APPLE COOL STORAGE INVESTIGATIONS IN 1955

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SUMMARY.

Investigations have confirmed the importance of maturity with regard to the storage life of Granny Smith apples both in normal air storage and in controlled atmosphere storage.

As in earlier experiments, the incidence of storage disorders was closely related to the age of the tree from which the fruit was picked.

Superficial scald incidence was again closely related to the amount of carbon dioxide present in the storage atmosphere, but under conditions of high carbon dioxide concentrations the effect of maturity on the incidence of this disorder was most pronounced.

Wastage in fruit picked at the correct stage of maturity was reduced by controlled atmosphere storage and the fruit kept firmer.

Delaying the storage of fruit reduced scald incidence but increased wastage from mould and soggy breakdown and resulted in softer fruit.

The most satisfactory storage atmosphere was a mixture of 16 per cent. oxygen and 5 per cent. carbon dioxide. In 1954, when earlier picking dates were used, a mixture of 10 per cent. oxygen and 2.5 per cent. carbon dioxide was found to be the most satisfactory, as fruit in this atmosphere did not develop as much scald as in the higher concentration of carbon dioxide. This was the case again for early picks in 1955. However, fruit picked at the later picking date developed less scald and when stored under a 16 per cent. oxygen plus 5 per cent. carbon dioxide mixture was firmer than that stored under the 10 per cent. oxygen plus 2.5 per cent. carbon dioxide mixture.

Ozone-generating ultra-violet lamps did not have any effect on the incidence of storage disorders.

I. INTRODUCTION.

Within recent years it has become particularly important to the apple industry in Queensland for the crop to be marketed over a fairly long period. Accordingly, since 1951 problems of cool storage, particularly of the Granny Smith variety, have been investigated in Queensland.

Progress in these experiments has been reported briefly by Trout in the Annual Reports of the Queensland Department of Agriculture and Stock for the years 1951-52 to 1955-56, and more extended progress reports have appeared in "Queensland Fruit and Vegetable News," a weekly paper published by the Committee of Direction of Fruit Marketing.

The studies have been concerned with the effects of stage of maturity at picking and age of tree on the keeping quality of Granny Smith and Delicious varieties and with the effect of storage atmosphere on the Granny Smith.

The 1955 investigations reported here covered the following aspects:—

(1) Delicious

(*a*) Effects of maturity and tree age on keeping quality.

(2) Granny Smith

(*a*) Effects of maturity and tree age on keeping quality.

(*b*) Effects on keeping quality of ozone-generating ultra-violet lamps fitted in a store equipped with a system of air purification.

(*c*) Effects of controlled storage atmospheres on keeping quality.

(*d*) Effects on keeping quality of delays prior to storage in controlled atmospheres.

II. EXPERIMENTS WITH DELICIOUS.

(1) Experimental Details.

Fruit of three maturities was used, the picking dates being:—

First pick (Maturity 1)	..	Feb. 14, 1955
Second pick (Maturity 2)	..	Feb. 23, 1955
Third pick (Maturity 3)	..	Mar. 7, 1955

The experimental fruit was obtained from six orchards in the Granite Belt surrounding Stanthorpe. Eighteen half-bushel cases were obtained from each orchard, comprising three half-bushel cases of each maturity from old and young trees. The fruit was wrapped in oiled wraps, packed, and stored in the C.O.D. Cool Store, Thulimbah, on the Granite Belt, at 34-36 deg. F. Removals of fruit from store were made on Aug. 1 (Removal 1), Sept. 5 (Removal 3) and Oct. 3 (Removal 3).

After removal from store, the cases were railed to Brisbane, held there at air temperature for seven days to simulate normal marketing conditions, and then inspected for storage disorders.

Firmness was measured by means of the Magness Penetrometer. Five fruits from each case were taken as a sample and readings were made on opposite sides of the fruit with the 7/16 in. plunger. The mean of the 10 readings was recorded.

(2) Results.

The results are presented in Table 1.

Only a small number of fruit was affected by *mould*. Fruit from Removal 1 had less mould than from Removal 3, and mould was more prevalent in fruit from young trees than in that from old trees. Degrees of maturity of the fruit did not affect its susceptibility to mould.

Table 1.

ADJUSTED MEAN PERCENTAGES OF DEFECTS, AND FIRMNESS, OF DELICIOUS APPLES AFTER REMOVAL FROM COOL STORE.

