FURTHER INVESTIGATIONS INTO THE BEHAVIOUR OF DELICIOUS APPLES STORED IN CONTROLLED ATMOSPHERES

Stevenson and Carroll (1963) obtained good results by holding Delicious apples at 32°F in an atmosphere containing 5 per cent. oxygen plus 2·5 per cent. carbon dioxide. In order to determine whether these results were due to seasonal effects, a further experiment was carried out during the 1963 apple season to confirm these earlier results, to study the effect of other atmospheres and to determine whether superficial scald could be more effectively controlled by diphenylamine in place of ethoxyquin, which had not proved completely successful in the earlier work.

Methods and Materials

The experimental fruit was obtained from the same six orchards in the Granite Belt as were used in the 1961 and 1962 investigations. Picking date was March 3, 1963, which falls into the period found by Stevenson (1959) to be the most satisfactory for optimum storage behaviour of this variety. The fruit was stored in 12 wide-mouthed, 44-gal gas-tight drums, each drum containing one ½-bus case of fruit from each of the six orchards. Storage temperatures used were 32°, 34° and 36°F and four drums were held at each temperature. Controls consisting of one ½-bus case from each of the six orchards were also stored at each of the three temperatures. The five storage atmospheres used in the experiment were—

(1) Normal air storage
(2) 2·5 per cent. oxygen plus 2·5 per cent. carbon dioxide
(3) 2·5 per cent. oxygen plus 5·0 per cent. carbon dioxide
(4) 5·0 per cent. oxygen plus 2·5 per cent. carbon dioxide
(5) 5·0 per cent. oxygen plus 5·0 per cent. carbon dioxide

Prior to storage the fruit was dipped in a solution containing 2000 p.p.m. diphenylamine (DPA) in 35 per cent. ethyl alcohol to control superficial scald. The required storage atmospheres were obtained and maintained by passing air diluted with calculated amounts of nitrogen through manometric flowmeters into the drums. Regular analyses were made for oxygen and carbon dioxide during the storage period and necessary corrections made by adjustment of the air dilution and flow rates. The fruit was removed from store on September 4, 1963, held at 70° for seven days and inspected for disorders. Firmness of the fruit was measured on five fruit selected at random from each case, using a Magness penetrometer fitted with the $\frac{7}{16}$-in. plunger.

Results

The results are summarized in Tables 1 and 2. The incidence of mould, breakdown, withering and superficial scald was slight irrespective of storage

temperature or atmosphere in which the fruit was held. For this reason analyses of variance were not carried out on the percentages of these disorders present. There is a trend which suggests that controlled atmosphere storage reduces the incidence of internal breakdown. A similar trend has been reported in earlier work by Stevenson and Carroll (1963). The incidence of bitter pit was significantly reduced by the use of controlled atmospheres, all atmospheres having less pit than normal air storage, but there were no significant differences between the controlled atmospheres used in the experiment. Total disorders present, comprising the sum of fruit affected by mould, scald breakdown, withering and bitter pit, were significantly affected by storage atmosphere. There were significantly fewer disorders in all the controlled atmospheres than in normal air storage but there were no significant differences between any of the controlled atmospheres used. Firmness was significantly affected by atmosphere and storage temperature. The firmest fruit resulted from storage at 34°F. An atmosphere containing 2·5 per cent. oxygen plus 2·5 per cent. carbon dioxide yielded significantly firmer fruit than atmospheres of 2·5 per cent. oxygen plus 5·0 per cent. carbon dioxide and 5·0 per cent. oxygen plus 5·0 per cent. carbon dioxide. Fruit held in these atmospheres was significantly firmer than that held in 5·0 per cent. oxygen plus 2·5 per cent. carbon dioxide, which was in turn significantly firmer than that held in normal storage atmospheres.

TABLE 1

MEAN PERCENTAGES OF MOULD, SCALD, BREAKDOWN AND WITHERED FRUIT AFTER REMOVAL FROM COOL STORE

Treatment	Mould (%)	Scald (%)	Breakdown (%)	Withered Fruit (%)
Normal air storage				
32°F	2·01	0·70	0·66	0
34°F	3·64	0·70	2·71	0
36°F	3·25	0	2·71	0
2·5% O_2 + 2·5% CO_2				
32°F	3·27	0	0·31	0
34°F	2·27	0·40	0·74	1·32
36°F	0·90	0	0	0·51
2·5% O_2 + 5·0% CO_2				
32°F	2·73	0	0·28	0
34°F	2·65	0	0	1·65
36°F	1·29	0·31	0	0·59
5·0% O_2 + 2·5% CO_2				
32°F	1·98	2·08	0·59	0·63
34°F	2·50	0	0·56	0·53
36°F	3·85	0	0	2·31
5·0% O_2 + 5·0% CO_2				
32°F	2·38	0·28	0·40	0
34°F	1·94	0	0	0·25
36°F	2·20	0	0·71	1·01

