APRC PROJECT REPORT

Project SP112:	Strategies to improve the textural quality of CA-stored Cox apples
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Background

This 3-year project began in June 1997 and is directed towards an improvement in the textural quality of Cox apples stored under controlled atmosphere conditions. Three approaches were taken in the final year of the project:

1. Investigation of the residual effects of ReTain^{TM} on fruit quality
2. Effect of nutrient sprays on the firmness of Cox apples.
3. Influence of water loss on textural properties of fruit in CA storage

This report covers the period from January-June 2000 inclusive.

1. Investigation of the effect of ReTain^{TM} on fruit quality

The product ReTain^{TM} which is registered for use in the USA (Abbott Laboratories) has shown major promise as an orchard spray treatment to maintain the firmness of Cox apples in controlled atmosphere (CA) storage. Results of experiments carried out in a commercial orchard in 1997 and at HRI-East Malling in 1998 were described in previous progress reports to APRC. No new experiments were carried out in 1999 although, in a separate initiative between Abbott Laboratories and the APRC, efficacy trials were initiated on Bramley. A full report of the Bramley work was provided to both sponsors in May 2000.

It was decided that possible residual effects of ReTain^{TM} application on the storage quality of Cox apples required investigation. Consequently apples from the trees used in the 1998 experiment were harvested on 14 September 1999 and the total crop from each tree was weighed and counted. Sub-samples of fruit were dipped in 'Bavistin' fungicide prior to storage in 1.2% O_2 + <1% CO_2 at 3.5^{o}C.

Details of the 1998 treatments were given in the previous reports to APRC but these may be summarised as follows. The experiment was carried out in a Queen Cox M.9 orchard planted in 1979. ReTain^{TM} sprays were applied on 13 August 1998 (4 weeks prior to the anticipated harvesting date of Cox for long-term storage). The product was applied at 0.73g litre^{-1} in combination with a proprietary surfactant at 1ml litre^{-1}. Two litres of solution was applied to each tree using a knapsack sprayer. There were 2 chemical treatments, ReTain^{TM} and untreated control, and 3 harvest date treatments allocated to 2-tree plots and replicated 6 times in a latin-square design

Fruit from the 1999 crop was removed from CA storage on 12 April 2000 and an assessment of quality was carried out.

Trees sprayed with ReTain^{TM} in 1998 gave a 9.4% higher yield in 1999 compared with untreated trees. The numbers of fruits increased on trees that were sprayed in the previous year but the average weight of fruit was reduced from 142 to 128g.There were fewer rotted fruit at harvest (4.1% compared to 6.9%) and after CA storage (3.2% compared to 6.6%) in fruit from trees sprayed previously. This may be associated with the residual effects of treatments on fruit size. The smaller fruit from the 1998 ReTain^{TM} treatment may have had a higher calcium status; generally this would confer higher resistance to rotting. However, in the absence of any mineral analysis data the precise mechanism of the residual effect of ReTain^{TM} on rotting cannot be established. There were no residual effects of ReTain^{TM} on the firmness or background colour of CA-stored fruit and there was insufficient evidence of any physiological disorders to assess treatment effects.

2. Effect of nutrient sprays on the firmness of Cox apples.

In a recently completed LINK project involving MAFF, APRC and English Apples and Pears Ltd. important leads were established between mineral nutrition and textural quality of Cox apples. A full summary of the project results was published in the APRC News (Issue 22). One of the important findings was that the use of late sprays (late-June to harvest) of calcium nitrate improved fruit texture at harvest and after CA storage. Early sprays (full bloom to mid-June) containing zinc or calcium chloride also improved texture of fruits at harvest and after storage but often caused thinning of the crop. It was recognised that further work was required to optimize nutrient supplements and to consider the possible substitution of calcium nitrate for calcium chloride in Cox spray programmes.