	Mould.	Superficial Scald.	Total Wastage.	Firmness.
Removal 1—				
Maturity 1	0·5	16·3	16·8	13·04
Maturity 2	1·6	4·3	6·2	12·58
Maturity 3	0·6	Nil	0·6	11·46
Old trees	0·3	3·7	4·0	12·08
Young trees	1·7	6·7	8·6	12·64
Removal 2—				
Maturity 1	1·2	34·4	36·0	14·12
Maturity 2	1·0	5·9	6·9	12·62
Maturity 3	1·3	0·1	1·6	11·71
Old trees	1·0	7·2	8·4	12·72
Young trees	1·2	13·6	14·8	12·92
Removal 3—				
Maturity 1	1·9	34·5	36·5	15·21
Maturity 2	2·0	9·4	11·9	14·29
Maturity 3	2·0	0·1	2·6	12·96
Old trees	1·4	8·8	10·6	13·94
Young trees	2·6	15·6	18·5	14·36

Mould : Removal 1 sig. less than Removal 3 (1% level).
Old trees sig. less than Young trees (5% level).

Superficial Scald : Maturity 2 sig. less than Maturity 1 (1% level).
Old trees sig. less than Young trees (1% level).
Removal 1 sig. less than Removal 2 (5% level).
Removal 1 sig. less than Removal 3 (1% level).

Total Wastage : Maturity 3 sig. less than Maturity 2 and 1 (1% level).
Maturity 2 sig. less than Maturity 1 (1% level).
Removal 1 sig. less than Removal 3 (1% level).
Removal 1 sig. less than Removal 2 (5% level).
Old trees sig. less than Young trees (1% level).

Firmness : Removal 3 sig. greater than Removal 2 and Removal 1 (1% level).
Removal 2 sig. greater than Removal 1 (1% level).
Maturity 1 sig. greater than Maturity 2 and 3 (1% level).
Maturity 2 sig. greater than Maturity 3 (1% level).
Young trees sig. greater than Old trees (1% level).

In previous years no *superficial scald* developed in the variety Delicious, but in the 1955 investigations a considerable amount was present. Fruit from the third pick was not affected by scald, and that from the second pick showed less wastage than that of earlier harvested fruit. There was more scald in fruit from young trees and also an increase in the incidence of the disorder with increase in storage time.

Total wastage from mould and scald decreased with increase of maturity at picking and increased with storage time. Fruit from old trees had less wastage than that from young trees.

The *firmness* of the fruit on removal was affected by maturity, storage time and age of tree. Fruit remained firmer the earlier it was picked. On the other hand, the fruit increased in firmness with length of storage; this is at variance with results of previous tests. Fruit from young trees was firmer than that from old trees; this did not support results obtained previously.

The increase in firmness with increase in storage period and the fact that fruit from old trees was softer than that from young trees cannot be satisfactorily explained. However, it had been noticed on previous occasions that towards the end of the storage period of the variety Granny Smith some withering occurred, particularly with fruit from young trees. It is possible that moisture loss accompanying withering makes the fruit more resistant to penetration by the test plunger and this may account for the increasing firmness of the fruit.

(3) Discussion.

From the experiments carried out in 1953 and 1954, it appeared that for cool storage the optimum picking date for Delicious apples grown on the Granite Belt was between Feb. 25 and Mar. 3. The results of the 1955 experiments largely confirm this finding, but since scald did not develop in fruit from the third pick, it would appear that the later part of the period would be the safer. It was again demonstrated that, for long storage, fruit from old trees is much more suitable than that from young trees because it remains firmer and is less susceptible to breakdown.

III. INVESTIGATIONS WITH GRANNY SMITH.

(1) Effects of Maturity and Tree Age on Keeping Quality.

(a) Experimental Details.

This experiment was a continuation of investigations commenced in 1953. The three picking dates were, however, somewhat later than those used in previous years, because it had been shown that there was a considerable reduction in the incidence of superficial scald with increasing maturity.

The three picking dates in 1954 were:—

First pick (Maturity 1)	Mar. 16–18
Second pick (Maturity 2)	Mar. 30–Apr. 2
Third pick (Maturity 3)	Apr. 12–14

The 1955 picking dates were:—

First pick (Maturity 2)	Mar. 28
Second pick (Maturity 3)	Apr. 12
Third pick (Maturity 4)	Apr. 27

It will be noted that the first pick in 1955 is designated Maturity 2, the second Maturity 3 and the third Maturity 4. This is because it is proposed to combine all the results in one report at the completion of the investigations and this nomenclature of maturities was designed to avoid confusion.

