FURTHER INVESTIGATIONS INTO THE EFFECT OF STORAGE ATMOSPHERE AND TEMPERATURE ON COOL-STORED GRANNY SMITH APPLES

Stevenson, Watkins, and Blake (1961) and Stevenson (1962*a*) have reported on a 9-year study of the storage behaviour of the Granny Smith apple, grown in Queensland, in controlled atmospheres of oxygen and carbon dioxide. Their results have shown that one of the most serious problems associated with controlled atmosphere storage of this variety is the high incidence of superficial scald encountered. While a number of satisfactory atmospheres have been determined, the most satisfactory appears to be one containing 16 per cent. oxygen plus 5 per cent. carbon dioxide, provided efficient scald control is obtained. This atmosphere is easy to obtain and maintain by simple ventilation of the storage chamber, and Stevenson (1962*a*) showed that the severity of core flush in this atmosphere is lower than in a number of others otherwise found to be suitable.

In the 1961 investigations, Stevenson (1962*a*) reported that despite the use of a 1000-p.p.m. post-harvest dip of ethoxyquin there was a high incidence of superficial scald in fruit stored in an atmosphere containing 16 per cent. oxygen plus 5 per cent. carbon dioxide. Since Hall, Scott, and Coote (1961) have shown that the amount of ethoxyquin necessary to control scald depends on the susceptibility of the fruit to the disorder, this experiment was designed to study the effect of a 2000-p.p.m ethoxyquin post-harvest dip, i.e. twice the concentration used in 1961, as a means of controlling superficial scald, in this variety, cool-stored in controlled atmospheres of oxygen and carbon dioxide. In addition, it was to be used to confirm earlier work with respect to the effect of maturity, storage temperature and atmosphere on the cool storage behaviour of this variety, with particular reference to their effect on the incidence of core flush.

Methods and Materials

Fruit for the experiment was obtained from six different orchards on the Granite Belt, surrounding Stanthorpe. Ten half-bushel cases were picked from each orchard on April 4, 1962 (first pick, Maturity 1–M1) and April 16, 1962 (second pick, Maturity 2–M2).

After picking, the fruit was packed in the field and railed to Brisbane, where it was dipped in an emulsion containing 2000 p.p.m. ethoxyquin to which a small amount of a non-ionic wetting agent was added to ensure good coverage of the fruit. The fruit was then repacked and stored in gas-tight drums at the Food Preservation Research Laboratory, Hamilton. Three different storage atmospheres were used, viz. 16 per cent. oxygen plus 5 per cent. carbon dioxide; 5 per cent. oxygen plus 5 per cent. carbon dioxide; and normal air storage.

Replicates were held at 32°, 34° and 36°F, with an additional half-bushel case from each grower from each pick held in normal storage atmospheres at 30°F. After stacking the cases in the gas-tight containers, they were sealed, and the required atmospheres in each drum were maintained by passing small amounts of compressed air, diluted when necessary with nitrogen, into each drum by means of a capillary-type manometric flowmeter. Regular daily checks were made on the atmospheres and adjustments made to the rates of flow as required. The drums were opened on November 28, 1962, and the fruit removed to 70°F, where it was held for seven days prior to examination for disorders.

Firmness was measured, on five fruit taken at random from each case, by means of a Magness penetrometer, using the 7/16-in. plunger. Readings were taken on opposite sides of each fruit and the means of 10 readings recorded. These fruit were then cut and inspected for core flush. Severity of this disorder was graded into absent, slight, medium, and severe, and 0, 1, 2, 4 ratings used. The weighted core flush rating was deduced by expressing the recorded incidence as a percentage of the maximum amount of core flush.

Superficial Scald and Mould.—No analysis of variance was carried out on the amount of mould present. An inspection of the results reveals that maturity, storage atmosphere and storage temperature appear to have little effect on the incidence of mould. Despite the use of a 2000 p.p.m. ethoxyquin dip as a scald inhibitor, the number of fruit affected by superficial scald was high in fruit held at 30°F in normal atmospheres or in any of the temperatures tested when an atmosphere containing 16 per cent. oxygen plus 5 per cent. carbon dioxide was used. Nevertheless, even under these conditions the degree of severity was slight and would not have been of commercial importance. Scald incidence was greater in fruit stored in controlled atmospheres than in that stored under normal atmospheric conditions, with the highest incidence occurring in fruit stored in an atmosphere containing 16 per cent. oxygen plus 5 per cent. carbon dioxide. However, the difference in scald incidence between normal atmosphere storage and 5 per cent. oxygen plus 5 per cent. carbon dioxide was very small and does not appear to be significant. Temperature had no effect on the amount of the disorder present. These results confirm those of Stevenson (1962*a*), who found that scald incidence was significantly affected by storage atmosphere and that storage temperatures of 32°, 34° and 36°F had no effect. The effect of maturity was confined to those treatments where scald incidence was high, and in these cases fruit from the later picking had less scald than that from the earlier picking.