In an experiment designed to follow these important leads sprays containing zinc and/or calcium chloride were applied to M9 Cox trees during the cell division phase of fruit development (5 May - 15 June 1999). Half of the trees from each treatment also received a late programme of calcium nitrate sprays (24 June-3 September 1999). Trees were picked on 8 September and the crop from each tree was weighed and counted. Sub-samples of fruit were taken immediately for firmness measurement using an automated penetrometer fitted with an 11mm probe. Additional samples were dipped in 'Bavistin' fungicide prior to storage in 1.2% O_2 + <1% CO_2 at 3.5°C. Quality assessments were carried out on fruit removed from CA storage on 5 January and 13 March 2000. Additional samples removed from store in March were inspected after a simulated marketing period of 7 days at 20°C. Mineral analysis of fruits was also carried out.

Early sprays containing zinc produced a 5-fold increase in the concentration of zinc in the fruits at harvest. Fruit calcium concentrations were increased from 3.1 to 4.4 mg $100g^{-1}$ by late sprays of calcium nitrate but early sprays of calcium chloride did not improve fruit calcium levels significantly. Early calcium chloride application in combination with late calcium nitrate increased fruit nitrogen concentration. The firmness of fruits from treatments that did not include calcium sprays was compared with those that included calcium chloride (early), calcium nitrate (late) or both (Table

1). Fruit firmness was improved to a similar extent by early calcium chloride and late calcium nitrate sprays but there was no additive effect of the treatments.

Table 1. Effects of calcium sprays on the firmness of Cox's Orange Pippin apples at harvest and after storage in 1.2% O_2 (<1% CO_2) at 3.5°C until 5 January or 14 March 2000. Firmness measured using an automated penetrometer fitted with an 11mm probe. (*, ** treatments significantly different from the no calcium treatment at P<0.05 and <0.01 respectively).

	Firmness (N)			
	Harvest	January	March	+7d at 20°C
Calcium chloride (early)	83.1**	69.1*	65.6**	58.1*
Calcium nitrate (late)	81.2*	69.5*	65.5**	56.5
Calcium chloride (early) + calcium nitrate (late)	81.3*	69.7*	64.8*	58.4**
No calcium	78.6	66.9	62.5	55.7

Table 2 shows the firmness data for fruit from all treatments measured after CA storage until March. The greatest improvement in firmness was achieved from early sprays containing calcium chloride and zinc.

Table 2. Effects of sprays containing zinc and/or calcium on the firmness of Cox's Orange Pippin apples stored in 1.2% O_2 (<1% CO_2) at 3.5°C 14 March 2000. Firmness measured using an automated penetrometer fitted with an 11mm probe. Figures in brackets relate to fruits measured after a further 7 days at 20°C. (*, ** treatments significantly different from the no calcium treatment at P<0.05, <0.01 and <0.001 respectively).

	Calcium chloride (early)		No calcium chloride	
	Calcium nitrate (late)	No calcium nitrate	Calcium nitrate (late)	No calcium nitrate
Zinc (early)	66.9 **(59.5)**	67.4** (61.0)***	66.5** (57.3)	62.9 (56.8)
No zinc	62.6 (57.3)	63.8 (55.2)	64.5 (55.7)	62.1 (54.7)

In view of the low calcium status of the untreated fruit (3.1 mg $100g^{-1}$) it was not surprising that 30% of fruits examined in March were affected by bitter pit. Calcium nitrate sprays reduced bitter pit to 6% whilst zinc sprays increased the incidence to 45%. There was no overall significant effect of early calcium chloride sprays on bitter pit incidence. An additional benefit of calcium nitrate application was a reduction in the incidence of rotting. However, there was a slight reduction in the amount of red colour on the fruits. There was an overall effect of zinc and calcium nitrate in retarding the yellowing of the background colour of CA-stored fruits.

Repeated (early) application of zinc sprays caused serious damage to the leaves. Late sprays of calcium nitrate caused little or no leaf necrosis but caused lenticel injury on the fruit. Early sprays of calcium chloride were not damaging to leaves or fruits.

