CONTROLLED ATMOSPHERE STORAGE OF DELICIOUS APPLES

A survey of available literature reveals considerable variation in opinion regarding the suitability of the Delicious apple variety for storage in controlled atmospheres. Australian workers, as a general rule, have shown the method to be of doubtful value, while workers in the U.S.A. have apparently obtained good results.

Huelin and Tindale (1947) studied the behaviour of this variety in a number of different atmospheres of oxygen and carbon dioxide over a range of temperatures from 32° to 40°F, and reported that the use of controlled atmospheres did not appear promising for the variety. Vickery *et al.* (1953) reported that while controlled atmosphere storage was very successful with some varieties, it was not beneficial to Delicious. Hall and Sykes (1954), in a 5-year study on this variety, found controlled atmospheres somewhat better than the use of applied skin coatings, but stated that neither method showed any important advantage over air storage. In trials carried out in Tasmania with atmospheres containing low oxygen concentrations, Martin and Cerny (1956) obtained marked improvement in texture and quality after storage at 32°F in atmospheres of 6·8 and 12·0 per cent. oxygen.

Van Doren (1952) recommended storage of the Delicious variety at 31°F in an atmosphere containing 2 per cent. oxygen plus less than 0·05 per cent. carbon dioxide. In this recommendation of low oxygen concentration, he is supported by Smock (1958), who found that storage in an atmosphere containing 3 per cent. oxygen plus 2–3 per cent. carbon dioxide at 32°F increased the shelf life of this variety although not so much as with other varieties. Eaves (1953, 1954, 1955) found 5 per cent. oxygen plus 5 per cent. carbon dioxide to be a satisfactory atmosphere for Delicious, particularly at 32°F, but at cellar temperatures slight core browning was observed when the fruit was removed and held at air temperatures for two weeks.

With Delicious rapidly becoming the major variety grown in the Stanthorpe area, considerable interest has been shown in developing storage techniques by which the storage life of this variety can be increased. For this reason, particularly in view of the good results claimed for atmospheres containing low oxygen concentrations, investigations were commenced in 1961 to study the storage behaviour of the Delicious apple variety, grown in Queensland, in controlled atmospheres over a range of storage temperatures.

1961 Experiment

The experimental fruit was obtained from six different orchards in the Granite Belt, surrounding Stanthorpe. Picking date was March 6, 1961, which falls in the period recommended by Stevenson (1959) for optimum storage behaviour of this variety. The fruit was stored in nine wide-mouthed, 44-gal, gastight 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 three 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 storage atmospheres used in the experiment were:—

(1) 3 per cent. oxygen

(2) 3 per cent. oxygen plus 2·5 per cent. carbon dioxide

(3) 3 per cent. oxygen plus 5 per cent. carbon dioxide

(4) Normal air storage.

The required atmospheres were obtained and maintained by passing air diluted with calculated amounts of nitrogen through manometric flow meters 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 October, 3, 1961, held at 70°F for seven days, and inspected for disorders.

The results are summarized in Table 1. Because of large variation in source of fruit no analysis of variance was carried out on the results; however, a number of important trends are indicated. Internal breakdown and superficial scald were the main disorders present and their incidence was high in all treatments. The results suggest that fruit held in controlled atmospheres was more severely affected than that held in normal storage atmospheres. A further trend in the results indicates that the incidence of disorders increased with increase in the storage temperature, but that increase in the amount of carbon dioxide in the storage atmosphere had little effect.

TABLE 1

MEAN PERCENTAGES OF DEFECTS OF DELICIOUS APPLES AFTER REMOVAL FROM COOL STORE

Treatment	Mould (%)	Superficial Scald (%)	Breakdown (%)	Total Disorders (%)
Control				
32°F	1·23	11·52	9·30	22·03
34°F	2·47	23·52	4·57	30·52
36°F	6·35	16·52	5·82	28·67
3% oxygen				
32°F	0	19·78	15·33	35·10
34°F	0·70	19·43	15·97	36·10
36°F	1·05	33·12	14·82	48·50
3% oxygen + 2·5% carbon dioxide				
32°F	0·40	20·13	19·00	37·53
34°F	0	21·23	39·53	55·37
36°F	0	18·15	36·58	52·60
3% oxygen + 5% carbon dioxide				
32°F	0·41	16·77	20·67	35·95
34°F	0·79	20·73	22·96	42·97
36°F	1·85	22·19	26·79	50·18

No analysis of variance carried out because of variable fruit source effects

These results tend to confirm those of other Australian investigators, which indicate that the Delicious variety, grown in Australia, is not suitable for storage in controlled atmospheres.

