DEVELOPMENT OF INTERNAL BROWNING IN FUJI APPLES DURING STORAGE

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Fuji apples may develop the physiological disorders core flush or flesh browning during cold storage in air (RA) or controlled atmosphere (CA) (Argenta et al., 2000). Core flush is a symptom of senescence characterized by yellow-brown discoloration in the core (Wilkinson and Fidler, 1973). In Fuji apples, flesh browning (Photo 1) resembles senescent breakdown because the diffuse, light brown discoloration develops initially in the outer portion of the cortex tissue and is often associated with browning of the vascular tissues.

Photo 1. Flesh browning in Fuji apple.

Photo 2. Brown heart in Fuji apple.

The primary factor leading to development of core flush and senescent breakdown are late harvest and extended storage of over-mature fruit (Wilkinson and Fidler, 1973, Meheriuk et al., 1994). Delaying cold storage, watercore, low calcium content and production in locations with cool temperatures accentuate development of senescent breakdown. In Fuji apples, core flush and flesh browning are more likely to occur when fruit is stored in RA (Argenta et al., 2000).

One means to reduce the risk of core flush and flesh browning is to limit the storage period of late harvest fruit with severe watercore. Use of calcium sprays may also help to reduce the severity of flesh browning (Wilkinson and Fidler, 1973, Meheriuk et al., 1994).

Fuji apples are also susceptible to brown-heart (internal dark browning) during CA storage (Photos 2 and 3). This is a CO_2-induced disorder as it is exacerbated by high CO_2 concentrations in air or CA storage (Argenta et al., 2001).

Some factors contributing to greater incidence and severity of brown-heart in Fuji (Argenta et al., 2001) and Braeburn (Elgar et al., 1999) apples are: harvest at advanced maturity, presence of severe watercore, light crop load and production in colder regions or seasons and higher altitude districts within a region. The susceptibility of Fuji and Braeburn apples to CO_2-injury is highest during the first weeks of RA or CA storage after harvest.

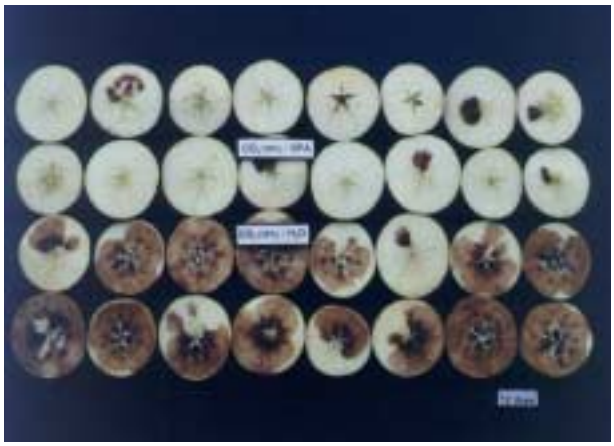

Photo 3. Brown heart (CO_2 injury) in Fuji. Fruit were exposed 9 days to 10% O_2 + 20% CO_2 at 68 ºF. Top two rows of fruit treated with diphenylamine (DPA) at 2000 ppm.

Postharvest treatment with diphenylamine (DPA) effectively prevents the development of CO_2-injury in Fuji apples (Photo 3). However, restrictions on postharvest chemical use for some markets have spurred research to develop alternative non-chemical procedures for prevention of CO_2-injury. There are both production and postharvest practices that can reduce the development of CO_2 injury. Crop load management and minimal use of nitrogen fertilizer can allow fruit to be harvested earlier with good red and breaking background colors and with a minimum of watercore. Delaying CA (1 to 1.5% O_2, 0.5 to 1% CO_2) or CO_2 accumulation during CA reduces the incidence of CO_2-injury. The CA- and CO_2-delay procedures can result in some loss of firmness (0.5 to 1 lb) and acidity (0.02% to 0.05%) compared with rapid CA; however quality loss is not sufficient to negate the benefits of CA compared with RA storage. The period of CO_2 delay required for effective reduction of CO_2-injury may vary (1 to 3 months) depending on the season. The CA or CO_2 delay should be as short as possible to preserve the beneficial effects of CA on fruit quality. Fruit should still be cooled promptly after harvest. For Fuji apples harvested with good maturity (starch 3 to 4, slight to moderate watercore), a delay of CA for 10 to 14 days after harvest or a delay of CO_2 accumulation for one month after harvest is advised. If harvested at advanced maturity (starch index higher than 5) and severely watercored (scored higher than 3, Photo 4) fruit should be stored in CA only if it is delayed for at least 4 weeks or if CO_2 is held below 0.5% during first 2 months after harvest.

Photo 4. Watercore scores for Fuji apple.

