FACTORS INFLUENCING THE INCIDENCE AND CONTROL OF SUPERFICIAL SCALD ON COOL-STORED GRANNY SMITH APPLES

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SUMMARY

In experiments, scald incidence was significantly affected by maturity at time of picking and storage temperature, but neither of these factors separately nor together gave sufficient control to allow fruit to be successfully stored without some effective means of scald control.

Prestorage dips of 1000 p.p.m. ascorbic, gallic and tannic acid failed to effect control of the disorder, but the effectiveness of diphenylamine and ethoxyquin was confirmed.

Preharvest sprays of ethoxyquin were not only found to be less effective than post-harvest dips but also injured the fruit.

Storage at 40°F for a number of weeks prior to continuous storage at 30°F for the rest of the storage period significantly reduced scald in unwrapped fruit, but scald incidence remained too high to allow recommendation of this method for commercial storage operators.

I. INTRODUCTION

Superficial scald is the most common disorder associated with the cool storage of the Granny Smith apple variety. During 1961, four separate experiments were carried out to study the following aspects in respect of scald incidence:—

(*a*) The effect of maturity and storage temperature.

(*b*) Chemical means of control.

(*c*) The effect of preharvest sprays of ethoxyquin.

(*d*) Falling temperature storage technique.

II. EFFECT OF MATURITY AND STORAGE TEMPERATURE ON THE INCIDENCE OF SUPERFICIAL SCALD

There is considerable evidence that immature apples are more susceptible to superficial scald than those picked at later dates. Tindale and Huelin (1939) observed this with the Granny Smith variety grown in Victoria and claimed that the reduction in the incidence of the disorder occurs only over a short period, after which there is a marked increase in incidence with further increase in maturity. Padfield (1950), working with this variety, also reported a decrease

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in scald incidence with increase in maturity. Stevenson (1957) and Stevenson and Watkins (1961) similarly found a marked effect of maturity on superficial scald in investigations with the Granny Smith variety. Tindale (1960) studied the effect of maturity and storage temperature on scald incidence on the Victorian Granny Smith and concluded that scald in this variety is a low-temperature disorder. His work indicates that low temperatures not only tend to induce scald but also considerably delay its appearance. The experiment below was therefore designed to study the effect on scald incidence of fruit picked over a wide range of picking dates and stored at four different temperatures.

(a) Methods and Materials

Fruit for the experiment was obtained from a block of trees in the C.S.I.R.O. orchard at Applethorpe, in the Stanthorpe district, five separate picks being made at regular intervals. The actual picking dates were:—

Maturity 1—March 20, 1961.
Maturity 2—April 4, 1961.
Maturity 3—April 19, 1961.
Maturity 4—May 2, 1961.
Maturity 5—May 16, 1961.

Twenty-four half-bushel cases of fruit were picked from the experimental trees on each picking date. After picking, the fruit was randomized, packed unwrapped into cases and transported to the Food Preservation Research Laboratory, Hamilton, where six cases were stored at each of the following temperatures—30°F, 32°F, 34°F and 36°F. Removals of fruit from store were made as follows:—

Removal 1—October 5, 1961.
Removal 2—November 13, 1961.
Removal 3—December 4, 1961.

After removal from store the fruit was held at atmospheric temperatures for seven days to simulate normal marketing delays, and then examined for superficial scald incidence.

(b) Results

The results are summarized in Table 1. Scald incidence was extremely high irrespective of time of picking or temperature of storage. Fruit from the first pick was more affected by scald than fruit from the other four picks, but fruit from the second pick had more scald than that from the third pick. Temperature had a marked effect on scald incidence, significantly less scald being present at 30°F and more scald at 34°F than at any of the other storage temperatures. Fruit from the first removal was less affected by scald than that from either the second or the third removal. Fruit from the first three picks had less scald when stored at 36°F, but for the last two picks there was less scald at 30°F and 32°F.

TABLE 1

EQUIVALENT PERCENTAGES SUPERFICIAL SCALD AFTER REMOVAL FROM COOL STORE

—	30°F	32°F	34°F	36°F
Maturity 1	98·9	99·7	99·5	88·7
Maturity 2	93·6	89·3	91·0	79·4
Maturity 3	82·1	84·2	89·0	60·2
Maturity 4	65·2	73·6	91·2	97·4
Maturity 5	39·6	86·5	94·2	98·1
Removal 1	67·8	79·4	88·5	76·5
Removal 2	85·4	92·7	96·9	93·6
Removal 3	85·3	92·2	94·8	90·4

Maturity 1 sig. greater than Maturities 2, 3, 4 and 5 (1% level).
Maturity 2 sig. greater than Maturity 3 (1% level).
34°F sig. greater than 30°F, 32°F, 36°F (1% level).
32°F and 36°F sig. greater than 30°F (1% level).
Removals 2 and 3 sig. greater than Removal 1 (1% level).
Temperature x Maturity Interaction—For Maturities 1, 2 and 3 scald decreases at 36°F, but for Maturities 4 and 5 scald is less at 30°F and 32°F.

