CONTROLLED ATMOSPHERE STORAGE OF QUEENSLAND GROWN GRANNY SMITH APPLES

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SUMMARY

Investigations conducted over a period of eight years demonstrated that controlled atmosphere storage can be used successfully with Granny Smith apples.

Fruit retained its firmness better in the presence of carbon dioxide, and carbon dioxide did not encourage soggy breakdown. However, superficial scald increased as the proportion of carbon dioxide was raised, particularly in fruit harvested earlier than mid-April.

The most satisfactory atmosphere was found to be 5% oxygen, but the cost involved in removing carbon dioxide is high.

A satisfactory alternative if a scald inhibitor is used is a mixture of 16% oxygen and 5% carbon dioxide.

I. INTRODUCTION

It was demonstrated by Kidd and West (1935) that the refrigerated storage life of certain varieties of English grown apples could be appreciably extended by storage in atmospheres containing less oxygen and more carbon dioxide than are normally present in the atmosphere. The results of Kidd and West with gas, or controlled atmosphere, storage were confirmed by a number of workers with a wide range of apple varieties (Smock and Van Doren 1939, 1941; Huelin and Tindale 1947; Mandeno and Padfield 1953; Martin and Cerny 1956).

With the increasing necessity to extend the marketing period of Queensland apples because of expansion of the industry, investigations were commenced in 1952 to study the effects of controlled atmosphere storage on the Queensland grown Granny Smith variety. Progress in these experiments was briefly reported in the Annual Reports of the Queensland Department of Agriculture and Stock for the years 1952-53 to 1959-60. More extended progress reports by Stevenson have appeared in *Queensland Fruit and Vegetable News,* a weekly newspaper published by the Committee of Direction of Fruit Marketing. In addition, the 1955 investigations were fully reported by Stevenson (1957) as part of a report on apple cool storage investigations for that year, and the 1956 investigations were reported by Stevenson and Blake (1961) as part of a study of the use of chemical compounds in inhibiting superficial scald on stored Granny Smith apples.

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II. 1952 EXPERIMENTS

(i) *Objective.*—To study the effects of controlled atmosphere storage on keeping quality.

(ii) *Fruit.*—Fruit for the experiment was obtained from a commercial packing shed in the Stanthorpe district. It had been picked in early April.

(iii) *Pre-storage Treatments.*—The fruit was graded for size, wrapped in oiled paper wraps containing 15% mineral oil and packed in standard 1 bus timber cases. It was then railed to Brisbane, where it was stored in the Hamilton Cool Stores.

(iv) *Storage and Post-storage.*—Four cases of uniformly sized fruit from each of two growers were stored in each of five storage atmospheres, viz. normal air storage; 5% oxygen plus 2·5% carbon dioxide; 5% oxygen plus 5% carbon dioxide; 5% oxygen with less than 1% carbon dioxide present; and 2·5% oxygen with less than 1% carbon dioxide present.

In commercial controlled atmosphere stores, it has been a common practice to hold fruit at a temperature several degrees higher than that normally used for normal cool storage as it is considered that controlled atmosphere storage makes the fruit more susceptible to low-temperature injury. For this reason, the storage cabinets were fitted with heating elements which maintained the fruit temperature at 38°F, while the control fruit was held at the normal storage temperature of 34°F.

After the fruit was loaded into the experimental gas-tight containers, the atmospheres were allowed to build up to approximately the concentrations required and were then adjusted with nitrogen, oxygen and carbon dioxide from an external source. Regular checks on concentration were made during the storage period with an Orsat gas analyser and necessary adjustments made with nitrogen and carbon dioxide cylinders.

Removals from storage were made on September 2, 1952 (Removal 1) and October 6, 1952 (Removal 2). After each removal was made, the atmospheres in the cabinets were re-adjusted to the required concentration.