Eighteen half-bushel cases were obtained from each of six growers, and comprised three half-bushel cases at each of the picking dates from old and young trees. The fruit was wrapped in oiled wraps, packed, and stored at 34–36 deg. F. in the C.O.D. Cool Store, Thulimbah. Removals from store were made on Oct. 3 (Removal 1), Nov. 7 (Removal 2) and Nov. 28, 1955 (Removal 3).

After removal from the cool store, the fruit was railed to Brisbane, held at air temperatures for seven days to simulate normal marketing practices, and then inspected for storage disorders.

(b) Results.

The results are given in Table 2.

Table 2.

ADJUSTED MEAN PERCENTAGES OF DEFECTS, AND FIRMNESS, OF GRANNY SMITH APPLES AFTER REMOVAL FROM AIR COOL STORAGE.

—	Mould.	Soggy Breakdown.	Superficial Scald.	Total Wastage.	Firmness.
Removal 1—					
Maturity 2 ..	4·6	0·3	7·4	13·4	12·50
Maturity 3 ..	12·5	0·6	7·9	21·8	12·25
Maturity 4 ..	5·7	0·4	0·8	7·0	12·62
Old trees	3·7	0·3	6·5	11·8	12·42
Young trees ..	11·2	0·4	3·4	15·2	12·50
Removal 2—					
Maturity 2 ..	3·7	8·4	14·4	27·2	11·88
Maturity 3 ..	5·6	12·1	13·4	33·2	12·00
Maturity 4 ..	5·8	6·3	1·0	13·2	11·83
Old trees	3·4	8·4	8·5	21·8	11·94
Young trees ..	6·6	9·1	10·1	26·2	11·86
Removal 3—					
Maturity 2 ..	5·0	30·7	4·3	41·7	10·88
Maturity 3 ..	5·9	31·0	5·6	44·2	10·35
Maturity 4 ..	8·5	17·0	3·1	30·2	10·75
Old trees	4·5	18·8	7·2	33·2	10·46
Young trees ..	8·6	33·5	1·4	44·1	10·86

Mould : Old trees sig. less than Young trees (1% level).

Soggy Breakdown : Removal 2 sig. less than Removal 3 (1% level).
Old trees sig. less than Young trees (5% level).

Superficial Scald : Removal 3 sig. less than Removal 2 (5% level).
Maturity 4 sig. less than Maturity 2 and 3 (5% level).
Young trees sig. less than Old trees, all removals (5% level).
Young trees sig. less than Old trees, Removal 1 (5% level).
Young trees sig. less than Old trees, Removal 3 (1% level).
No sig. difference between Young trees and Old trees, Removal 2.

Total Wastage : Removal 1 sig. less than Removal 2 and 3 (1% level).
Removal 2 sig. less than Removal 3 (1% level).
Maturity 4 sig. less than Maturity 2 and 3 (1% level).

Firmness : Removal 1 sig. greater than Removal 2 and 3 (1% level).
Removal 2 sig. greater than Removal 3 (1% level).

Although only a small number of fruit was affected, fruit from young trees was more susceptible to *mould* wastage than fruit from old trees. Mould did not increase with length of storage, nor was the susceptibility of the fruit to mould affected by the maturity of the fruit.

There was a considerable increase in the incidence of soggy breakdown with storage time. The occurrence of breakdown was not affected by the time of picking, but fruit from old trees was less susceptible than that from young trees.

The effect of maturity on *superficial scald* was very marked, as the average wastage was approximately 0·5 per cent. for the third pick, compared with 5·6 per cent for earlier picks. The later picking dates in 1955 resulted in much less scald wastage than that in previous years. This effect of decrease in the incidence of superficial scald with increase in maturity has been reported by Padfield (1950), although it was claimed by Tindale and Huelin (1939) that the reduction in scald occurs only over a short period, after which there is a marked increase in the disorder with further increase in maturity. Previously, no variation in the susceptibility of fruit from trees of different ages was observed, but in 1955 fruit from young trees had less scald than that from old trees in two of the three removals.

Fruit from the third pick showed less *total wastage* than that from either of the other two picks, and increase in storage time increased the total wastage. No significant difference due to age of trees was recorded.

The only factor that affected *firmness* of the fruit was the length of storage, the fruit becoming softer with time of holding.

(c) Discussion.

