Project Title:	Storage of Braeburn apples
Project Number:	TF 152
Report:	Year 1 annual report, October 2004
Previous reports:	None
Key Workers:	Mr David Johnson, East Malling Research Dr Martin Luton, Worldwide Fruit / Qualytech Mr Andrew Russell, Worldwide Fruit / Qualytech Mr Tim Biddlecombe, FAST Ltd
Location of Project:	East Malling Research New Road East Malling Kent ME19 6BJ Tel: 01732 843833 Fax: 01732 849067
Date Project commenced:	1 July 2003
Date completion due:	30 June 2006
Keywords:	Braeburn, storage, quality, air storage, controlled atmosphere storage, CA, Lochbuie, Hilwell, Schneider, fruit maturity, ethylene, Braeburn Browning Disorder

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The results and conclusions in this report are based on a series of experiments conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

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EAST MALLING RESEARCH

Principal Scientists and authors of report:

D S Johnson (Post-harvest Physiologist and project leader)
Dr Martin Luton, Worldwide Fruit / Qualytech
Mr Andrew Russell, Worldwide Fruit / Qualytech
Mr Tim Biddlecombe, FAST Ltd

Authentication

I declare this work was done under my supervision according to the procedures described herein and that this report is a true and accurate record of the results obtained.

.....D S Johnson
Signature

Date .....

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Picking Braeburn apples too early induces superficial scald and has negative effects on appearance and eating quality of fruit from air and CA storage. In 2003 picking on 16 October generally resulted in optimal quality ex-store. A low temperature storage regime of 0-0.5^{o}C appears to be favourable, but the susceptibility to low temperature injury has yet to be determined. The Lochbuie clone offered the best eating attributes but its storage performance was more variable than Schneider or Hillwell.

Background and expected deliverables

The number of Braeburn orchards in the UK is increasing. Clones currently favoured by UK growers include Hillwell, Schneider and Lochbuie. As production increases there will be a need to provide growers with advice on when to harvest and on the most appropriate conditions for storage. No previous storage research has been carried out in the UK on this variety although in the past 2 years FAST Ltd and Worldwide Fruit (WWF) have been assessing harvest maturity in relation to eating quality of stored fruit on behalf of certain multiple retailers. Results of work done abroad suggest that storage could be problematic since the variety is susceptible to calcium-dependent disorders and is damaged by more stringent controlled atmosphere (CA) regimes. It is also susceptible to scald in long-term CA conditions. Advice provided in the Defra Best Practice Guide for UK Apple Production is based on Belgian experience.

The aim of this 3 year project is to undertake detailed trials to establish the optimum maturity indices and storage conditions for Braeburn and its clones, grown in the UK. The work will provide growers and marketers with (i) the maturity criteria for harvesting UK grown Braeburn apples intended for storage, (ii) recommendations for the short- and long-term storage of Braeburn apples and (iii) information on the clonal differences in harvest maturity and storage potential.

Summary of project and main conclusions

Braeburn apples from 6 commercial orchards were used in the study. There were 2 orchards for each of the 3 clones (Hillwell, Lochbuie and Schneider) currently favoured by UK growers. Samples of fruit for maturity assessment and storage tests were picked on 6 occasions at weekly intervals beginning on 25 September 2003. Fruit was stored in air and controlled atmosphere (CA) conditions (2% O_2, <1% CO_2) at 0-0.5^{o}C and 1.5-2^{o}C. Establishment of CA conditions was delayed for 21 days to reduce susceptibility to Braeburn Browning Disorder (BBD). Measurements on samples taken at harvest for maturity assessment included internal ethylene concentration (IEC), background colour, firmness, soluble solids concentration and starch staining pattern. Samples of apples from each harvest were removed from air storage on 24 November 2003 and 26 January 2004 and from CA storage on 2

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February and 26 April 2004. After weighing, one set of samples was used for an immediate assessment of quality (background colour, firmness and soluble solids concentration) and a similar set of samples was transferred to containers in air at 20°C. Samples previously stored at 1.5-2°C were removed after 4 days and a few apples were used for sensory evaluation by representatives of WWF and EMR. The remainder of the samples were placed back into 20°C. Samples previously stored at both temperatures were removed after 7 or 8 days at 20°C for an assessment of external and internal condition.

Effect of picking date

For storage in air until late November 2003 there were no constraints imposed by the development of disorders. Consequently picking date could be directed to achieving the desired appearance, optimum eating quality and least greasiness of the skin. On the basis of appearance and eating quality, pick 1 (25 September 2003) was clearly too immature but there was little difference in the combined eating quality scores for the fruit from the other picks.