On each occasion that fruit was removed from the storage cabinet it was held for seven days at atmospheric temperatures to simulate normal marketing delays and then examined for storage disorders and firmness. Firmness readings were made with the $\frac{7}{16}$ in. plunger of a Magness penetrometer on opposite sides of five fruit from each case.

(v) *Results.*—The results are summarized in Table 1.

There was very little wastage due to mould and soggy breakdown.

Fruit from the first removal had significantly less scald than that from the second removal. While there were no significant differences in scald incidence between atmospheres, there is a trend in the results which suggests that the amount of scald present increased with concentration of carbon dioxide in the storage atmosphere.

TABLE 1

DATA ON DEFECTS AND FIRMNESS OF APPLES AFTER REMOVAL FROM CONTROLLED ATMOSPHERE STORAGE. 1952 EXPERIMENT

Treatment	Superficial Scald (%)	Total Wastage (%)	Firmness
Control			
Removal 1	1·7	2·5	18·9
Removal 2	10·6	15·7	26·0
5% O_2+2·5% CO_2			
Removal 1	9·1	11·0	21·8
Removal 2	18·8	24·2	26·5
5% O_2 + 5% CO_2			
Removal 1	11·2	12·7	27·0
Removal 2	24·1	32·7	26·5
5% O_2 +< 1% CO_2			
Removal 1	3·2	4·0	29·0
Removal 2	8·0	16·2	26·0
2·5% O_2 +< 1% CO_2			
Removal 1	1·4	2·5	30·1
Removal 2	13·8	18·9	26·6

Superficial scald :

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

No significant differences between atmospheres.

Total wastage :

No analysis of variance carried out.

Firmness :

Removal 1—5% oxygen + 5% carbon dioxide ; 5% oxygen + less than 1% carbon dioxide ; 2·5% oxygen + 1% carbon dioxide all significantly firmer than Control and 5% oxygen + 2·5% carbon dioxide.

Removal 2—No significant differences.

Control—Removal 2 significantly firmer than Removal 1 (1% level).

5% oxygen + 2·5% carbon dioxide—Removal 2 significantly firmer than Removal 1 (1% level).

5% oxygen + 5% carbon dioxide—Difference not significant.

5% oxygen + less than 1% carbon dioxide—Difference not significant.

2·5% oxygen + less than 1% carbon dioxide—Removal 1 significantly firmer than Removal 2 (5% level).

Firmness determinations on the experimental fruit were extremely high. A number of significant differences were revealed by an analysis of variance (Table 1).

III. 1953 EXPERIMENT

(i) *Objective.*—In view of the work of Tindale and Huelin (1939) and Padfield (1950), who reported a decrease in the incidence of superficial scald with increase in the maturity of the fruit, the 1953 experiment was designed to compare the effects of controlled atmosphere storage on fruit of two stages of maturity and from trees of different ages.

(ii) *Fruit.*—Granny Smith apples were obtained from each of four growers in the Stanthorpe district and comprised fruit from young and old trees at two different picking dates, April 4 (Maturity 2) and April 14 (Maturity 3). The maturity designations Maturity 2 and Maturity 3 are used so that the results can be compared with those obtained by Stevenson and Watkins (1961) with normal air storage of this variety over a number of different picking dates over a more extended period.

(iii) *Pre-storage Treatments.*—The fruit was wrapped in oiled paper wraps containing 15% mineral oil, packed and railed to Brisbane, where it was stored in gas-tight containers at the Hamilton Cool Stores.

(iv) *Storage and Post-storage.*—Three half-bushel cases of each category of fruit were stored at 34°F in three different atmospheres, viz. normal air storage; 5% oxygen with less than 0·5% carbon dioxide; and 5% oxygen plus 2·5% carbon dioxide.

The carbon dioxide concentration in the storage atmosphere was maintained at the required level by passing the gas mixture in the chambers through vessels containing aqueous sodium hydroxide. Oxygen levels were maintained constant by means of a small cock, open to the external air, with an aperture which could be adjusted to allow small amounts of air to enter the chamber, thus replacing any oxygen used up in the respiration processes of the fruit. Regular checks of the storage atmospheres were made by means of an Orsat gas analysis apparatus.