In previous years, the most suitable picking period for storage of the variety Granny Smith was during the first two weeks of April. Fruit picked towards the end of this period developed less scald during storage, but this advantage was offset by an increase in the other storage disorders together with softening of the fruit. However, the 1955 results showed that picking the fruit later considerably reduced the incidence of superficial scald, and firmness was retained without any increase in wastage from mould or soggy breakdown. Further investigations will be necessary to determine whether these effects are seasonal or due to the later picking date.

(2) Effects on Keeping Quality of Ozone-generating Ultra-violet lamps.

In view of claims of beneficial results in cool stores equipped with ozone-generating utra-violet lamps, the effects of such equipment on the storage disorders of Granny Smith apples were investigated. The cool store in which the experiment was conducted is fitted with an air purification system employing activated charcoal as the volatile absorbent. Investigations by Trout (1951) with this variety showed that air purification alone did not give any less wastage

than the normal method of storage, so any beneficial storage results which have been claimed could be attributed to the ultra-violet lamps. A number of ultra-violet lamps were fitted throughout the experimental chamber.

(a) Experimental Details.

Three picking dates were used:—

First pick (Maturity 2) .. .. .. Mar. 28
Second pick (Maturity 3) .. .. .. Apr. 12
Third pick (Maturity 4) .. .. .. Apr. 27

Table 3.

ADJUSTED MEAN PERCENTAGES OF DEFECTS, AND FIRMNESS, OF GRANNY SMITH APPLES AFTER REMOVAL FROM A COOL STORE EQUIPPED WITH OZONE-GENERATING LAMPS.

—	Mould.	Soggy Breakdown.	Superficial Scald.	Total Wastage.	Firmness.
Removal 1—					
Maturity 2 ..	2·4	0·4	10·1	12·9	13·31
Maturity 3 ..	3·5	Nil	2·6	7·1	13·19
Maturity 4 ..	8·9	Nil	Nil	9·7	13·38
Old trees	3·8	0·2	1·9	7·2	13·42
Young trees ..	6·0	Nil	6·6	12·6	13·17
Removal 2—					
Maturity 2 ..	3·9	6·8	15·5	27·6	11·81
Maturity 3 ..	7·2	13·9	5·0	26·7	11·56
Maturity 4 ..	9·7	6·2	4·9	21·2	12·38
Old trees	4·5	4·8	3·3	14·3	12·00
Young trees ..	9·9	13·6	14·3	37·8	11·83
Removal 3—					
Maturity 2 ..	3·1	37·4	12·8	53·4	11·06
Maturity 3 ..	7·1	34·7	3·7	46·4	11·38
Maturity 4 ..	9·6	20·6	0·7	31·2	11·62
Old trees	3·6	20·2	7·8	32·4	11·08
Young trees ..	10·0	41·8	3·1	55·1	11·62

Mould: Maturity 3 sig. less than Maturity 4 (5% level).
Maturity 2 sig. less than Maturity 4 (1% level).
Maturity 2 sig. less than Maturity 3 (5% level).
Old trees sig. less than Young trees (1% level).

Soggy Breakdown: Removal 2 sig. less than Removal 3 (1% level).
Old trees sig. less than Young trees (1% level).

Superficial Scald: Maturity 4 sig. less than Maturity 2 (1% level).
Maturity 3 sig. less than Maturity 2 (5% level).

Total Wastage: Removal 1 sig. less than Removal 2 and 3 (1% level).
Removal 2 sig. less than Removal 3 (1% level).
Old trees sig. less than Young trees (1% level).

Firmness: Removal 1 sig. greater than Removal 2 (1% level) and Removal 3 (5% level).
Removal 2 sig. greater than Removal 3 (5% level).

Eighteen half-bushel cases were obtained from each of four growers and comprised three half-bushel cases at each of the picking dates from old and young trees. The fruit was wrapped in oiled wraps, packed, and stored at 32–33 deg. F. in a store on the Granite Belt. Removals were made on Oct. 3 (Removal 1), Nov. 7 (Removal 2) and Nov. 28, 1955 (Removal 3).

After removal from the cool store, the fruit was railed to Brisbane, held at air temperature for seven days to simulate normal marketing delays, and then inspected for storage disorders.

(b) Results.

The results appear in Tables 3 and 4.

Table 4.