1962 Experiment

The incidence of superficial scald was high in fruit in the 1961 experiment and in view of the results of Stevenson and Blake (1961) and Hall, Scott, and Coote (1961) with post-harvest dips of ethoxyquin as a scald inhibitor for Granny Smith apples, it was decided to determine whether this compound would effectively inhibit scald on the Delicious variety. Since atmospheres containing 3 per cent. oxygen used in the 1961 experiment appeared to be of no value for this variety, in the 1962 experiment 5 per cent. oxygen was used, as Eaves (1953, 1954, 1955) reported good results from this concentration.

Fruit for this experiment was obtained from the same six orchards as in 1961 and the same experimental procedure was adopted. The storage temperatures used were 32, 34 and 36°F and the storage atmospheres were:—

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

Prior to storage the fruit was dipped in a 2000 p.p.m. emulsion of ethoxyquin to which a non-ionic wetting agent had been added to ensure adequate cover. The fruit was removed from store on September 6, 1962, held at 70°F for seven days, and inspected for storage disorders.

The results are summarized in Table 2. The incidence of mould, bitter pit and breakdown 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. This effect has been reported with the Granny Smith variety by Stevenson, Watkins, and Blake (1961). The incidence of superficial scald was significantly affected by both storage temperature and storage atmosphere. Fruit held at 32° had significantly less scald than that held at 34°, which in turn had significantly less scald than that held at 36°. Storage atmosphere had a significant effect on the amount of scald present, with 5 per cent. oxygen, and 5 per cent. oxygen plus 2·5 per cent. carbon dioxide, having significantly less scald than either control or 5 per cent. oxygen plus 5 per cent. carbon dioxide. Total disorders present, comprising the sum of fruit affected by mould, breakdown, bitter pit and scald, were significantly affected by both storage temperature and storage atmosphere. Fruit held at 32° had significantly fewer disorders than that held at 34°, which in turn had significantly fewer disorders than that held at 36°. Both 5 per cent. oxygen and 5 per cent. oxygen plus 2·5 per cent. carbon dioxide had significantly less disorders than either control or 5 per cent. oxygen plus 5 per cent. carbon dioxide.

TABLE 2

MEAN PERCENTAGES OF DEFECTS OF DELICIOUS APPLES AFTER REMOVAL FROM COOL STORE

Treatment	Mould (%)	Superficial Scald (%)	Breakdown (%)	Bitter Pit (%)	Total Disorders (%)	Firmness
Control						
32°F	1·87	26·4	4·62	1·03	33·5	10·76
34°F	1·90	45·4	4·37	2·97	52·4	9·72
36°F	3·80	38·3	4·02	0·35	45·0	9·47
5% oxygen						
32°F	1·43	12·5	1·98	0·72	16·6	9·09
34°F	1·98	18·3	0·87	0·87	20·4	9·59
36°F	0·80	26·2	0·40	1·58	28·6	8·78
5% oxygen + 2·5 % carbon dioxide						
32°F	0·97	3·9	0·67	0	5·5	11·60
34°F	1·02	15·0	1·20	0	16·8	10·15
36°F	0·40	38·8	3·57	0	41·2	9·36
5% oxygen + 5% carbon dioxide						
32°F	3·08	17·3	0·40	1·18	21·6	9·68
34°F	2·60	33·6	1·15	0	37·4	9·95
36°F	2·07	46·3	1·67	0·70	50·1	10·25

Superficial Scald—

32°F sig. less than 34°F (1% level)

34°F sig. less than 36°F (5% level)

5% oxygen and 5% oxygen plus 2·5% carbon dioxide sig. less than control (1% level)

5% oxygen and 5% oxygen plus 2·5% carbon dioxide sig. less than 5% oxygen plus 5% carbon dioxide (5% level)

Total Disorders—

32°F sig. less than 34°F (1% level)

34°F sig. less than 36°F (5% level)

5% oxygen and 5% oxygen plus 2·5% carbon dioxide sig. less than Control and 5% oxygen plus 5% carbon dioxide (1% level)

Firmness—

32°F sig. firmer than 36°F (1% level)

32°F sig. firmer than 34°F (5% level)

34°F sig. firmer than 36°F (5% level)

Control, 5% oxygen plus 2·5% carbon dioxide, and 5% oxygen plus 5% carbon dioxide sig. firmer than 5% oxygen (1% level)

For Firmness, the interaction term Treatments by Temperatures is highly significant; the temperature effect varies from treatment to treatment, the general trend being reversed with treatment 5% oxygen plus 5% carbon dioxide.