Removals of fruit from the cabinets were made on October 19 (Removal 1), November 16 (Removal 2) and December 8 (Removal 3).

After each removal was made, the atmospheres in the cabinets were re-adjusted to the required concentrations by means of external cylinders of nitrogen, oxygen and carbon dioxide.

The fruit, after removal from store, was held at atmospheric temperatures for seven days to simulate normal marketing delays and was then inspected for storage disorders.

(v) *Results.*—The results are summarized in Table 2.

Fruit from the first removal had significantly less soggy breakdown than that from the second removal, which in turn had significantly less than that from the third removal. Fruit stored in an atmosphere containing 5% oxygen plus 2·5% carbon dioxide had significantly less soggy breakdown than that stored in normal atmospheres.

TABLE 2

DATA ON DEFECTS AND FIRMNESS OF APPLES AFTER REMOVAL FROM CONTROLLED ATMOSPHERE STORAGE. 1953 EXPERIMENT

Treatment	Severe Superficial Scald (%)	Total Superficial Scald (%)	Soggy Breakdown (%)	Total Wastage (%)	Firmness
Control					
Maturity 2	11·2	23·8	18·7	42·9	11·0
Maturity 3	8·0	16·5	26·8	45·4	10·8
Removal 1	4·7	17·9	3·6	22·6	11·9
Removal 2	10·5	24·6	24·8	46·9	10·6
Removal 3	13·5	18·0	39·8	62·9	10·2
$5\%O_2 + < 0{\cdot}5\%CO_2$					
Maturity 2	14·3	33·4	16·5	40·4	11·5
Maturity 3	14·3	26·5	20·1	48·7	11·5
Removal 1	11·2	28·2	4·8	28·6	12·8
Removal 2	17·8	37·6	15·6	51·3	11·0
Removal 3	13·8	23·9	34·4	52·8	10·6
$5\%O_2 + 2{\cdot}5\%CO_2$					
Maturity 2	29·4	47·7	13·7	48·1	12·2
Maturity 3	23·9	40·2	14·2	55·9	12·3
Removal 1	20·4	38·5	3·8	38·9	12·9
Removal 2	28·8	49·1	16·0	60·5	12·1
Removal 3	30·7	44·2	22·0	56·8	11·7

Soggy breakdown :

Removal 1 significantly less than Removal 2 (1% level).

Removal 2 significantly less than Removal 3 (1% level).

5% oxygen + 2·5% carbon dioxide significantly less than Control (5% level).

Superficial scald :

Severe—Removal 1 significantly less than Removals 2 and 3 (5% level).

Control and 5% oxygen + less than 0·5% carbon dioxide significantly less than 5% oxygen + 2·5% carbon dioxide (1% level).

Total—Removals 1 and 3 significantly less than Removal 2 (1% level).

Maturity 3 significantly less than Maturity 2 (1% level).

Control significantly less than 5% oxygen + less than 0·5% carbon dioxide (1% level).

5% oxygen + less than 0·5% carbon dioxide significantly less than 5% oxygen + 2·5% carbon dioxide (1% level).

Total wastage :

No analysis of variance carried out.

Firmness :

No analysis of variance carried out.

Fruit from the second pick had significantly less superficial scald than that from the first pick. The trend in the 1952 experiment, which suggested that the amount of superficial scald increased as the concentration of carbon dioxide

in the storage atmosphere increased, was confirmed in this experiment. The fruit stored under normal atmospheres had significantly less scald than that stored in an atmosphere containing 5% oxygen with less than 0·5% carbon dioxide present. This atmosphere, in turn, resulted in significantly less scald than when the fruit was stored in an atmosphere containing 5% oxygen plus 2·5% carbon dioxide.