ADJUSTED MEAN PERCENTAGES OF TOTAL WASTAGE OF GRANNY SMITH APPLES AFTER REMOVAL FROM A STORE EQUIPPED WITH OZONE-GENERATING LAMPS (STORE B) AND FROM NORMAL AIR STORAGE (STORE A).

—	Removal 1.		Removal 2.		Removal 3.	
	Store A.	Store B.	Store A.	Store B.	Store A.	Store B.
Maturity 2	13·4	12·9	27·2	27·6	41·7	53·4
Maturity 3	21·8	7·1	33·2	26·7	44·2	46·4
Maturity 4	7·0	9·7	13·2	21·2	30·2	31·2
Old trees	11·8	7·2	21·8	14·3	33·2	32·4
Young trees	15·2	12·6	26·2	37·8	44·1	55·1

Old trees sig. less than Young trees (1% level).
Removal 1 sig. less than Removal 2 (1% level).
Removal 2 sig. less than Removal 3 (1% level).
Maturity 4 sig. less than Maturity 3 (1% level).
Maturity 4 sig. less than Maturity 2 (5% level).

Mould infection increased with stage of maturity at picking but not with storage time. Fruit from old trees was less affected than that from young trees.

The incidence of *soggy breakdown* increased with length of storage but was not greatly affected by time of picking. Fruit from old trees was less affected than that from young trees.

Fruit from the second and third picks had less *superficial scald* than that from the first pick. Time of storage and age of tree had no effect.

Total wastage increased with length of storage. There was no effect of time of picking on total wastage, but fruit from old trees had less wastage than that from young trees.

The only factor which affected the *firmness* of the fruit was length of storage, the fruit becoming softer with time of holding.

(c) Discussion.

These results are in agreement with those obtained with fruit from the same sources and used for investigations into the effects of tree age and maturity on the storage behaviour of this variety. Table 4 shows a comparison of the total wastage from both stores obtained by adding the figures for mould, superficial scald and soggy breakdown.

There were no differences in wastage between fruit from the two stores. Fruit from Store B was ½ lb. firmer than fruit from Store A. The difference is not of commercial importance.

(3) Effect of Controlled Atmosphere Storage on Keeping Quality.

(a) Experimental Details.

In experiments conducted in 1952, 1953 and 1954 there was a very definite relationship between the incidence of superficial scald and the carbon dioxide concentration of the storage atmosphere, and also a considerable decrease in the incidence of scald in fruit from the later pickings. The 1955 investigations were designed to determine the effects of later picking dates on the incidence of superficial scald.

For this purpose 36 half-bushel cases were obtained from each of four growers on the Granite Belt, comprising three half-bushel cases from young and old trees at two picking dates. The fruit was stored in three different atmospheres—normal air storage, 10 per cent. oxygen plus 2·5 per cent. carbon dioxide, and 16 per cent. oxygen plus 5 per cent. carbon dioxide. These were the atmospheres used in 1954 and were retained because of the good results obtained. The two picks correspond with the second and third picks used in the other Granny Smith investigations and were:—

First pick (Maturity 3)	Apr. 12
Second pick (Maturity 4)	Apr. 27

After picking, the fruit was wrapped in oiled wraps, packed, and stored at 34–36 deg. F. in the C.O.D. Cool Store, Thulimbah, in airtight containers. The atmospheres within the storage cabinets were allowed to build up to the approximate concentrations, and then adjusted with nitrogen and carbon dioxide. During the storage period regular checks on the concentrations of oxygen and carbon dioxide in the cabinet were made by means of an Orsat gas analyser and any necessary adjustments made with nitrogen or carbon dioxide. Removals of fruit from the cabinets were made on Oct. 3 (Removal 1), Nov. 7 (Removal 2), and Nov. 28, 1955 (Removal 3). After each removal was made, the atmospheres in the cabinets were re-adjusted to the required concentrations with nitrogen and carbon dioxide.

The fruit, after removal from store, was railed to Brisbane, where it was held at air temperature for seven days to simulate normal marketing delays and then inspected for storage disorders.

(b) Results.

The results are set out in Table 5.

Table 5.

ADJUSTED MEAN PERCENTAGES OF DEFECTS, AND FIRMNESS, OF GRANNY SMITH APPLES AFTER REMOVAL FROM CONTROLLED ATMOSPHERE STORAGE.