For storage in air until late January 2004, scald development was a constraint. Delay in picking until pick 4 (16 October 2003) was required to avoid scald although pick 3 (9 October 2003) may be considered an acceptable commercial risk. Pick 4 was also best for eating quality and had acceptable background colour (2.3) and firmness (6.9 kg). Starch cover (% black), firmness (kg) and soluble solids concentration (%) at pick 4 were 63, 9.0 and 13.5 respectively with a Streif index of 0.18. Pick 4 (16 October 2003) provided the best combined scores for appearance, aroma and texture.

For storage in CA until early February 2004 there were no constraints imposed by the development of disorders. Consequently picking date could be directed to achieving the desired appearance, optimum eating quality and least greasiness of the skin. Pick 1 fruit was too immature and pick 4 (16 October) provided optimum eating quality. This is in accordance with the best stage to pick for optimum quality from air storage in late January.

For storage in CA until late April 2004 scald development was a constraint. Pick 4 (16 October 2003) was the best time to harvest for minimal scald but pick 3 (9 October 2003) may have provided an acceptable risk. Pick 1 (25 September 2003) fruit was also visually unacceptable and picks 5 (23 October 2003) and 6 (30 October 2003) produced an unacceptable texture in the fruit. None of the picks provided fruit free of all disorders with core flush development in shelf-life being the biggest problem. Fruit from picks 3 and 4 were still good for background colour (2-2.2) and firmness (7.1-7.3 kg).

Effect of storage temperature

There were no significant effects of storage temperatures on skin greasiness, background colour or soluble solids concentration in fruits from air or CA storage. The effect of storage temperature on fruit firmness was generally small and only on the first removal of fruit from air storage was there a significant benefit of the lower storage temperature. There was no effect of storage temperature on weight loss in air-stored fruit though in CA-stored fruit the higher storage temperature resulted in a

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slightly higher weight loss. There were no effects of storage temperature on scald incidence in air-stored fruit though in CA-stored fruit less scald developed on fruit from the lower storage temperature. The lower storage temperature was beneficial in reducing the percentage of CA-stored fruit affected by core flush.

There were no adverse effects of the lower storage temperature (0-0.5^{o}C) and there were some benefits particularly in reducing core flush during prolonged air storage and in reducing scald in prolonged CA storage. At the present time the lower storage temperature is preferred but further experience is required before recommendations can be established. It is well known that climatic conditions during the growing season affect the susceptibility of apples to low temperature injury and the work proposed in years 2 and 3 of the project should help to identify the optimum storage temperature.

Effect of clone

There were no significant effects of clones on background colour or soluble solids concentration in fruits from air or CA storage and there were no effects of clones on scald development. The storage performance of Schneider and Hillwell was generally similar but that of Lochbuie was often different. Positive effects of Lochbuie included higher firmness and less greasiness of the skin which may relate to its tendency to be least mature at harvest. Negative effects included a higher weight loss and a higher susceptibility to core flush and low temperature breakdown. Most of the adverse effects of Lochbuie were evident only in the final removal of fruit from air and CA storage. It is possible that once the storage duration and optimal conditions have been defined the negative aspects of Lochbuie will not be expressed.

Financial benefits

It is too early to comment on the financial implications of the work in progress.

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Action points for growers

- Growers need to be aware of advice being provided on the best time to harvest Braeburn. This may be available through the Quality Fruit Group and other sources.

- Provisional maturity criteria for picking for storage are: -
    - starch cover of 63 (% black),
    - firmness of 9kg (11mm probe), and
    - soluble solids concentration of 13.5%

- Picking Braeburn at a too immature stage will result in an inferior appearance and eating quality and a heightened susceptibility to superficial scald.

- Picking too late can result in a greasy skin and poor texture of the flesh.

- Picking on 16 October 2003 (pick 4 of the 2003 season) prevented scald development and generally provided the best eating quality in fruit from air and CA storage.

- Although there is evidence that a storage temperature of 0-0.5^{o}C shows benefits, the susceptibility to low temperature injury has yet to be determined and so the current storage recommendations in the Defra Best Practice Guide for UK Apple Production, stand (storage temperature 1^{o}C and CA conditions of <1% CO_2 + 2-3% O_2).

- Avoid storing too long. Provisional termination months for air and CA-stored fruit are December and March, respectively.