No analysis of variance was carried out on total wastage, which was composed mainly of superficial scald and soggy breakdown. Since large differences are necessary for significance it is unlikely that maturity had any effect on the amount of total wastage present. However, there was an increase in wastage with increase in the length of the storage period.

Although no analysis of variance was carried out on firmness, fruit held in controlled atmospheres appeared to be firmer than that stored under normal atmospheres. The results also indicate that the firmness of the fruit increased as the carbon dioxide content of the atmosphere was increased.

IV. 1954 EXPERIMENT

(i) *Objective.*—To study the effect of controlled atmospheres not previously used, viz. 16% oxygen plus 5% carbon dioxide, which is easily obtained in a sealed chamber by the natural respiration of the fruit and can be easily maintained by ventilation with normal air, and 10% oxygen plus 2·5% carbon dioxide, which can be fairly easily maintained by mechanical means and is an atmosphere intermediate between those used previously and the easily maintained 16% oxygen plus 5% carbon dioxide atmosphere.

(ii) *Fruit.*—Granny Smith apples were obtained from each of four different growers in the Stanthorpe district and comprised fruit from old and young trees in each orchard at each of two picking dates, April 2 (Maturity 2) and April 14 (Maturity 3).

(iii) *Pre-storage Treatments.*—The fruit was wrapped in oiled paper wraps containing 15% mineral oil, packed into cases and railed to Brisbane, where it was stored in the Hamilton Cool Stores.

(iv) *Storage and Post-storage.*—Three half-bushel cases of each category of fruit were stored at 34-36°F in three storage atmospheres, viz. normal air storage; 10% oxygen plus 2·5% carbon dioxide; and 16% oxygen plus 5·0% carbon dioxide.

The controlled atmosphere fruit was sealed in gas-tight containers and the atmospheres were allowed to build up approximately to the required storage atmospheres and then adjusted with nitrogen and carbon dioxide from external cylinders. During the storage period, regular checks on the concentrations in the containers were made with an Orsat gas analysis apparatus and any necessary adjustments made with nitrogen and carbon dioxide from external cylinders.

Removals of fruit from the storage cabinets were made on October 4 (Removal 1), November 9 (Removal 2) and December 6 (Removal 3).

TABLE 3

DATA ON DEFECTS AND FIRMNESS OF APPLES AFTER REMOVAL FROM CONTROLLED ATMOSPHERE STORAGE. 1954 EXPERIMENT

Treatment	Mould (%)	Soggy Breakdown (%)	Superficial Scald (%)	Total Wastage (%)	Firmness
Control					
Maturity 2	4·3	12·8	13·3	27·4	13·1
Maturity 3	7·2	9·3	7·5	24·8	12·5
Old Trees	4·5	9·8	9·6	24·1	12·9
Young trees	7·0	12·3	11·2	28·1	12·7
Removal 1	3·3	0·0	11·5	15·8	14·0
Removal 2	7·0	6·1	11·1	25·2	13·3
Removal 3	6·8	27·1	8·6	37·3	11·1
$10\%O_2 + 2{\cdot}5\%CO_2$					
Maturity 2	2·9	0·4	24·3	27·7	15·9
Maturity 3	4·0	0·0	6·6	13·7	15·5
Old Trees	2·7	0·4	15·0	19·8	15·4
Young trees	4·3	0·1	15·9	21·5	16·0
Removal 1	2·2	0·1	9·9	14·3	16·2
Removal 2	3·1	0·2	18·7	23·3	16·4
Removal 3	5·1	0·3	17·8	24·4	14·5
$16\%O_2 + 5\%CO_2$					
Maturity 2	2·8	0·4	38·3	41·0	17·0
Maturity 3	3·0	0·2	16·3	19·8	16·7
Old trees	1·6	0·2	25·2	26·8	16·9
Young trees	4·2	0·4	29·5	34·1	16·7
Removal 1	2·4	0·0	24·6	27·4	17·3
Removal 2	2·8	0·2	27·5	30·6	18·1
Removal 3	3·5	0·8	29·9	33·3	15·1

Mould :

No analysis of variance carried out.