Possible residual effects of foliar treatments applied in the previous year, i.e. final year of the LINK project (SP88) referred to above, are being investigated. In 1998 M9 Cox trees had received sprays containing zinc, calcium chloride, urea or calcium nitrate. Sprays were applied during the cell division or cell expansion phase of fruit development. Results obtained during the year of treatment have been described (see APRC News Issue 22) but possible effects on the storage quality in the year after treatment have not been investigated. Trees were picked on 15 September 1999 and the crop from each tree was weighed and counted. Sub-samples were dipped in 'Bavistin' fungicide prior to storage in 1.2% O_2 + <1% CO_2 at 3.5°C. Fruit was removed from CA storage on 10 April 2000 for measurement of firmness and an assessment of quality. Mineral analysis of leaves and fruits was also carried out.

Sprays containing urea or calcium chloride applied in 1998 increased the concentration of nitrogen and manganese and reduced potassium concentration in the leaves sampled in 1999. Urea sprays also reduced phosphorus and increased magnesium levels in the leaves. Sprays containing zinc or calcium nitrate had no residual effects on leaf mineral composition. Urea and calcium chloride sprays reduced potassium concentrations in the fruit at harvest. This effect was consistent with the reduction in leaf potassium. The nitrogen and zinc concentrations in the fruit were reduced by zinc and calcium nitrate sprays respectively. There were no significant effects of treatments on fruit yield. There were no residual effects of spray treatments on the firmness of CA-stored apples but less flesh breakdown occurred where calcium chloride or urea was applied in 1998. This effect may be attributable to the reduction in potassium concentration in the fruit.

3. Influence of water loss on textural properties of fruit in CA storage

The objective of the work is to identify appropriate values of moisture loss in stored Cox apples that provide a pleasant texture and maximize crop value. Prior to the first experiments carried out in 1997/98 dehumidifying equipment was developed to facilitate controlled removal of moisture from fruit during CA storage. For Cox apples the overall rate of moisture loss, from a cabinet containing c. 90 kg of fruit, can be varied from 10 to 45 g/day - equivalent to a weight loss over six months of 1.8% to 8%.

Fruit from the first year trial were removed and weighed, individually, prior to removal of a sub-sample that was assessed by a taste panel and by instrumental measurement. This was done in both January and March, and on each occasion the assessments were carried out after keeping the fruit for 1 day and 7 days at 20 °C, the longer period provided information on the shelf-life behaviour of the fruit.

A preliminary assessment of the results obtained in the first year suggested that the taste panel were able to distinguish between the treatments in a different manner to the instruments. The panel generally perceived the fruit with high moisture loss to be firmer, whereas readings from the penetrometer showed little difference. In contrast, few panelists noted differences in juiciness, though from instrumental measurements the fruit with high moisture loss was judged to be less juicy. A more rigorous analysis of the results will be deferred until the current year's data is gathered.

To confirm the results obtained in the first year and take advantage both of the more typical growing season and the more normal distribution of fruit sizes, another similar experiment was started in September 1999, along the lines described in the report to December 1997. (Frost damage in the first year having lead to a very small crop which, for the site selected, was predominated by large and small fruit at the expense of moderate sizes). In this instance, Cox apples, grown at East Malling, were harvested on 9 September, the fruit for the experiment, in the size range 65 to 75 mm being selected from 4 bulk bins. After treatment with fungicide (Ridomil mbc), the fruit was cooled overnight to 4°C. Initial firmness was 79 N. Check weighing of the fruit, in December, confirmed that weight loss of the three experimental treatments was on course to reach 2%, 3.5 % and 5% by the end of the experiment.

All of the fruit in the trial were weighed in the period 17 to 19 January 2000 to facilitate calculation of the weight loss of each individual fruit, as a pre-requisite to selecting fruit for the first removal for instrumental and taste panel assessment. All the remaining fruit were weighed again in the period 8 to 10 March, to select fruit for the second removal.