—	Mould.	Soggy Breakdown.	Superficial Scald.	Total Wastage.	Firmness.
Control—					
Maturity 3 ..	10·2	13·8	6·3	32·0	11·76
Maturity 4 ..	6·5	4·5	0·5	12·3	11·60
Old trees	3·9	8·5	3·3	17·8	11·63
Young trees ..	12·7	9·1	2·9	25·0	11·73
Removal 1 ..	9·8	0·2	2·0	12·7	12·59
Removal 2 ..	6·4	7·9	5·8	21·3	11·88
Removal 3 ..	8·0	19·8	1·6	31·3	10·58
10% O_2; 2·5% CO_2—					
Maturity 3 ..	5·4	5·9	22·6	35·4	13·44
Maturity 4 ..	5·5	3·5	1·5	10·7	13·19
Old trees	3·4	3·7	12·0	20·6	13·29
Young trees ..	7·4	5·3	9·9	23·0	13·33
Removal 1 ..	3·9	0·3	7·3	12·4	14·28
Removal 2 ..	6·9	2·6	13·3	23·9	13·09
Removal 3 ..	5·5	11·6	12·9	30·6	12·56
16% O_2; 5% CO_2—					
Maturity 3 ..	5·5	2·7	31·4	40·4	13·58
Maturity 4 ..	5·1	1·4	2·1	10·7	13·48
Old trees	4·1	1·1	14·2	21·3	13·31
Young trees ..	6·4	3·0	16·3	26·7	13·75
Removal 1 ..	3·7	0·1	11·5	15·9	14·31
Removal 2 ..	4·9	1·1	16·2	22·8	13·41
Removal 3 ..	7·3	7·1	18·2	34·2	12·88

Mould : 16/5 sig. less than Control (5% level).
Old trees sig. less than Young trees (1% level).

Soggy Breakdown : 16/5 sig. less than Control (1% level).
10/2·5 sig. less than Control (5% level).
Removal 2 sig. less than Removal 3 (1% level).

Superficial Scald : Control sig. less than 10/2·5 and 16/5 for Maturity 3 (1% level).
No sig. diff. between atmospheres for Maturity 4.
Control sig. less than 10/2·5 and 16/5 for age of trees and storage time (1% level).

Total Wastage : Removal 1 sig. less than Removal 2 (5% level).
Removal 2 sig. less than Removal 3 (5% level).
Removal 1 sig. less than Removal 3 (1% level).
Maturity 4 sig. less than Maturity 3 (1% level).

Firmness : Removal 1 sig. greater than Removal 2 and 3 (1% level).
Removal 2 sig. greater than Removal 3 (1% level).
10/2·5 and 16/5 sig. greater than Control (1% level).

Mould wastage was greater in fruit from young trees than in fruit from old trees. Fruit stored in the 16 per cent. oxygen plus 5 per cent. carbon dioxide mixture had less wastage than the control fruit; the other storage atmosphere showed no difference from the control.

The incidence of *soggy breakdown* was low irrespective of maturity, tree age or composition of the atmosphere. No soggy breakdown was present in fruit from the first removals, but it increased with length of storage. The age of the trees had no bearing on the incidence of the disorder.

An increase in *superficial scald* with an increase in carbon dioxide concentration was observed in fruit not fully mature. This effect has been noted in all controlled atmosphere experiments carried out with this variety in Queensland since 1952. Huelin and Tindale (1947) observed the same effect with controlled atmosphere storage of Victorian Granny Smith apples. In the early work of Brookes, Cooley and Fisher (1919) it was reported that an accumulation of carbon dioxide was not responsible for the incidence of superficial scald; rather did high carbon dioxide concentrations tend to reduce the incidence of the disorder. However, the effect of carbon dioxide on Granny Smith apples, grown in Queensland and stored under controlled atmospheres, has been very significant. Scald incidence has been related to maturity and the injurious effects of carbon dioxide can be overcome by picking the fruit at a late stage of maturity. A similar trend had been noted in previous years. Neither the length of the storage period nor the age of the tree had any effect on the incidence of scald.

There was an increase in the amount of *total wastage* with increase in length of storage. Fruit from the second pick had less wastage than that from the first pick. For each pick the differences in total wastage in fruit stored under the different atmospheres were not significant. However, the controlled atmospheres increased superficial scald in the first pick but reduced soggy breakdown in both picks.