No analyses of variance carried out

TABLE 2

EQUIVALENT MEAN PERCENTAGES* OF BITTER PIT, TOTAL DISORDERS AND FIRMNESS AFTER REMOVAL FROM COOL STORE

Treatment	Bitter Pit (%)	Total Disorders (%)	Firmness (lb)
Normal air storage			
32°F	6·76	11·31	10·68
34°F	8·29	16·53	10·38
36°F	5·28	12·23	9·75
2·5% O_2 + 2·5% CO_2			
32°F	2·21	6·42	14·59
34°F	0·87	5·79	14·05
36°F	0·14	1·47	14·34
2·5% O_2 + 5·0% CO_2			
32°F	1·23	4·54	13·73
34°F	1·50	6·62	13·78
36°F	0·20	1·65	13·01
5·0% O_2 + 2·5% CO_2			
32°F	0·83	6·34	12·35
34°F	2·58	7·17	14·01
36°F	0·58	5·30	10·94
5·0% O_2 + 5·0% CO_2			
32°F	1·98	5·73	12·86
34°F	0·45	1·73	14·43
36°F	1·53	5·41	13·57

* Inverse sine transformation used for analysis

Bitter Pit—2·5 per cent. oxygen plus 2·5 per cent. carbon dioxide; 2·5 per cent. oxygen plus 5·0 per cent. carbon dioxide; 5·0 per cent. oxygen plus 2·5 per cent. carbon dioxide; 5·0 per cent. oxygen plus 5·0 per cent. carbon dioxide significantly less than normal air storage (1 per cent. level)

Total Disorders—2·5 per cent. oxygen plus 2·5 per cent. carbon dioxide; 2·5 per cent. oxygen plus 5·0 per cent. carbon dioxide; 5·0 per cent. oxygen plus 2·5 per cent. carbon dioxide; 5·0 per cent. oxygen plus 5·0 per cent. carbon dioxide significantly less than normal air storage (1 per cent. level)

Firmness—34°F significantly firmer than 36°F (1 per cent. level); 32°F significantly firmer than 36°F (5 per cent. level); 2·5 per cent. oxygen plus 2·5 per cent. carbon dioxide significantly firmer than 2·5 per cent. oxygen plus 5·0 per cent. carbon dioxide; 5·0 per cent. oxygen plus 5·0 per cent. carbon dioxide (1 per cent. level); 2·5 per cent. oxygen plus 5·0 per cent. carbon dioxide; 5·0 per cent. oxygen plus 5·0 per cent. carbon dioxide significantly firmer than 5·0 per cent. oxygen plus 2·5 per cent. carbon dioxide (1 per cent. level); 5·0 per cent. oxygen plus 2·5 per cent. carbon dioxide significantly firmer than normal air storage (1 per cent. level)

The interaction temperatures × atmospheres is highly significant; temperature differences vary at the different atmospheres:—

Normal air storage: 32°F significantly firmer than 36°F (5 per cent. level)

2·5 per cent. oxygen plus 2·5 per cent. carbon dioxide: no significant differences

2·5 per cent. oxygen plus 5·0 per cent. carbon dioxide: no significant differences

5·0 per cent. oxygen plus 2·5 per cent. carbon dioxide:
32°F significantly firmer than 36°F (1 per cent. level)
34°F significantly firmer than 32°F (1 per cent. level)

5·0 per cent. oxygen plus 5·0 per cent. carbon dioxide: 34°F significantly firmer than 32°F (1 per cent. level)

Discussion

A number of important facts emerge from the results. It has been clearly demonstrated that superficial scald can be effectively controlled by the use of dips containing 2000 p.p.m. diphenylamine. This compound has been shown by Hall, Scott, and Coote (1961) to be approximately twice as effective as ethoxyquin, and failure by Stevenson and Carroll (1963) to eliminate this disorder with ethoxyquin dips containing 2000 p.p.m. is no doubt due to this fact. This indicates that ethoxyquin dips of the order of 4000 p.p.m. are necessary to effectively control scald in this variety. The results indicate that controlled atmosphere storage will reduce bitter pit during storage of this variety, but whether this is due to the choice of atmosphere or the retarding of senescence by the process is not known; the matter is worthy of further study. Fruit held in the controlled atmospheres was up to 4 lb firmer than the air-stored controls and this was reflected by the green ground colour of the controlled atmosphere fruit compared with the yellow ground colour of the controls. Inspection of the fruit indicated at least a further six weeks' storage life of the controlled atmosphere stored fruit.

The results clearly indicated that this variety can be successfully held in controlled atmospheres of oxygen and carbon dioxide provided adequate control of superficial scald can be effected. As ethoxyquin will not be marketed commercially in Australia and diphenylamine has not yet been approved for commercial use in this country, the controlled atmosphere storage of this variety cannot be recommended at present. The small differences in storage behaviour obtained between the atmospheres tested confirms the results of American workers, who have obtained good results with atmospheres containing from 2·0 to 5·0 per cent. oxygen plus 0 to 5·0 per cent. carbon dioxide (Van Doren 1952; Smock 1958; Eaves 1953, 1954, 1955).

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