The firmness of the fruit, measured as the mean readings on opposite sides of five fruits taken at random with a Magness penetrometer using the $\frac{7}{16}$-in plunger, was significantly affected by both storage temperature and storage atmosphere. Fruit held at 32° was significantly firmer than that held at 34°, which in turn was significantly firmer than that held at 36°. Control, 5 per cent. oxygen plus 2·5 per cent. carbon dioxide, and 5 per cent. oxygen plus 5 per cent. carbon dioxide were significantly firmer than 5 per cent. oxygen.

Despite the use of post-harvest dips containing 2000 p.p.m. ethoxyquin, the incidence of superficial scald was extremely high. It was observed, however, that the scald present was very slight and not of commercial significance. Stevenson and Blake (1961) and Hall, Scott, and Coote (1961) have shown that the amount of inhibitor required to control this disorder depends on the susceptibility of the fruit. It therefore appears that complete control could be obtained by increasing the concentration of the inhibitor in the dip. The most satisfactory temperature used was 32°; at this temperature fewer disorders were present and the fruit was firmer. Two of the atmospheres tested gave good results, viz. 5 per cent. oxygen, and 5 per cent. oxygen plus 2·5 per cent. carbon dioxide. The latter was more satisfactory as it resulted in firmer fruit.

Conclusions

The results indicate that the Queensland-grown Delicious variety will respond satisfactorily to storage at 32°F in an atmosphere containing 5 per cent. oxygen plus 2·5 per cent. carbon dioxide. As a general rule, other Australian workers concentrated on atmospheres containing over 10 per cent. oxygen and this could account for their lack of success with this variety. The results of these experiments support those of the American workers, who favour low oxygen concentrations. It is proposed, however, to study further the performance of this variety in atmospheres containing 5 per cent. oxygen prior to making definite recommendations.

REFERENCES

EAVES, C. A. (1953).—Gas storage studies with fruit and vegetables. Rep. Dep. Agric. Can. Fruit & Veg. Prod. Res. Comm.:89-96.

EAVES, C. A. (1954).—Gas storage of apples. Rep. Canad. Comm. Fruit & Veg. Pres. 1954:6.

EAVES, C. A. (1955).—Gas storage of apples. Rep. N. S. Fruit Grow. Ass. 1955:59-62. (Abstract in *Hort. Abstr.* 27, No. 3177.)

HALL, E. G., SCOTT, K. J., and COOTE, G. G. (1961).—Control of superficial scald on Granny Smith apples with diphenylamine. *Aust. J. Agric. Res.* 12:834-53.

HALL, E. G., and SYKES, S. M. (1954).—Effect of skin coatings on the behaviour of apples in storage. IV. Comparisons of skin coatings and gas (controlled atmosphere) storage. *Aust. J. Agric. Res.* 5:626-48.

HUELIN, F. E., and TINDALE, G. B. (1947).—The gas storage of Victorian apples. Tech. Bull. Vict. Dep. Agric. No. 6.

MARTIN, D., and CERNY, J. (1956).—Low oxygen gas storage trials of apples in Tasmania. Tech. Pap. Commonw. Sci. Industr. Res. Org. No. 6.

SMOCK, R. M. (1958).—Controlled atmosphere storage of apples. *Cornell Ext. Bull.* 759:7-8.

STEVENSON, C. D. (1959).—The effect of maturity and tree age on the behaviour of Queensland grown Delicious apples stored at 34-36°F. *Qd J. Agric. Sci.* 16:291-7.

STEVENSON, C. D., and BLAKE, J. R. (1961).—Investigations into the control of superficial scald in cool-stored Queensland grown Granny Smith apples by chemical means. *Qd J. Agric. Sci.* 18:293-314.

STEVENSON, C. D., WATKINS, J. B., and BLAKE, J. R. (1961).—Controlled atmosphere storage of Queensland grown Granny Smith apples. *Qd J. Agric. Sci.* 18:463-75.

VAN DOREN, A. (1952).—The storage of golden Delicious and red Delicious apples in modified atmospheres. *Proc. 48th Annu. Mtg Wash. Sta. Hort. Ass.* 91-5.

VICKERY, J. R., HUELIN, F. E., HALL, E. G., and TINDALE, G. B. (1953).—The gas storage of apples and pears in Australia. Proc. 8th Int. Congr. Refrig. London 1951: 416-20.

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