Soggy breakdown :

No analysis of variance carried out.

Superficial scald :

Control significantly less than 10% oxygen + 2·5% carbon dioxide and 16% oxygen + 5% carbon dioxide (5% level).

Maturity 3 significantly less than Maturity 2 (1% level).

Total wastage :

Old trees significantly less than young trees (5% level).

Maturity 3 significantly less than Maturity 2 (1% level).

10% oxygen + 2·5% carbon dioxide significantly less than Control (5% level) and 16% oxygen + 5% carbon dioxide (1% level).

Removal 1 significantly less than Removal 2 (1% level).

Removal 2 significantly less than Removal 3 (5% level).

Firmness :

16% oxygen + 5% carbon dioxide significantly firmer than 10% oxygen + 2·5% carbon dioxide (1% level).

10% oxygen + 2·5% carbon dioxide significantly firmer than Control (1% level).

Maturity 2 significantly firmer than Maturity 3 (5% level).

Removal 1 and Removal 2 significantly firmer than Removal 3 (1% level).

After each removal of fruit from the storage chambers, the atmospheres were returned to the required concentrations with nitrogen and carbon dioxide from external cylinders.

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

(v) *Results.*—The results are summarized in Table 3.

Mould incidence was comparatively slight and an analysis of variance was not carried out. There was less mould in the fruit held in controlled atmospheres than in fruit held in air but the difference was small. Mould was approximately twice as common in fruit from young trees as in fruit from old trees. There was also an increase in this disorder with increase in the length of the storage period.

The incidence of soggy breakdown in fruit in the controlled atmospheres was negligible irrespective of maturity, tree age, composition of storage atmosphere or length of the storage period. The control fruit, however, showed a considerable increase of the disorder with increase in the length of the storage period. Carbon dioxide concentration in the storage atmosphere had a marked effect on the amount of superficial scald present. Fruit from the first pick had significantly more scald than that from the second pick. The length of the storage period and tree age had no significant effect on the amount of the disorder.

There was a highly significant decrease in total wastage with increase in the maturity of the fruit. In addition, fruit from old trees showed significantly less wastage than that from young trees. The effects of atmosphere were most significant, fruit from both of the controlled atmospheres having less wastage than that from the control. However, of the two atmospheres used, the 10% oxygen plus 2·5% carbon dioxide had significantly less wastage than the 16% oxygen plus 5% carbon dioxide, mainly because of the lower incidence of superficial scald. There was a significant increase in the incidence of wastage with increase in the length of the storage period.

Fruit from the first pick was significantly firmer than that from the second pick. There was a significant increase in firmness with increase in the carbon dioxide content of the storage atmosphere. No significant differences in firmness existed between fruit from the first and second removals, but fruit from both these removals was significantly firmer than that from the third removal.

V. 1955 EXPERIMENT

(i) *Objective.*—To determine the effects of later picking dates on the incidence of superficial scald in controlled atmosphere storage.

(ii) *Materials and Methods.*—These have been reported by Stevenson (1957).

(iii) *Results.*—The results reported by Stevenson (1957) are summarized here as follows:

Mould wastage was greater in fruit from young trees than in fruit from old trees. Fruit stored in a 16% oxygen plus 5% carbon dioxide atmosphere had less mould than fruit in normal air storage, and an atmosphere of 10% oxygen plus 2·5% carbon dioxide showed no difference from the control.

The incidence of soggy breakdown was low. None occurred in fruit from the first removal but there was an increase with length of storage period. Age of tree had no effect on the incidence of the disorder. Increase in carbon dioxide concentration reduced soggy breakdown in both picks.