By careful selection of the fruit used for the first removal, it was possible to ensure there was available, for the second removal, fruit of very similar weight loss status. In each case, half of the fruit removed was put into a store at 20 °C, for seven days, to simulate a typical shelf-life period. Individual fruit were again weighed immediately prior to assessment so that the weight loss at that time could be calculated. Table 3, summarises the mean moisture loss of samples for each treatment category at the time of assessment. As can be seen the moisture loss values were very close to the target values referred to above.

Table 3 - Moisture loss of fruit at each assessment date.

	High moisture loss (A) (%)	Moderate moisture loss (B) (%)	Low moisture loss (C) (%)
Removal 1 +1 day at 20 °C (4 Feb)	4.8	3.3	2.2
Removal 1 +7 days at 20 °C (10 Feb)	7.0	5.5	4.7
Removal 2 + 1day at 20 °C (15 Mar)	4.9	3.3	2.0
Removal 2 +7 days at 20 °C (21 Mar)	5.6	4.4	3.0

Taste panel results: On each of four occasions, on the dates shown in Table 3, participants were presented with three pairs of fruit. The three moisture-loss treatments High (A), Moderate (B) and Low (C) were evaluated in the pairings A to B, B to C and A to C. The sequence of presentation was randomised to eliminate any systematic errors. Comment was invited on the attributes aroma, acidity, sweetness, juiciness, firmness, toughness and mealiness. Statistical analysis of the results indicates significant differences were detected for firmness and toughness. [In relation to the instrumental assessment described later, it is noteworthy that no significant differences in juiciness were detected]. In the case of firmness 60 % of respondents indicated a difference between treatments. Fruit having high or moderate levels of moisture loss were selected as significantly firmer than fruit with a low moisture loss No significant difference was detected between high and moderate moisture loss treatments. The remaining 40 % of respondents reported no difference between treatments. For toughness, 51 % of respondents detected a difference, with the fruit having high or moderate moisture loss being judged tougher than that with low moisture loss. The remaining respondents detected no difference between treatments.

Instrumental measurements: Corresponding to each of the taste panel sessions, closely matched samples of fruit were assessed for firmness, juiciness and colour. The firmness measurements, made with an automated penetrometer fitted with an 11 mm probe, showed no significant differences between treatments (Table 4). There was little softening in the six week period between the first and second removals; keeping at 20 °C for an additional six days caused firmness to drop by four to six Newtons.

Table 4 - Firmness of fruit in Newtons (N) in relation to extent of moisture loss

	High moisture loss (N)	Moderate moisture loss (N)	Low moisture loss (N)
Removal 1 +1 day at 20 °C (4 Feb)	60	61	60
Removal 1 +7 days at 20 °C (10 Feb)	54	58	54
Removal 2 + 1day at 20 °C (15 Mar)	58	61	57
Removal 2 +7 days at 20 °C (21 Mar)	54	56	52

Juiciness was measured using an instrument known as a Chylofel. Designed by the French research organisation CTIFL, this device is specifically intended for making comparisons of the relative juiciness of fruit samples. It functions by collecting the juice expressed in response to the insertion into the fruit of a cylindrical plunger having a conical end section and with a total displacement volume of 2 cm^3. To achieve a satisfactory level of accuracy and resolution the juice from two insertions into each of 20 fruit was aggregated from which a juiciness index (χ), shown in table 5, is derived. This shows that the instrument senses the loss of moisture from the fruit as a reduction in juiciness. Since the taste panel was unable to detect significant differences in juiciness, it is to be assumed that all the treatments in this trial remained adequately juicy.

Table 5 - Juiciness index (χ)

	High moisture loss (χ)	Moderate moisture loss (χ)	Low moisture loss (χ)
Removal 1 +1 day at 20 °C (4 Feb)	18.3	25.2	32.9
Removal 1 +7 days at 20 °C (10 Feb)	14.0	15.9	16.9

Removal 2 + 1day at 20 °C (15 Mar)	21.5	21.6	27.4
Removal 2 +7 days at 20 °C (21 Mar)	15.0	18.1	19.7

The measurements of fruit colour, using a Hunter colour analyser, revealed no significant differences between the three moisture loss treatments (no data presented).