The *firmness* of the fruit decreased as the storage period lengthened. Fruit from both the controlled atmospheres was firmer than that from air storage. The increase in firmness with increase in carbon dioxide concentration was of the same order as in the 1954 experiments. Fruit stored in the 16 per cent. oxygen plus 5 per cent. carbon dioxide atmosphere was about $\frac{1}{2}$ lb. firmer than that stored in the 10 per cent. oxygen plus 2·5 per cent. carbon dioxide. Fruit stored in the higher carbon dioxide mixture was about 2 lb. firmer than the control fruit. Firmness was not affected by maturity or by tree age.

(c) Discussion.

The results indicate that picking maturity is the most important factor in controlled atmosphere storage. If fruit of correct maturity is stored, then increased scald due to high carbon dioxide concentrations is avoided and wastage from soggy breakdown is reduced. Further, such fruit is much firmer than if kept in normal air storage. Thus controlled atmosphere storage will give better results than normal air storage methods. Of the two atmospheres used, the mixture containing 16 per cent. oxygen plus 5 per cent. carbon dioxide resulted in slightly firmer fruit and less breakdown. Huelin and Tindale (1947)

found this atmosphere to be the most satisfactory of a number they tested with Victorian Granny Smith apples. This atmosphere is easier to maintain than the 10 per cent. oxygen plus 2·5 per cent. carbon dioxide mixture because it can be maintained by simple ventilation of the storage chamber.

The results are in good agreement with those obtained previously and supports the previous recommendation to use later picking dates.

(4) Effects on Keeping Quality of Delays Prior to Storage.

It is a common practice for some growers in southern States to hold their fruit for a period in the packing shed before placing it in store, as the delayed storage results in a reduction of scald, particularly in the early picks. Tindale and Huelin (1939) investigated the effects of delay on the incidence of superficial scald of Victorian Granny Smith apples held under refrigerated air storage and found that good control was effected with delays of 10–12 days provided the fruit was picked at the correct stage of maturity. However, if delays greater than this period were used there was a marked increase in the incidence of the disorder. The 1954 experiments showed a highly significant decrease in the incidence of superficial scald with increase in maturity. In view of this fact, the effects of delay after picking were studied, particularly in relation to controlled atmosphere storage.

(a) Experimental Details.

Fifty-four half-bushel cases of fruit were obtained from each of four growers; they comprised 27 cases from each of young and old trees. Only one pick was made—on Apr. 12, corresponding to Maturity 3.

Three storage atmospheres were used—normal air storage, 16 per cent. oxygen plus 5 per cent. carbon dioxide, and 10 per cent. oxygen plus 2·5 per cent. carbon dioxide. Three delay periods were investigated—nil, 7 days and 14 days. After picking, the fruit was wrapped in oiled wraps, packed into cases, and stored at the end of the delay period in the C.O.D. Cool Store, Thulimbah, in airtight cabinets, at 34-36 deg. F.

The atmospheres within the storage cabinets were allowed to build up to the approximate concentrations and then adjusted with nitrogen and carbon dioxide. During the storage period regular checks on the concentration of oxygen and carbon dioxide in the storage atmospheres were made with an Orsat gas analyser and any necessary adjustments made with nitrogen and carbon dioxide. Removals of fruit from the cabinets were made on Oct. 3 (Removal 1), Nov. 7 (Removal 2), and Nov. 28, 1955 (Removal 3).

After each removal was made, the atmospheres in the cabinets were re-adjusted to the required concentrations with nitrogen and carbon dioxide. The fruit, after removal from store, was railed to Brisbane, held at air temperatures for seven days to simulate normal marketing delays and then inspected for storage disorders.

(b) Results.

The results are shown in Table 6.

Table 6.

ADJUSTED MEAN PERCENTAGES OF DEFECTS, AND FIRMNESS, OF GRANNY SMITH APPLES AFTER REMOVAL FROM CONTROLLED ATMOSPHERE STORAGE—DELAYED STORAGE.