(c) Discussion

The results clearly show that the Granny Smith apple cannot be held for long periods under refrigerated conditions without a scald inhibitor. While maturity and temperature influence scald development, neither of these factors separately nor together will give control of sufficient magnitude to allow untreated fruit to be stored successfully.

III. INVESTIGATIONS INTO CONTROL BY CHEMICAL MEANS

Experiments carried out over a 5-year period by Stevenson and Blake (1961), to determine whether superficial scald in Queensland grown Granny Smith apples could be controlled by chemical means, had shown that the best control was obtained from dips containing low concentrations of either diphenylamine or ethoxyquin (6-ethoxy-1, 2-dihydro-2, 2, 4-trimethylquinoline), which have been cleared for commercial use in the U.S.A. Ethoxyquin was approved in 1961 by the Queensland health authorities for Departmental use. Padfield and Bollard (1960) reported encouraging results with Granny Smith apples dipped in solutions containing 1000 p.p.m. ascorbic, tannic or gallic acids. In view of this and the extremely low toxicity of these compounds, an experiment was conducted during the 1961 apple season to determine whether these substances inhibit superficial scald and to compare their performance with dips of both diphenylamine and ethoxyquin.

(a) Methods and Materials

Fruit for the experiment was picked on April 4, 1961, from an orchard in thet Stanthorpe district.

Six different storage treatments were used:—(*a*) 1000 p.p.m. diphenylamine dip; (*b*) 1000 p.p.m. ethoxyquin dip; (*c*) 1000 p.p.m. ascorbic acid dip; (*d*) 1000 p.p.m. gallic acid dip; (*e*) 1000 p.p.m. tannic acid dip; (*f*) undipped control.

Both the diphenylamine and the ethoxyquin dips were applied as alcoholic solutions, while the remaining compounds were applied as aqueous solutions with a wetting agent added.

After picking, the experimental fruit was transported to the Food Preservation Research Laboratory, Hamilton, where it was treated the following day. The fruit was then packed into half-bushel cases, each treatment consisting of four half-bushel cases. The treated cases were stored at 30°F until November 7, 1961, when they were removed from store, held for seven days at atmospheric temperatures to simulate normal marketing delays, and then examined for superficial scald incidence.

(b) Results

The results are summarized in Table 2. Because of the large differences between treatments an analysis of variance was not carried out. As in earlier experiments, both diphenylamine and ethoxyquin gave excellent control of the disorder, but ascorbic, gallic and tannic acids failed to effect any control at the concentration used by Padfield and Bollard (1960). Smock (1957), using a dip of 500 p.p.m. ascorbic acid, also failed to obtain any control of superficial scald. It was noticed that tannic acid left an unsightly blackish-brown residue on the fruit.

TABLE 2

PERCENTAGES SUPERFICIAL SCALD AFTER REMOVAL FROM COOL STORE

Replicate	1000 p.p.m. Diphenylamine Dip	1000 p.p.m. Ethoxyquin Dip	1000 p.p.m. Ascorbic Acid Dip	1000 p.p.m. Gallic Acid Dip	1000 p.p.m. Tannic Acid Dip	Untreated Control
1	0	0	81·3	96·2	92·6	88·1
2	0	6·1	75·9	83·3	93·8	57·1
3	0	0	87·0	100·0	89·4	92·4
4	0	0	81·5	84·8	79·2	91·7
Means ..	0	1·5	81·4	91·1	88·8	82·3

No analysis of variance carried out because of the large differences.

(c) Discussion

The scald-inhibiting properties of both diphenylamine and ethoxyquin were once more confirmed by these results, which indicate that control of the disorder is more than the simple application of known anti-oxidants.

IV. EFFECT OF PREHARVEST SPRAYS OF ETHOXYQUIN ON SCALD INCIDENCE

As a result of the discovery by Smock (1955) of the scald-inhibiting properties of diphenylamine, a number of workers investigated the possibility of there being other effective inhibitors. Smock (1957) reported that ethoxyquin also had good scald-inhibiting properties. Stevenson and Blake (1961) and Hall, Scott, and Coote (1961) found that while this compound was not as effective as

diphenylamine, good control of superficial scald on Granny Smith apples resulted from post-harvest dips with low concentrations of this substance, and advice was received from Smock (private communication) that in addition to its use as a post-harvest dip ethoxyquin gives satisfactory control if used as a preharvest spray, provided the fruit was picked within 48 hr of spraying. Accordingly, this experiment was designed to determine the efficacy of preharvest sprays of ethoxyquin as a means of controlling superficial scald in cool-stored Granny Smith apples.