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Science Section

Introduction

The number of Braeburn orchards in the UK is increasing. Clones currently favoured by UK growers include Hillwell, Schneider and Lochbuie. As production increases there will be a need to provide growers with advice on when to harvest and on the most appropriate conditions for storage. No previous storage research has been carried out in the UK on this variety although in the past 2 years FAST Ltd and Worldwide Fruit (WWF) have been assessing harvest maturity in relation to eating quality of stored fruit on behalf of certain multiple retailers. Results of work done abroad suggest that storage could be problematic since the variety is susceptible to calcium-dependent disorders and is damaged by more stringent controlled atmosphere (CA) regimes. It is also susceptible to scald in long-term CA conditions. Advice provided in the Defra Best Practice Guide for UK Apple Production is based on Belgian experience.

The aim of this 3 year project is to undertake detailed trials to establish the optimum maturity indices and storage conditions for Braeburn and its clones, grown in the UK. The work will provide growers and marketers with (i) the maturity criteria for harvesting UK grown Braeburn apples intended for storage, (ii) recommendations for the short- and long-term storage of Braeburn apples and (iii) information on the clonal differences in harvest maturity and storage potential.

The considerable amount of work that was done in 2003-04 was only possible through a collaborative effort by staff of EMR, WWF and FAST Ltd. The input by EMR was funded by HDC whilst the inputs from staff of WWF and FAST were funded by their respective organisations. The only restriction on the publication of data from the joint venture was made by a major multiple retailer that had funded the tasting work done within the project. It was agreed that the outcome of the informal tasting could be discussed in the report but the actual tasting data should not be published.

Materials and Methods

Braeburn apples from 6 commercial orchards were used in the study. There were 2 orchards for each of the 3 clones (Hillwell, Lochbuie and Schneider) currently favoured by UK growers. Orchards of all 3 clones were present on one of the farms used in the study but the remaining 3 orchards were on different farms and as a consequence any potential clonal differences were likely to be confounded by effects of orchard location.

Samples of fruit for maturity assessment and storage tests were picked on 6 occasions at weekly intervals beginning on 25 September 2003. Fruits were selected at random from trees reserved for the study and apart from the first pick only fruit above 65 mm were sampled. After picking all fruit was transported immediately to the Jim Mount Building at EMR.

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Fruit was selected at random from the crop from each orchard to form 20-fruit samples for maturity assessment and for storage in air and controlled atmosphere (CA) conditions (2% O_2, <1% CO_2) at 0-0.5^oC and 1.5-2^oC. Storage samples were placed into 360 L containers on the same day as picking but establishment of CA conditions was delayed for 21 days to reduce susceptibility to Braeburn Browning Disorder (BBD). CA conditions were established by flushing the containers with nitrogen and CO_2 produced by fruit respiration was removed continuously using hydrated lime scrubbers. Oxygen concentrations were maintained at 2% by automated injection of compressed air. Gas measurement and control was achieved using an Oxystat 2002 system (David Bishop Instruments Ltd).

Measurements on samples taken at harvest for maturity assessment included internal ethylene concentration (IEC), background colour, firmness, soluble solids concentration and starch staining pattern. Details of the assessment methods are given below. Work was carried out in accordance with HRI experimental procedures and protocols. Smith (1985) has described many of the objective methods used for the assessments of quality in apples.

Internal ethylene concentration (IEC). IEC was measured on 5 intact undamaged apples from each replicate of each treatment. A sample of the internal atmosphere of each apple was taken by syringe (0.5ml) and injected into a gas chromatograph fitted with an alumina column and FID detector. Results were expressed as $\log_{10}$ parts per billion (ppb) of ethylene.

Background colour. The colour of the non-blush side of the fruit was assessed using commercial (World Wide Fruit / Qualytech) colour charts. Background colour of each fruit was compared against 4 cards that range from green (1) to yellow (4). The average score was calculated for each sample.

Fruit firmness. Two measurements were made on the opposite sides of each fruit using an 'Effigi' penetrometer mounted in a drill-stand and fitted with an 11mm probe. Measurements were made in the equatorial region after removal of the peel. Firmness was the maximum force (kg) recorded during the insertion of the probe to a depth of 8mm.

Soluble solids concentration. Juice was extracted from each apple using a steel rod and the soluble solids concentration (%) was measured using a BRX-242 refractometer (Camlab Ltd).