An increase in superficial scald was found with an increase in the carbon dioxide concentration in fruit from the first pick. Neither the length of the storage period nor the age of the trees had any effect on the incidence of scald.

Total wastage increased with length of the storage period. Fruit from the second pick had less wastage than that from the first pick. Storage atmosphere had no significant effect on total wastage.

The firmness of the fruit decreased as the storage period lengthened. Fruit from both the controlled atmospheres was firmer than that from air storage. That stored in the 16% oxygen plus 5% carbon dioxide atmosphere was about ½ lb firmer than that stored in the 10% oxygen plus 2·5% carbon dioxide atmosphere. In the higher carbon dioxide atmosphere the fruit was about 2 lb firmer than the control fruit. Firmness was not affected by maturity or by tree age.

VI. 1956 EXPERIMENT

(i) *Objective.*—To study the inhibiting effect of DPA on superficial scald in storage.

(ii) *Materials and Methods.*—These have been reported in detail by Stevenson and Blake (1961).

(iii) *Results.*—The results of the 1956 experiment (Stevenson and Blake (1961) may be summarized as follows so far as the effects of controlled storage atmospheres are concerned:

There was a highly significant increase in mould with increase in the length of the storage period, and fruit from the first pick had significantly less mould than that from the second pick.

Very little soggy breakdown was encountered in the experiment irrespective of whether the fruit was wrapped, unwrapped or treated with DPA. However, in fruit stored under normal atmospheres there was a definite increase of the disorder with increase in the length of the storage period and, in addition, fruit from the first pick had more soggy breakdown than fruit from the second pick.

The effect of storage atmosphere on superficial scald incidence was highly significant and was related to the length of the storage period. In the first and second removals, fruit from normal air storage and a 5% oxygen atmosphere had significantly less scald than that from either a 16% oxygen plus 5% carbon dioxide or a 11% oxygen plus 10% carbon dioxide atmosphere. In the third removal, fruit stored under 5% oxygen had slightly more scald than that held under normal atmospheres, but this may have been due to inadequate removal of carbon dioxide (Stevenson and Blake 1961). Fruit held under 16% oxygen plus 5% carbon dioxide was more affected by the disorder than fruit stored in either air or 5% oxygen, but was significantly less affected than fruit held under 11% oxygen plus 10% carbon dioxide.

Very little superficial scald was present when DPA dips were used and up to 5% carbon dioxide was present in the storage atmosphere. A concentration of 10% carbon dioxide in the storage atmosphere resulted in a greater amount of scald present even when DPA dips were used. However, the use of oiled paper wraps in addition to a DPA dip reduced this scald incidence to almost zero. Because of the small amount of scald present in the experimental fruit treated with DPA, the effect of time of picking and length of the storage period on the storage behaviour of fruit treated with this compound could not be analysed statistically.

When oiled paper wraps alone were used, considerable scald was present, and the increase of the disorder with longer storage periods and with high carbon dioxide concentrations in the storage atmosphere were highly significant. Fruit from the first removal had less scald than that from either of the two later removals. Fruit from the second pick was less affected than that from the first pick.

The effect of storage atmosphere on total wastage was highly significant, less wastage being present in fruit stored under 5% oxygen than in the other atmospheres at the third removal. In the first and second removals both the 5% oxygen and normal air-stored fruit were significantly less affected than that in the other two storage atmospheres. However, further increase in the length of the storage period greatly increased wastage in the fruit stored under normal atmospheric conditions. For all removals the 16% oxygen plus 5% carbon dioxide atmosphere was significantly better than the 11% oxygen plus 10% carbon dioxide atmosphere.

The effect of storage atmosphere on firmness of fruit was highly significant. Air-stored fruit was not as firm as fruit stored in an atmosphere of 5% oxygen, which in turn was not as firm as that stored in the 16% oxygen plus 5% carbon dioxide or the 11% oxygen plus 10% carbon dioxide atmospheres. Under an atmosphere of 5% oxygen, fruit in oiled paper wraps was significantly softer than that treated with DPA irrespective of whether the treated fruit was wrapped or not. There were also some effects on firmness due to DPA dips when fruit was stored under atmospheres of either 5% oxygen or 16% oxygen plus 5% carbon dioxide.