(a) Methods and Materials

Three representative orchards were selected in the Stanthorpe district. Blocks of eight trees were chosen in each orchard, two trees being used for each of the four treatments:—

(*a*) 2000 p.p.m. ethoxyquin preharvest spray.
(*b*) 3000 p.p.m. ethoxyquin preharvest spray.
(*c*) 4000 p.p.m. ethoxyquin preharvest spray.
(*d*) 1000 p.p.m. ethoxyquin post-harvest dip.

The spray treatments were applied on three separate occasions, March 22, April 6, and April 18, 1961.

One half-bushel case of fruit from each tree was picked 24 hr after spraying, i.e.,

Maturity 1—March 23, 1961
Maturity 2—April 7, 1961
Maturity 3—April 19, 1961,

making a total of 24 half-bushel cases from each pick. After picking and packing, the cases were transported to the Food Preservation Research Laboratory. Hamilton, where the fruit from the unsprayed trees was dipped in 1000 p.p.m. ethoxyquin. All cases were then cool-stored at 32°F until November 6, 1961, when they were removed to atmospheric temperatures. After holding for seven days to simulate normal marketing delays, the fruit was examined for superficial scald incidence.

(b) Results

The results are summarized in Table 3. Treatment and maturity effects were most marked. Scald incidence decreased with increase in spray concentration and with increase in maturity. In fruit from the first and second picks a 1000 p.p.m. ethoxyquin dip was more effective than any of the spray concentrations used, but with fruit from the third pick differences in scald incidence were extremely small, irrespective of treatment. Fluorimetric analyses for ethoxyquin residues were carried out on samples from each treatment after inspection and in all cases the residues were less than 1 p.p.m., which was well below the American tolerance of 3 p.p.m. Fruit from trees sprayed with 3000 p.p.m. was slightly affected by blotches of spray residue of a blackish brown colour, while that from the 4000 p.p.m. spray treatment suffered skin injury around the calyx end of the fruit.

TABLE 3

MEAN PERCENTAGES SUPERFICIAL SCALD AFTER REMOVAL FROM COOL STORE

Treatment	Maturity 1	Maturity 2	Maturity 3
2000 p.p.m. spray	76·5	18·6	0·4
3000 p.p.m. spray	66·1	11·4	0·4
4000 p.p.m. spray	59·0	5·8	0
1000 p.p.m. dip	11·4	0	0

No analysis of variance carried out because of large differences.

(c) Discussion

The results suggest that ethoxyquin preharvest sprays may be only of limited use in the control of superficial scald on Granny Smith apples, for the concentration has to be increased for the early-picked fruit and at the concentrations required to control scald, injury and unsightly blemishes may be caused. When dips are used, better fruit coverage is obtained and control is effected with lower concentrations. Thus when the scald susceptibility of the fruit is such that concentrations exceeding 3000 p.p.m. are required to control scald, spraying should be avoided and dipping used.

V. FALLING TEMPERATURE STORAGE TECHNIQUE AND ITS EFFECT ON SCALD INCIDENCE

Melville and Hardisty (1953) reported that good control of superficial scald in Granny Smith apples, from a practical point of view, can be obtained by storing the fruit at 40°F until the end of May, and then at approximately 32°F for the remainder of the storage period. Fruit so stored was virtually free from superficial scald and had appearance and condition superior to that stored continuously at 32° F. Their results also indicated that oiled-paper wrappers were an essential part of scald control and that complete wrapping was necessary for good effect. Melville (1959), however, reporting trials over a 2-year period with this variety, showed that fruit may be stored unwrapped, with negligible loss from scald, for a considerable period. In view of these results this experiment was conducted to determine whether this method is suitable for scald control of Queensland grown Granny Smith apples.

(a) Methods and Materials

Fruit for the experiment was picked from six separate orchards in the Stanthorpe district, on three separate occasions:—

First pick (Maturity 1)—March 22, 1961

Second pick (Maturity 2)—April 6, 1961

Third pick (Maturity 3)—April 19, 1961

Six half-bushel cases were picked from each of the six orchards on each of the three picking dates, giving a total of 108 half-bushel cases.

