Friction Discoloration of McIntosh Apples from Low-Oxygen, Controlled-Atmosphere Storage

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ABSTRACT

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Physiologic injury resulting from abrasion of McIntosh (*Malus domestica*) apples removed from low-oxygen and conventional controlled-atmosphere storage appeared as superficial light or dark brown areas on the skin and was distinguished from superficial scald or low-oxygen injury. The injury seemed to be the result of normal poststorage handling of the fruit and could be induced through abrasion by scraping or brushing. Fruit previously stored in 1% oxygen + 2.5% carbon dioxide were more susceptible to injury than those stored in 3% oxygen + 5% carbon dioxide.

Friction discoloration or friction bruises have been commonly reported on pears (5). The etiology of the disorder may involve increases in phenolic compounds with storage (4,7) and may be related to maturity of the fruit. As the fruit matures, the development of surface wax may reduce the susceptibility of the fruit to abrasion (1,4).

Some apple cultivars such as Northern Spy are susceptible to "limb rub" caused by abrasion of the fruit surface by limbs or twigs, especially in strong winds. Some McIntosh (*Malus domestica* Borkh.) apples previously stored in a low-oxygen (O_2) atmosphere (approximately 1% O_2 + 2.5% carbon dioxide [CO_2] at 3 C) from commercial storage in Ontario exhibited some light brownish areas on the surface of the fruit (Fig. 1). Scraping the surface with a fingernail led to surface discoloration (Fig. 2) within 24 hr at 20 C. These were not the typical surface, low-O_2 injury as described by Pierson et al (5) and Smock (6) and observed by us in other work. There was also no evidence of internal injury often coincident with external low-O_2 injury. McIntosh fruit from other commercial controlled-atmosphere (CA) storage in which low-O_2 levels had been used also showed some tendency toward this injury.

MATERIALS AND METHODS

To investigate the development of this disorder, McIntosh fruit from a low-O_2, commercial CA storage in which the atmosphere was a nominal 1% O_2 + 2.5% CO_2 and from a "conventional" CA storage (3% O_2 + 5% CO_2) was obtained on 23 June. The low-O_2 storage had been opened on 15 June, and the conventional CA room some 2 mo earlier. From those times to the time of this experiment, the apples were held at 0 C in air.

Upon receipt, the fruit were allowed to warm to room temperature (23 C) or were held at 0 C and treated while still cold. Similar lots (10 fruits for low-O_2, five only for CA because of the limited number available) were then treated as follows: untreated (control), bruised by striking sharply with the handle of a screwdriver, scraped with the blade of a screwdriver, or brushed firmly with a "hard" toothbrush. Fruit were treated on both red and green "sides," one bruise per side, and three strokes approximately 5 cm long with both the blade of the screwdriver and the brush across the periphery of the fruit and parallel to the stem-calyx axis. The fruits were then held at about 23 or at 0 C for 10 days, plus a further 8 days at 23 C. They were rated from 0 (no injury) to 3 (severe or very noticeable injury).

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RESULTS AND DISCUSSION

The color of the injured area varied from light or dark brown to brownish yellow (Figs. 1 and 2). The former colors were noted more often on the blushed areas of the fruit, the latter on the yellow or originally green areas. The brownish yellow color resembled storage scald but was distinguished from storage scald in this experiment, at least, by darker lines indicating the edge of the injury made by the screwdriver blade or by striations made by the brush. Some storage scald occurred on both low-O_2 and CA fruit, but it is not recorded here.

The skin abrasion ratings found in the untreated control fruit that had been stored in 1% O_2 indicated that during normal inspection and handling this fruit was susceptible to minor abrasions that are not the result of controlled treatment (Table 1). The fruit from conventional CA was almost unaffected by such handling. Impact bruising of the fruit did not increase the ratings for skin abrasions after 10 days but may have slightly increased the ratings after 18 days. Brushing or scraping the fruit greatly increased skin abrasions in both low-O_2 and CA storage. The fruit that had been previously stored in 1% O_2 tended to develop higher ratings in response to brushing or scraping than did fruit stored in CA. The injury was not clearly affected

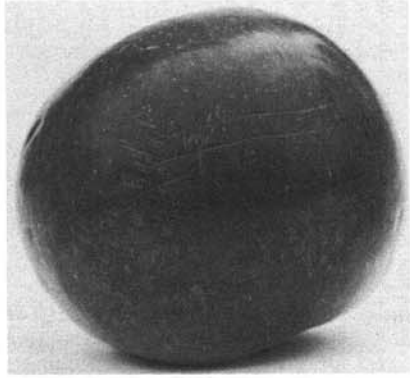

Fig. 1. Friction discoloration caused by abrasion during handling on McIntosh apples from a low-oxygen atmosphere.