Starch test. Half of each apple was dipped in a solution containing 0.1% w/v iodine and 4% w/v potassium iodide. Dipped sections were left for at least 30 minutes before being assessed. The percentage of the cut surface stained black was estimated with the aid of transparent sheets printed with a series of gauges (concentric rings of decreasing radii) (Cockburn and Sharples, 1979).

The Streif maturity index was calculated by dividing the firmness value expressed in Newtons (kg*9.81) by the product of the soluble solids concentration (%) and starch cover (%) subtracted from 100. Samples of apples from each harvest were removed from air storage on 24 November 2003 and 26 January 2004 and from CA storage on 2 February and 26 April 2004. After weighing, one set of samples were used for an

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immediate assessment of quality (background colour, firmness and soluble solids concentration) and a similar set of samples was transferred to containers in air at 20°C. Samples previously stored at 1.5-2°C were removed after 4 days and a few apples were used for sensory evaluation by representatives of WWF and EMR. The remainder of the samples were placed back into 20°C. Samples previously stored at both temperatures were removed after 7 or 8 days at 20°C for an assessment of external and internal condition. Each fruit was examined externally for the presence of rotting and external physiological disorders such as superficial scald. An assessment was made of the greasiness of the skin either ex-store or after 4 or 7 days at 20°C. Finally all the fruits were cut and examined for internal physiological disorders.

Statistical analysis

All data were subjected to an analysis of variance (ANOVA) using a treatment structure to compare the effects of picking dates and clones and any possible interaction. On the storage data storage temperature was an additional factor in the analysis. The overall effects of picking dates, clones and storage temperature can be compared using the standard errors of the difference between means (SED) and degrees of freedom (df) given in the tables. Internal ethylene concentrations (IEC) were transformed to $\log_{10}$ prior to statistical analysis.

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Results and Discussion

1. Harvest maturity

Data on the effects of picking dates on the maturity parameters of the Braeburn clones are presented in Table 1.

Table 1. The effects of picking dates and clones on maturity parameters of Braeburn apples in 2003. Dates for picks 1, 2, 3, 4, 5, and 6 were 25 September and 2, 9, 16, 23 and 30 October 2003, respectively.

	Colour 1, green - 4, yellow	Firmness (kg)	S. Solids (%)	Starch (% black)	Streif Index	IEC (Log_{10} ppb)
Schneider	1.7	9.0	13.4	65	0.26	2.50
Hillwell	1.8	8.9	13.4	66	0.23	2.37
Lochbuie	1.6	9.4	13.1	70	0.30	2.42
SED (15 df)	0.10	0.22	0.49	1.9	0.045	0.114
Pick 1	1.4	9.6	12.7	79	0.41	-
Pick 2	1.6	9.4	12.4	85	0.51	2.41
Pick 3	1.7	9.5	13.3	67	0.22	2.34
Pick 4	1.7	9.0	13.5	63	0.18	2.50
Pick 5	1.8	8.1	13.6	60	0.15	2.42
Pick 6	2.0	8.9	14.3	49	0.12	2.48
SED (15 df)	0.14	0.32	0.69	2.8	0.064	0.147

Delay in picking was associated with a progressive yellowing of the background colour of the fruit and progressive decline in firmness. An unexpectedly high firmness reading was recorded at the final pick which in part may be due to the reduction in the number of orchards sampled from 6 to 4 which was due to insufficient trees being left after commercial picking. Starch cover reached a maximum at pick 2 and subsequently declined progressively with harvest delay. There was no significant change in the concentration of soluble solids over the 6 picks.

The Streif maturity index changed in a manner similar to that described for starch cover. Ethylene concentration in the fruit (IEC) remained low over the entire sampling period. Ripening in apples is generally considered to be underway when the IEC is above 100 ppb ($Log_{10}2.0$) and on a sustained increase.

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2. Visual appearance and eating quality

Effect of picking date

Air storage

The visual appearance of fruit stored in air at 1.5-2ºC until 24 November followed by 4 days at 20ºC was similar for picks 2-6 but fruit picked on the first occasion was less appealing. Fruit aroma was also worst in fruit from the first pick. Aroma was similar in fruit from picks 3-5 and though higher than in pick 1 fruit the scores were lower than for fruit picked on the final occasion. Fruits from picks 2-6 were similar in juiciness but higher than those from pick 1. It was clear that picking on the first occasion (25 September) was too early and resulted in poor appearance, low aroma and juiciness. There were no effects of picking date on any of the other sensory attributes.