VII. 1957–1959 EXPERIMENTS

(i) *Objective.*—To test consumer and market reaction to Granny Smith apples stored under controlled atmospheres.

(ii) *Fruit.*—In each year experimental fruit was selected in four Stanthorpe district growers' packing sheds from fruit picked in mid-April, which earlier experiments had shown was the earliest suitable stage of maturity for controlled atmosphere storage.

(iii) *Pre-storage Treatments.*—The fruit was wrapped in oiled wraps containing 15% mineral oil, railed to Brisbane, and stored in the Hamilton Cool Stores.

(iv) *Storage and Post-storage.*—Seventy-two 1 bus cases were stored in gas-tight containers at 34°F. The storage atmosphere selected was 5% oxygen without any carbon dioxide. Although the presence of carbon dioxide results in firmer fruit, it was considered desirable to exclude carbon dioxide because it tends to increase the incidence of superficial scald, particularly in early-picked fruit, and growers could be expected to pick some fruit earlier than the middle of April. DPA could not be used as a scald inhibitor because of public health restrictions on its use.

The experimental chambers were sealed, and prior to sealing, trays of commercial grade flake sodium hydroxide were enclosed to remove carbon dioxide given off by the respiration of the fruit. After sealing, the atmospheres were allowed to build up to the approximate oxygen level and were then adjusted by nitrogen from an external cylinder. During the storage period regular checks were made with an Orsat gas analysis apparatus and any necessary adjustments made with oxygen and nitrogen from external cylinders.

The chambers were opened in mid-December each year and the fruit forwarded to the Brisbane Wholesale Fruit Market for sale through the normal marketing channels.

(v) *Results.*—The response of both the consumer and the retailer was very satisfactory. Premium prices were paid for the fruit, which was in excellent condition. Visual examination on the market floor revealed very few disorders.

VIII. DISCUSSION

Throughout the eight years of experimental work surveyed in this paper, the Queensland grown Granny Smith apple proved well suited to controlled atmosphere storage.

Fruit stored in controlled atmospheres was firmer than that held under normal air-storage methods. It was practically free from soggy breakdown, and superficial scald was unimportant when fruit of suitable maturity was stored in an atmosphere containing little or no carbon dioxide.

It was shown that fruit intended for controlled atmosphere storage should not be picked before mid-April, as fruit harvested earlier is extremely susceptible to superficial scald, particularly in atmospheres containing carbon dioxide.

Though the presence of carbon dioxide in the storage atmosphere resulted in firmer fruit, the increased incidence of superficial scald due to the gas generally precludes its use. The most satisfactory atmosphere was found to be 5% oxygen. To maintain this atmosphere requires removal of the carbon dioxide liberated by the fruit. On a commercial basis this necessitates the use of a scrubbing device, involving considerable expense and labour.

The tests reported by Stevenson and Blake (1961) on inhibition of superficial scald in Granny Smith apples by chemical means have shown that diphenylamine and 6 ethoxy 1,2 dihydro 2,2,4 trimethylquinoline give good control of the disorder, and the use of one or the other would permit fruit to be stored in an atmosphere containing carbon dioxide without appreciable development of scald. The most satisfactory storage atmosphere for fruit treated with a scald inhibitor would be one containing a mixture of 16% oxygen and 5% carbon dioxide. This atmosphere would be easy to maintain in the storage chamber since it can be obtained readily by controlled ventilation. The use of an inhibitor must await the clearance of a suitable chemical by public health authorities. 6 ethoxy 1,2 dihydro 2,2,4 trimethylquinoline has been cleared in the United States for use as either a preharvest spray or a post-harvest dip treatment of apples for human consumption.

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