The ethylene action inhibitor 1-MCP effectively reduces firmness and titratable acidity loss in Fuji apples during RA or CA storage. The objective of the present study was to determine the

interactive effects of 1-MCP treatment and delaying CA establishment or CO_2 accumulation during CA on development of CO_2-injury and preservation of fruit quality.

Fuji apples harvested from a commercial orchard in north central Washington one week after optimum maturity for long-term storage were cooled to 33 ºF within 24 hr of harvest and then stored in RA or in CA at 1.5% O_2 + 0.05% CO_2 or 1.5% O_2 + 3% CO_2 for 8 months. We used 3% CO_2 to increase the risk of developing injury but do not recommend this concentration for commercial storage. CA treatments/conditions were established as follows:

- Rapid CA: CA conditions (1.5 % O2 + 3 % CO2) were established within 72 hr of harvest.
- CA delay: Fruit were held in RA for 2, 4 or 6 weeks after harvest, then CA (1.5% O_2 + 3% CO_2) was established and maintained for the remainder of the storage period.
- CO_2 delay: fruit were stored in 1.5% O_2 + 0.05% CO_2 for 1, 2 or 3 months after harvest, then CO_2 was increased to 3% for the remainder of the storage period.

Fruit were treated with 1 ppm MCP for 24 hours at 33 ºF at harvest or during storage; i.e., fruit stored using a CA delay were treated with 1 ppm MCP 2, 4 or 6 weeks after harvest while fruit stored using a CO_2 delay were treated with 1 ppm MCP 1, 2 or 3 months after harvest.

Results indicated that both CA conditions and 1-MCP treatment improved maintenance of firmness and titratable acidity and reduced incidence of scald and core browning during long-term storage compared with untreated fruit stored in air.

Previous results (1998) indicated 1-MCP-treated Fuji apples stored in RA had higher firmness and titratable acidity than control fruit stored in CA with low (0.05%) CO_2 after 6 months. The 1999 results showed 1-MCP treatment was as effective as CA storage for preservation of firmness but less effective then CA storage for preservation of acidity after 8 months storage. In both years, treatment with 1-MCP did not provide enhanced preservation of firmness or titratable acidity for fruit stored in CA with 3% CO_2.

CA- and CO_2-delay procedures effectively reduce severity of CO_2-injury (brown-heart) regardless of 1-MCP treatment. There are no significant impacts of 1-MCP treatment on development of CO_2-injury in RA- or rapid CA-stored fruit. However, CA- and CO_2-delay procedures are less effective on prevention of CO_2-injury for fruit treated with 1-MCP at harvest compared with untreated fruit, indicating that 1-MCP treatment extends the period after harvest when Fuji apples are susceptible to CO_2-injury (brown-heart).

Similarly, there are no significant impacts of 1-MCP treatment on dissipation of watercore in RA- and rapid CA-stored fruit. However, for fruit stored in CA- or CO_2-delayed conditions, 1-MCP slows watercore dissipation compared with untreated fruit.

For CA-stored fruit, delaying 1-MCP treatment after harvest results in less development of CO_2-injury compared with 1-MCP treatment at harvest. However, delaying 1-MCP treatment after harvest is less effective for reducing firmness and titratable acidity loss compared with 1-MCP treatment at harvest.

In conclusion, maximum retention of firmness and acidity with minimum development of brown-heart occurs when Fuji apples are stored in CA delayed for 4 or 6 weeks after harvest or in CA with CO_2 accumulation delayed for 1 month after harvest or in 1-MCP-treated fruit stored in RA or CA with low (0.05%) CO_2.

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REFERENCES

Argenta, L.C., Fan, X., Mattheis, J.P., 2000. Delaying establishment of controlled atmosphere or CO2 exposure reduces Fuji apple CO2 injury without excessive fruit quality loss. **Postharvest Biology and Technology** 20, 221-229.

Argenta, L.C., Fan, X., Mattheis, J.P., 2001. Responses of Fuji Apples to Short and Long Duration Exposure to Elevated CO_2 Concentration. **Postharvest Biology and Technology.** In press.

Elgar, J.H., Burmeister, D.M., Warkins, C.B., 1998. Storage and handling effects on a CO_2-related internal browning disorder of Braeburn apples. **HortScience**, 33, 719-722.

Meheriuk, M., Prange, R.K. Lidster, P.D., Porritt, S.W., 1994. Postharvest disorders of apples and pears. Agriculture Canada Publication 1737E. Communications Branch, Agriculture Canada Ottawa, Ont. 66p.

Wilkinson, B.G., Fidler, J.C., 1973. Physiological disorders. In: Fidler, J.C., Wilkinson, B.G., Edney, K.L., Sharples, R.O (ed), The biology of apple and pear storage. Research Review no. 3, Commonwealth Bureau of Horticulture and Plantation Crops, East Malling, UK, pp. 65-131.