—	Mould.	Soggy Breakdown.	Superficial Scald.	Total Wastage.	Firmness.
No delay—					
Control	10·2	13·8	6·3	32·0	11·76
10% O_2; 2·5% CO_2	5·6	5·9	22·6	35·4	13·44
16% O_2; 5% CO_2	5·6	2·7	31·3	40·3	13·58
Removal 1 ..	8·3	0·5	15·6	25·4	13·67
Removal 2 ..	6·6	5·8	23·6	37·8	13·00
Removal 3 ..	6·1	16·7	21·1	45·1	12·11
Old trees	4·1	6·1	20·2	32·6	12·80
Young trees ..	10·0	8·8	19·8	39·2	13·06
7 Days' delay—					
Control	18·4	10·9	1·9	33·4	11·20
10% O_2; 2·5% CO_2	13·3	10·7	3·4	28·1	11·43
16% O_2; 5% CO_2	11·9	11·1	1·4	25·1	11·14
Removal 1 ..	22·6	1·0	2·5	26·2	11·79
Removal 2 ..	12·9	8·7	1·4	24·9	11·50
Removal 3 ..	7·2	24·1	2·8	35·7	10·48
Old trees	11·2	12·4	3·1	28·8	11·06
Young trees ..	17·7	9·5	1·4	28·9	11·46
14 Days' delay—					
Control	12·2	12·8	1·7	28·3	11·13
10% O_2; 2·5% CO_2	11·5	7·4	2·4	22·8	12·00
16% O_2; 5% CO_2	16·0	6·5	1·3	25·4	11·02
Removal 1 ..	15·1	0·5	1·3	18·4	12·29
Removal 2 ..	13·9	8·5	2·1	26·0	11·19
Removal 3 ..	10·6	18·3	2·0	32·6	10·67
Old trees	11·2	8·4	3·2	24·9	11·29
Young trees ..	15·2	9·4	0·4	26·0	11·47

Mould : No delay sig. less than 7 days and 14 days (1% level).
Removal 3 sig. less than Removal 2 (1% level).
Removal 2 sig. less than Removal 1 (5% level).
Old trees sig. less than Young trees (1% level).
No sig. diff. in Removals for No delay.
Removal 3 sig. less than Removal 2 and 1 (1% level) for 7 days.
Removal 2 sig. less than Removal 1 (1% level) for 7 days.
Removal 3 sig. less than Removal 1 (1% level) for 14 days.
Removal 3 sig. less than Removal 2 (5% level) for 14 days.

Total Wastage : 14 days sig. less than No delay (1% level).
Removal 1 sig. less than Removal 3 (1% level).
Removal 2 sig. less than Removal 3 (5% level).

Firmness : No delay sig. greater than 7 days and 14 days (1% level).
10/2·5 sig. greater than 16/5 (5% level).
16/5 sig. greater than Control (1% level).
Removal 1 sig. greater than Removal 2 (1% level).
Removal 2 sig. greater than Removal 3 (1% level).
Young trees sig. greater than Old trees (5% level).
No. sig. diff. in atmospheres for 7 days.

There was an increase in *mould* wastage with a delay of seven days, but wastage did not increase significantly beyond that point. Wastage was not affected by the storage atmospheres, but fruit from old trees had less mould than that from young trees. When there was no delay there was no difference between removals, but with delayed fruit the increase in wastage was marked as the length of the storage period increased.

No analysis of *soggy breakdown* was made, as 60 per cent. of that present was found in fruit from one of the four growers whose fruit was used in the experiment. Some trends do appear, however, and are worthy of mention. In the no-delay fruit, there was less breakdown in the 16 per cent. oxygen plus 5 per cent. carbon dioxide atmosphere than in either the 10 per cent. oxygen plus 2·5 per cent. carbon dioxide atmosphere or the normal air storage control. When the fruit was delayed, differences were not apparent. There did not appear to be any difference in wastage between fruit from old trees and that from young trees. Irrespective of the delay period, there was a considerable increase in soggy breakdown with increase in the length of storage.

Appreciable wastage from *superficial scald* occurred only in the no-delay fruit. Delays considerably reduced scald irrespective of the storage atmosphere. Neither age of tree nor time of storage affected the incidence of the disorder.

Storage atmosphere and tree age had no influence on *total wastage.* Fruit from the 14 days' delay had less wastage than that placed in store immediately after picking, but this was due to the large amount of scald present in the no-delay treatment. The effect of length of storage was significant.

Fruit from the no-delay treatment was of greater firmness than that which was delayed. In addition, fruit from the controlled atmosphere storage was firmer than that from normal air storage when there was no delay. Fruit from young trees was firmer than that from old trees, but the difference was of the order of only $\frac{1}{2}$ lb. The fruit softened with increase in the storage period.

(c) Discussion.

The results show that the incidence of superficial scald can be reduced to a minimum by delaying storage, irrespective of the atmosphere in which the fruit is stored. However, delay results in a reduction of firmness by at least 1 lb. and the fruit is also much more susceptible to mould and soggy breakdown. Thus, delayed storage cannot be recommended, since better control of storage disorders can be obtained by delaying the picking of the fruit

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