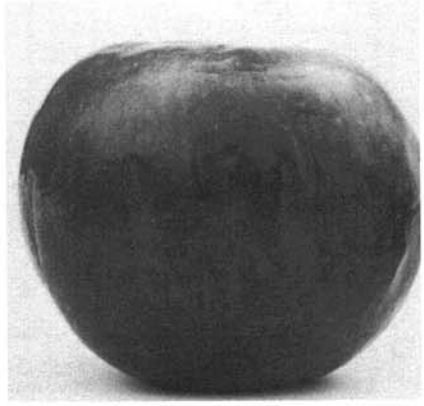

Fig. 2. Friction injury caused by scraping with a fingernail on McIntosh apples from a low-oxygen atmosphere. Note that this injury is superimposed upon abrasion injury from handling.

Table 1. Friction discoloration induced on McIntosh apples from low-O_2 (1% O_2 + 2.5% CO_2) and conventional controlled-atmosphere (CA) (3% O_2 + 5% CO_2) storage

	Low-O_2				CA			
	0[a]		23[a]		0[a]		23[a]	
Treatment	0[b]	23[b]	0[b]	23[b]	0[b]	23[b]	0[b]	23[b]
	After 10 days							
Control	0.6[c]	0.2	0.0	0.2	0.0[d]	0.0	0.0	0.0
Bruised	0.4	0.3	0.0	0.2	0.0	0.0	0.0	0.0
Brushed	2.4	2.7	2.6	2.9	1.8	1.4	2.2	1.4
Scraped	2.8	2.7	1.7	2.2	1.2	0.6	0.8	0.4
LSD (0.05)	0.6	0.5	0.4	0.6	0.8	0.9	0.5	0.6
	After further 8 days (all fruit held at 23 C)							
Control	0.4	0.1	0.2	0.3	0.0	0.0	0.0	0.0
Bruised	0.6	0.8	0.7	0.2	0.2	0.0	0.0	0.0
Brushed	2.2	2.6	2.9	2.9	2.0	1.3	1.7	1.8
Scraped	3.0	2.5	2.5	2.3	2.0	1.0	1.3	2.0
LSD (0.05)	0.5	0.5	0.5	0.5	0.7	0.7	0.4	0.5

[a] Pretreatment temperature (C).
[b] Incubation temperature (C).
[c] Means of 10 fruits; 0 = no injury, 3 = severe.
[d] Means of five fruits.

by temperature either at time of treatment or during incubation, nor did the amount of injury increase consistently with duration after initial inspection. Fruit from the 1% O_2 storage developed a lower incidence of decay and breakdown (*data not reported*) and demonstrated superior shelf life performance to the CA fruit, which was consistent with previous observations (2,3).

Although the injury noted is not likely to be important in reduction of fruit grade, every attempt should be made to reduce causes of abrasion during packing and shipment. It is necessary, however, to distinguish this superficial abrasion injury from the low-O_2 injury caused by anaerobiosis to prevent confusion. We believe that the occurrence of the injury reflects the effect of the low-O_2 conditions upon maturation and ripening in that the tissue was still immature even after 10 mo of storage and very subject to abrasion injury (1,4). However, it is difficult to explain the similar development of injury at 0 and 23 C unless the injury was not enzymatic in nature or it developed so rapidly that there was no apparent difference after 10 days of incubation. The latter appears likely, because fruit scraped with a fingernail developed injury in 24 hr. It is likely that waxing during poststorage packing (1,4) might reduce the incidence and severity of injury during marketing. Work is continuing to study the etiology of the disorder and its relationship to the inhibition of ripening noted as a result of low-O_2 storage.

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