The visual appearance of fruit stored in air at 1.5-2ºC until 26 January followed by 4 days at 20ºC was similar for picks 2-4 and was generally significantly better than that of fruit from the first and last pick. Aroma tended to be better in fruit from picks 4-6 than in 1-3. Texture of fruits from picks 2-4 was rated similarly and better than that of fruit picked later. However, fruit from the first pick was rated highest for texture. On the basis of appearance picking on the first occasion was too early. Pick 4 (16 October) provided the best combined scores for appearance, aroma and texture. There were no effects of picking date on any of the other sensory attributes.

CA storage

The visual appearance of fruit stored in CA at 1.5-2ºC until 2 February 2004 followed by 4 days at 20ºC was similar for picks 2-5 and better than that of fruit from the first and last pick. Aroma in fruit from the later picks (3-6) was rated higher than in fruit from picks 1 and 2. Firmness declined progressively with harvest delay. Picks 3 and 4 (9 and 16 October) provided the best combined scores for appearance, aroma and firmness. There were no effects of picking date on any of the other sensory attributes.

Of the fruit stored in CA at 1.5-2ºC until 26 April 2004 followed by 4 days at 20ºC those picked on the second and third occasion were rated highest for visual appearance and were significantly more appealing than those from pick 1 and picks 5 and 6. Fruits from picks 1-4 were juicier than those from pick 6 and there was a progressive decline in firmness with harvest delay although firmness differences between picks 1-3 were did not differ significantly. There was a progressive decline in texture scores with harvest delay although statistically scores for picks 1-4 were similar and greater than those given to picks 5 and 6. Based on scores given for appearance, juiciness, firmness and texture the best picks were 2 and 3. There were no effects of picking date on any of the other sensory attributes.

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Effect of clone

It was not feasible to taste fruit from all 6 orchards in the study. Consequently fruit from only one orchard of each clone was tasted. It is possible that any apparent differences in visual or eating quality associated with the different clones may in fact be due to site differences.

Air storage

Evaluation of the fruit stored in air at 1.5-2^{o}C until 24 November 2003 followed by 4 days at 20^{o}C provided significant 'clonal' effects on most of the attributes tested with the exception of appearance, aroma and juiciness. Lochbuie was the preferred clone on the basis of highest scores for flavour, firmness and texture. Schneider was least preferred probably on the basis of being too acid and least sweet.

Evaluation of the fruit stored in air at 1.5-2^{o}C until 26 January 2004 followed by 4 days at 20^{o}C provided significant 'clonal' effects on aroma, sweetness, flavour and overall quality. Lochbuie was again preferred scoring highest for all these attributes. The remaining clones generally scored similarly for these attributes.

CA storage

Evaluation of the fruit stored in CA at 1.5-2^{o}C until 2 February 2004 followed by 4 days at 20^{o}C provided significant 'clonal' effects on most of the attributes tested with the exception of appearance, aroma and firmness. Generally Schneider was least liked having scored lower than Lochbuie and Hillwell for sweetness, juiciness, texture and overall acceptance.

Apart from flavour there were no effects of clones on visual or eating quality characteristics of fruit stored in CA 26 April 2004 followed by 4 days at 20^{o}C. Lochbuie was considered to have more flavour than Hillwell and Schneider.

Quality of fruit immediately ex-store

Colour (Table 2)

As expected the background colour of the fruit generally became more yellow with time in store and loss of greenness was retarded by the use of CA as opposed to air storage. Picking date was important in determining background colour after storage. There were no significant effects of clones or storage temperatures. Generally there was a progressive yellowing with harvest delay.

Firmness (Table 3)

Again, as with background colour changes, there was an expected loss of firmness with time in store and a benefit of CA over air storage. The effect of storage temperature on fruit firmness was generally small and only on the first removal of fruit from air storage was there a significant benefit of the lower storage temperature. There were highly significant effects of clones and picking dates on the firmness of fruit from air and CA storage. Lochbuie was firmer than Schneider or Hillwell and

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tends to support the tasting results where Lochbuie was often the preferred clone. Generally there was a progressive decline in firmness with harvest delay. However, firmness remained above the 6.5 kg threshold commonly applied for UK dessert apples including those harvested on the final occasion.

Soluble solids (Table 4)

Soluble solids (sugars) concentration in the fruit was unaffected by storage temperature, harvest date or clone. Average levels at harvest (13.3%) increased to 14.7 and 14.5% during air storage until 24 November 2003 and 26 January 2004 respectively and to 14.1% in CA storage until 2 February and 26 April 2004.