Soggy Breakdown.—The amount of soggy breakdown present was significantly affected by temperature, maturity and storage atmosphere. There was significantly less soggy breakdown in fruit stored at 34°F. In fruit stored at normal atmospheres the incidence of the disorder was further reduced by storage at 30°F and 32°F. Fruit from the second pick was less affected by this disorder than that from the first pick, although in air storage there was no significant difference between picks at 30°F. There was less soggy breakdown in controlled atmosphere storage than in normal air storage.

Total Disorders.—The total number of fruit affected by superficial scald, soggy breakdown and mould was significantly affected by temperature and atmosphere. Fruit stored at 32°F and 34°F had fewer disorders than that held at 36°F. The atmosphere containing 5 per cent. oxygen plus 5 per cent. carbon dioxide resulted in fruit having significantly fewer disorders than that held in the other atmospheres tested. This effect, however, was largely due to the high incidence of superficial scald in fruit from the 16 per cent. oxygen plus 5 per cent. carbon dioxide atmosphere. If the effect of scald is disregarded, differences between the two controlled atmospheres used in the experiment are negligible. Maturity had no significant effect on the number of disorders present except in the air-stored fruit, where the later picking had fewer disorders than fruit from the earlier picking.

Core Flush.—The amount of weighted core flush present was significantly related to temperature and storage atmosphere. As storage temperature was increased there was a significant reduction in the severity of this disorder, with the least severe core flush occurring at 36°F. Fruit stored in normal atmospheres was less affected by core flush than that stored in an atmosphere containing 16 per cent. oxygen plus 5 per cent. carbon dioxide, which in turn was less affected than that held in 5 per cent. oxygen plus 5 per cent. carbon dioxide. Maturity at the time of picking had no effect on the severity of this disorder.

Firmness.—Firmness of the fruit was significantly affected by temperature, maturity and storage atmosphere. Storage at 36°F resulted in softer fruit than that stored at the other temperatures used in the experiment. Fruit from the first pick was significantly firmer than that from the second pick, except for fruit held in normal atmospheres at 30°F, where there was no significant effect of maturity. The firmest fruit was that stored in an atmosphere containing 16 per cent. oxygen plus 5 per cent. carbon dioxide, which was significantly firmer than that stored in normal atmospheres, with this air-stored fruit being significantly firmer than that stored in 5 per cent. oxygen plus 5 per cent. carbon dioxide.

Results

The results are summarized in Tables 1 and 2.

TABLE 1

EQUIVALENT PERCENTAGES OF MOULD AND SUPERFICIAL SCALD IN GRANNY SMITH APPLES AFTER REMOVAL FROM CONTROLLED ATMOSPHERE STORAGE

Storage Conditions	Mould						Superficial Scald					
	M1			M2			M1			M2		
	32°F	34°F	36°F	32°F	34°F	36°F	32°F	34°F	36°F	32°F	34°F	36°F
Air storage	6·87	8·05	8·62	8·13	15·73	7·63	4·28	3·08	2·02	0	3·40	4·55
5% O_2 + 5% CO_2 ..	3·95	7·88	7·35	8·42	4·35	6·40	5·92	3·05	6·10	0·93	18·02	8·57
16% O_2 + 5% CO_2 ..	5·02	3·03	8·22	13·30	7·67	12·63	45·62	42·48	23·63	27·45	1·10	36·47
Air storage 30°F ..	3·88			4·37			36·63			3·22		

No analysis of variance carried out for Mould or Superficial scald.

TABLE 2

EQUIVALENT PERCENTAGES OF SOGGY BREAKDOWN, TOTAL DISORDERS, WEIGHTED CORE FLUSH AND FIRMNESS IN GRANNY SMITH APPLES AFTER REMOVAL FROM CONTROLLED ATMOSPHERE STORAGE

Storage Conditions	Soggy Breakdown				Total Disorders				Weighted Core Flush				Firmness (lb)			
	32°F	34°F	36°F	Means	32°F	34°F	36°F	Means	32°F	34°F	36°F	Means	32°F	34°F	36°F	Means
Air storage	3·4	22·2	63·4	25·8	12·8	38·0	75·5	40·9	24·58	20·00	20·00	21·53	12·19	11·46	9·24	10·97
5% O_2 + 5% CO_2	17·3	1·5	1·0	4·7	29·4	18·6	16·5	21·3	95·00	45·41	31·25	57·23	10·53	11·57	11·22	11·11
16% O_2 + 5% CO_2	5·1	1·8	0·8	2·2	55·3	26·9	41·0	40·8	72·08	46·66	15·00	44·59	12·20	12·00	11·68	11·96
	M1	M2			M1	M2			M1	M2			M1	M2		
Air storage	27·1	24·5			40·9	41·0			26·39	16·67			11·61	10·32		
5% O_2 + 5% CO_2	6·3	3·3			19·5	23·1			66·12	48·34			11·57	10·64		
16% O_2 + 5% CO_2	5·7	0·4			51·6	30·4			49·17	40·00			11·78	12·15		
32°F	11·6	4·6		7·7	38·2	24·6		31·2	64·17	63·62		63·89	11·90	11·39		11·64
34°F	11·5	2·3		6·1	34·3	21·2		27·5	46·67	28·06		37·36	11·53	11·83		11·68
36°F	11·7	14·5		13·1	37·6	49·8		43·7	30·84	13·33		22·09	11·54	9·90		10·72
Means	11·6	6·3		8·7	36·7	31·3		34·0	47·22	35·00		41·11	11·65	11·04		11·34
Air storage 30°F M1	3·6			4·4	46·0			28·5	64·17			62·08	12·09			12·32
M2	5·3				13·9				60·00				12·54			