The treatments used in the experiment were:—

(*a*) Storage at 40°F for 4 weeks followed by storage at 30°F.
(*b*) Storage at 40°F for 6 weeks followed by storage at 30°F.
(*c*) Storage at 40°F for 8 weeks followed by storage at 30°F.
(*d*) Storage at 40°F for 10 weeks followed by storage at 30°F.
(*e*) Storage at 40°F for 12 weeks followed by storage at 30°F.
(*f*) Continuous storage at 30°F.

Each treatment consisted of one half-bushel case from each orchard from each of the three picks, i.e. 18 half-bushel cases in all.

After picking, the fruit was packed in half-bushel cases and transported to Brisbane, where it was cool-stored at the Food Preservation Research Laboratory, Hamilton. All the fruit was removed from the storage chamber on November 14, 1961, held for seven days at atmospheric temperatures to simulate normal marketing delays, and then examined for the incidence of superficial scald.

(b) Results

The results are summarized in Table 4. Treatment had a significant effect on scald incidence: all fruit held at 40°F prior to storage at 30°F had less scald than fruit stored continuously at 30°F. However, storage at 40°F for four weeks did not control scald as effectively as storage at this temperature for longer periods. The effect of maturity was not significant except in the case of storage continuously at 30°F, where scald incidence decreased with increase in maturity.

TABLE 4

PERCENTAGES SUPERFICIAL SCALD AFTER REMOVAL FROM COOL STORE

—	40°F for 4 Weeks, then 30°F	40°F for 6 Weeks, then 30°F	40°F for 8 Weeks, then 30°F	40°F for 10 Weeks, then 30°F	40°F for 12 Weeks, then 30°F	30°F Continuously
Maturity 1	83·6	84·4	73·6	73·0	63·9	100·0
Maturity 2	86·0	74·6	78·8	90·9	78·1	92·8
Maturity 3	76·0	80·3	83·4	72·1	79·9	83·8
Means ..	81·9	79·8	78·6	78·7	74·0	92·2

40°F for 4 weeks then 30°F sig. less than 30°F continuously (5% level).
40°F for 6, 8, 10 and 12 weeks then 30°F sig. less than 30°F continuously (1% level).
Interaction Treatments x Maturity significant (5% level).

(c) Discussion

Despite the reduction in scald resulting from storage at 40°F prior to subsequent storage at 30°F, its incidence was extremely high and the method could not be recommended for commercial storage of unwrapped fruit. This effect of storage at 40°F, combined with the benefit of oiled-paper wrappers, appears in the case of Melville and Hardisty (1953) to have given better control

than either treatment acting independently. Padfield (1958), over a 3-year period, found that apples held for four weeks at 37-38°F and then at 31-32°F, after 7 months' storage were no better than fruit in oiled wrappers stored continuously at 31-32°F.

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REFERENCES

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.

MELVILLE, F. (1959).—The storage of the Granny Smith apple. *J. Agric. W. Aust.* 8:91-5.

MELVILLE, F., and HARDISTY, S. E. (1953).—Scald in Granny Smith apples. Practical aspects of control. *J. Agric. W. Aust.* 2:101-17.

PADFIELD, C. A. S. (1950).—Superficial scald on New Zealand Granny Smith apples. The period of greatest susceptibility. *N.Z. J. Sci. Tech.* A32:45-7.

PADFIELD, C. A. S. (1958).—Superficial scald. Some methods of control, reported overseas, applied to New Zealand grown Granny Smith apples. *N.Z. J. Agric. Res.* 1:231-8.

PADFIELD, C. A. S., and BOLLARD, E. G. (1960).—*In* Rep. 3rd Conference of Fruit Storage Investigators, Sherbrooke, Victoria.

SMOCK, R. M. (1955).—A new method of scald control. *Amer. Fruit Gr.* 75(11):20.

SMOCK, R. M. (1957).—A comparison of treatments for the control of the apple scald disease. *Proc. Amer. Soc. Hort. Sci.* 69: 91-100.

STEVENSON, C. D. (1957).—Apple cool storage investigations in 1955. *Qd J. Agric. Sci.* 14: 167-81.

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., and WATKINS, J. B. (1961).—Effect of maturity and tree age on the behaviour of Queensland grown Granny Smith apples stored at 34-36°F. *Qd J. Agric. Sci.* 18:77-84.

TINDALE, G. B. (1960).—Scald on Granny Smith apples. *In* Rep. 3rd Conference of Fruit Storage Investigators, Sherbrooke, Victoria.

TINDALE, G. B., and HUELIN, F. E. (1939).—Superficial scald in apples. Effect of picking maturity, delayed storage and wrappers. *J. Dep. Agric. Vict.* 37:77-9.

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