatments on a^* values of 'Anjou', 'Bartlett' and 'Bosc' pear slices during storage at 5 °C. Treatments: RA = 4-hexylresorcinol (0.001 M) + isoascorbic acid (0.5 M); RAS = same as RA + potassium sorbate (0.05 M); RASC = same as RAS + N-acetylcysteine (0.025 M); Water. Error bars represent $\pm$ SE ($n = 12$).

Fig. 2. Effect of 0.001 M 4-hexylresorcinol + 0.5 M Isoascorbic acid + 0.05 M potassium sorbate on the a^* values of 'Anjou' pear slices of different degrees of initial firmness (N) during 14 d of storage at 5 °C. Error bars represent $\pm$ SE (n = 10).

tissue necrosis. Firmness declined 55%, while treatment with calcium chloride reduced the decline to 28%. Although CO₂ levels were not measured in our preliminary experiments, a 17% decline in firmness of control of RAS 'Bartlett' slices suggested that CO₂ levels were not deleterious during 14 d at 5 °C.

No mold growth was evident on the pear slices during the 2 weeks at 5 °C in our experiments but did appear after $\approx$ 4 weeks (data not shown), beyond the normal period of storage for fresh-cut fruit (Watada, 1997). Mold growth has been reported on pear slices in treatments that did not contain sorbate after $\approx$ 2 weeks at 4 °C with MAP storage (Sapers and Miller, 1998).

Expt. 2. Treatment with RAS inhibited browning during storage at 5 °C in slices from 'Anjou' pears ranging in firmness (ripeness) from 21 to 52 N (Fig. 2). The initial degree of ripeness, as evidenced by firmness of the fruit prior to slicing, did not appear to be a limiting factor in preventing browning during storage. No mold growth was observed during the 2 weeks of cold storage.

In summary, treatments containing a sufficient concentration of 4-hexylresorcinol, a competitive inhibitor of PPO (McEvily et al., 1992), along with two other compounds de-

rived from natural products (isoascorbic acid and sorbic acid), were effective in inhibiting the browning of slices of 'Anjou', 'Bartlett', and 'Bosc' pears during storage at 5 °C for what would be the normal marketing period (14 d). Incorporation of N-acetylcysteine, an antioxidant and enzymatic (PPO) inhibitor, appeared to improve maintenance of firmness. No mold growth was observed during 14 d of cold storage. Although initial firmness greatly influences flavor and consumer acceptability, the effectiveness of the anti-browning treatments was not affected by initial firmness.

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