Soggy Breakdown—

34°F significantly less than 36°F (5% level).

Maturity 2 significantly less than Maturity 1 (5% level).

5% O_2 + 5% CO_2; 16% O_2 + 5% CO_2 significantly less than Air storage (1% level).

For Air storage: 30°F; 32°F significantly less than 34°F (1% level).

34°F significantly less than 36°F (1% level).

No significant differences between Maturities at 30°F.

Interactions: Temperature × Maturity × Atmosphere—not significant.

Temperature × Atmosphere—significant (1% level).

Total Disorders—

32°F; 34°F significantly less than 36°F (1% level).
5% O_2 + 5% CO_2 significantly less than Air storage; 16% O_2 + 5% CO_2 (1% level).
For Air storage: 30°F, 32°F, 34°F significantly less than 36°F (1% level).
32°F significantly less than 34°F (1% level).
32°F significantly less than 30°F (5% level).
Maturity 2 significantly less than Maturity 1 at 30°F (1% elevel).
Interactions: Temperature × Maturity × Atmosphere—significant (5% level).
Temperature × Maturity—significant (1% level).
Temperature × Atmosphere—significant (1% level).
Maturity × Atmosphere—significant (5% level).

Weighted Core Flush—

36°F significantly less than 34°F (1%level).
34°F significantly less than 32°F (1% level).
Air storage significantly less than 16% O_2 × 5% CO_2 (1% level).
16% O_2 + 5% CO_2 significantly less than 5% O_2 + 5% CO_2 (1% level).
For Air storage: 32°F; 34°F; 36°F significantly less than 30°F (1% level).
No significant differences between Maturities at 30°F.
Interactions: Temperature × Maturity × Atmosphere—significant (5% level).
Temperature × Maturity—significant (5% level).
Temperature × Atmosphere—significant (1% level).

Firmness—

32°F; 34°F significantly firmer than 36°F (1% level).
Maturity 1 significantly firmer than Maturity 2 (5% level).
16% O_2 + 5% CO_2 significantly firmer than Air storage (1% level).
Air storage significantly firmer than 5% O_2 + 5% CO_2 (1% level).
For Air storage: 30°F; 32°F; 34°F significantly firmer than 36°F (1% level).
No significant differences between Maturities at 30°F.
Interactions: Temperature × Maturity × Atmosphere—significant (5% level).
Temperature × Atmosphere—significant (1% level).
Temperature × Maturity—significant (5% level).
Maturity × Atmosphere—significant (5% level).

Discussion

The importance of superficial scald as a serious problem in the controlled atmosphere storage of Granny Smith apples has once again been demonstrated. Despite the use of a concentration of ethoxyquin double that used by Stevenson (1962*a*), there was a high incidence of this disorder in fruit held in an atmosphere containing 16 per cent. oxygen plus 5 per cent. carbon dioxide. In view of the fact that the concentration of the inhibitor required to control scald needs to be increased as the susceptibility of the fruit to the disorder increases (Hall, Scott, and Coote 1961), strengths of ethoxyquin dips greater than 2000 p.p.m. are indicated for fruit of this variety under these conditions. If this compound is cleared by public health authorities for commercial use in Australia, great care will need to be exercised to ensure that tolerance residues are not exceeded. It is understood that in the U.S.A., where ethoxyquin is used commercially, a maximum residue of 3 p.p.m. is laid down. Stevenson (1962*b*) has shown that preharvest sprays of 4000 p.p.m. gave residues below 1 p.p.m. after long storage, but there is no information available as to residues from dips of high concentration.

The results from the experiment confirm those of previous years and support the recommendation for an atmosphere containing 16 per cent. oxygen plus 5 per cent. carbon dioxide for long storage of this variety provided adequate scald control is effected. Fruit stored in this atmosphere was firmer and had less core flush than fruit stored in an atmosphere containing 5 per cent. oxygen plus 5 per cent. carbon dioxide. Such fruit was also firmer than fruit stored in air, while the incidence of core flush was kept to a minimum by storage at 36°F. This atmosphere can be easily maintained by ventilation and no expensive scrubbing devices are necessary.

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