Retention of Quality of ‘Golden Delicious’ Apples by Controlled- and Modified-atmosphere Storage

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Abstract. ‘Golden Delicious’ apples (Malus domestics Borkh.) were subjected to either 0°C controlled-atmosphere (CA) storage or to a postharvest coating of 1.0% to 2.5% Nutri-Save (NS; a polysaccharide derived from shellfish) plus air storage. NS-coated apples were greener and firmer and had higher titratable acidity (TA) and more shrivel and injured fruit than the control after storage in air at 0°C for 5 to 6 months. Better retention of skin greenness was the only benefit derived from a poststorage NS treatment of CA-stored fruit during the shelf-life test.

In this 3-year study, the postharvest use of 1.0% or more NS on ‘Golden Delicious’ apples improved retention of FF and TA in fruit during 0°C air storage. Coated fruit were also greener, firmer, and had higher TA than control fruit after the shelf-life test (7 days at 20°C in air). The response of fruit quality retention to the concentration of NS was linear (Table 1). The results substantiate previous reports in which postharvest coating treatments were beneficial to retention of FF, TA, and skin color in apples and pears (Drake et al., 1987; Elson et al., 1985; Lowings and Cutts, 1982; Magness and Diehl, 1924; Meheriuk and Lau, 1985). None of the NS treatments were as effective as the 1.5% O₂ + 1.5% CO₂ storage in maintaining FF and TA. NS-coated, air-stored fruit were, however, greener than noncoated, CA-stored fruit after the shelf-life test (Table 1).

The applications of NS resulted in an accumulation of CO₂ and CH₄ and a small reduction of O₂ in the storage atmosphere (Table 1). The effects of NS on retention of fruit quality may be a consequence of higher internal CO₂ based on results by Magness and Diehl (1924), Figdor and North (1966), and Lau (1985). Reductions of O₂ to 5% or less are needed to suppress respiration and CH₄ production (Burg and Thimann, 1959) and, thus, any NS benefits obtained are not initiated by the small changes in internal O₂ levels. Because NS treatments did not lower O₂ by much, one would not expect as much benefit on retention of FF or TA as found in CA fruit where 1.5% O₂ was used. The 4-fold increase in CH₄ accumulation in the coated fruit should not have any effect on fruit quality because high levels of CH₄ (101 µl-liter⁻¹) were also found in the noncoated fruit, sufficient to stimulate ripening in all fruit. Noncoated, CA-stored fruit had the lowest internal CO₂ and CH₄ concentrations (Table 1), which could be the result of the inhibitory effects of 1.5% O₂ and 1.5% CO₂ in the storage atmosphere on fruit respiration and CH₄ production (Burg and Thimann, 1959; Kader, 1986).
Table 1. Fruit quality and concentrations of CO$_2$, O$_2$, and C$_2$H$_4$ in fruit core cavities of Nutri-Save-coated, air ($\approx$ 90% RH)-stored or noncoated, CA (1.5% CO$_2$ + 1.5% CO$_2$, $\approx$ 94% RH)-stored 'Golden Delicious' apples upon removal from the storage and after a shelf-life test.

Storage durations were 148.188, and 177 days for 1984 (n = 10), 1985 (n = 8), and 1986 (n = 8; n = 20 for CO$_2$, O$_2$, and C$_2$H$_4$), respectively.

Rating: 0 = no shrivel, 1 = slight, 2 = moderate, and 3 = severe shrivel; ratings multiplied by the percentage of shrivelled fruit.

Table 2. Effects of poststorage washing on quality of Nutri-Save-coated 'Golden Delicious' apples (n = 8) after 6 months of air storage ($\approx$ 90% RH) and 7 days in air at 20°C.

Table 3. Effect of a postharvest Nutri-Save treatment on quality of 'Golden Delicious' apples during simulated shelf-life test following harvest (1984, n = 10).

Fruit shrivel was more severe in coated fruit than in noncoated fruit after air storage and the shelf-life test. Severity was increased by higher NS concentrations (Table 1) and lower RH regimes during the shelf-life test (shrivel score = 9 at $\approx$ 59% RH vs. 5 at $\approx$ 95% RH in 1985 and 122 at $\approx$ 11% RH vs. 85 at $\approx$ 54% RH in 1986). The mechanism by which NS increased water loss from fruit during storage or ripening is not known. Elson et al. (1985) reported that NS films in RH of 70% or less became impermeable to O$_2$ and CO$_2$ at 20°C. In this study, a 7-day exposure of fruit to lower RH regimes (11% to 59% RH compared to 54% to 95%) during the shelf-life test had no effect on dessert quality, skin color, skin disorders, and ethanol flavor in NS-coated fruit (data not shown).

Incidence of CO$_2$ and skin injury was negligible in NS-coated fruit after air storage (data not shown) but evident after the shelf-life test (Table 1). Coating had no consistent effects on ethanol flavor, and values were generally low (data not shown).

Poststorage washing to remove the NS coating slightly increased skin yellowing and also exacerbated skin injury in coated fruit after the shelf-life test (Table 2). NS might have rendered the cells more sensitive to frictional injury resulting from the washing process.

NS at 1% or 2% delayed flesh softening and skin yellowing (Table 3) but had no effect on TA or ethanol flavor (data not shown) of fruit ripened in air at 20°C for 14 or 28 days following harvest. Fruit shrivel was not found after 14 days but was a problem after 28 days of ripening (Table 3).
NS at 1.5% or 2.0%, applied to fruit after 6 months of 1.5% O₂ + 1.5% CO₂ storage, had no effect on FF, TA, fruit shrivel, or ethanol flavor (data not shown) but did assist in retention of a green skin (4.6, 3.5, and 3.4 on a 0 to 10 scale for 0%, 1.5%, and 2.0% NS, respectively; P = 0.001) during the shelf-life test.

Although NS treatments maintain FF, TA, and green skin color, fruit shrivel and, to a lesser extent, skin injury still remain as serious problems with the commercial use of NS on fresh-market ‘Golden Delicious’ apples. Also, the coating solution is very viscous and difficult to handle and the cost of dipping can be high. Consumer acceptance of fruit coated with shellfish products may be another obstacle. Storage of fruit in 1.5% O₂ + 1.5% CO₂ at 0C is simpler, safer, and more effective than NS plus air storage for maintaining high FF and TA in the fruit.

Literature Cited