Weight loss, greasiness and storage disorders

Air storage

There was no effect of storage temperature on weight loss but Lochbuie fruit tended to lose more weight than either Schneider or Hillwell and significantly so at the first removal of fruit on 24 November 2003 (Table 5). Fruits from picks 2 and 6 lost more weight than those from the other picks.

Fruit stored in air until 24 November 2003 followed by 7 days at 20^{o}C did not develop superficial scald or core flush although these disorders became problematic at the second removal (see below). Greasiness was a problem in some samples of fruit and was associated generally with delay in harvesting and was least evident in Lochbuie. Storage temperature did not influence greasiness (Table 7).

There were problems with superficial scald and core flush in fruit stored in air until 26 January 2004 followed by 4 or 7 days at 20^{o}C (Tables 6 and 8). Fruit from picks 4-6 were free of scald and there were no effects of clones or storage temperature. The incidence of core flush was low and, with the exception of fruit from pick 6, not of commercial significance. Lochbuie was most affected by core flush and the lower storage temperature was beneficial in reducing the percentage of affected fruit. Greasiness was scored on a severity basis by a market inspector from WWF and by EMR staff using slightly different scales (Table 7). There was generally broad agreement and results show clearly the effect of harvest delay in increasing the amount of grease detected on the apples. In the EMR assessment Lochbuie was least greasy and may relate to its tendency to be least mature at harvest.

CA storage

The same pattern of treatment effects on weight loss were found on CA-stored fruit as had been noted in air storage i.e. Lochbuie lost more weight than either Schneider or Hillwell and picks 2 and 6 were associated with higher weight loss (Table 5). Additionally for CA-stored fruit the higher storage temperature resulted in a higher weight loss.

There were no problems with superficial scald or core flush in fruit stored in CA until 2 February 2004 followed by 7 days at 20^{o}C. This is in contrast with a significant problem with scald and to a lesser extent core flush in fruit removed from air storage a

week earlier. Fruit tended to be greasy particularly those from later picking dates and, as in air storage, Lochbuie was least greasy (Table 7).

Fruit removed from CA on 26 April 2004 followed by 8 days at 20ºC were affected by superficial scald and core flush (Tables 6 and 8). There were a number of other internal disorders which affected the fruit albeit generally to a slight extent (Tables 9-11). Least scald occurred in fruit from pick 4. The apparent slight increase in scald with further delay in harvest was not seen on air-stored fruit assessed in January and is likely to be a form of senescent scald rather than true superficial scald observed on early-picked fruit. Significantly less scald developed on fruit from the lower storage temperature. The incidence of other disorders was not affected by storage temperature. Similarly, apart from superficial scald, none of the disorders were affected by picking date. However, as found in previous removals of air and CA-stored fruit the severity of greasiness increased with harvest delay. Lochbuie was more affected by core flush and low temperature breakdown than Schneider or Hillwell. None of the picks provided fruit that was free of all disorders which suggests that late April may be too late for the storage of Braeburn under modest CA conditions of 2% O_2, <1% CO_2.

Table 2. The effects of storage temperature, clones and picking dates on the background colour (WWF chart where 1 is green and 4 is yellow) of Braeburn apples stored in air and controlled atmosphere conditions (<1% CO_2 + 2% O_2). Dates for picks 1, 2, 3, 4, 5, and 6 were 25 September and 2, 9, 16, 23 and 30 October 2003 respectively.

	Air		CA	
	24.11.03	26.1.04	2.2.04	26.4.04
0-0.5ºC	1.9	2.1	1.9	2.1
1.5-2ºC	1.9	2.2	2.0	2.1
SED (30 df)	0.08	0.08	0.08	0.07
Schneider	1.9	2.2	2.0	2.1
Hillwell	2.0	2.2	2.0	2.1
Lochbuie	1.8	2.1	1.8	2.0
SED (30 df)	0.09	0.10	0.10	0.09
Pick 1	1.6	1.9	1.5	1.8
Pick 2	1.7	2.0	1.7	1.9
Pick 3	1.8	2.1	1.8	2.0
Pick 4	2.1	2.3	2.1	2.2
Pick 5	2.0	2.3	2.1	2.2
Pick 6	2.2	2.4	2.4	2.5
SED (30 df)	0.13	0.14	0.14	0.12

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Table 3. The effects of storage temperature, clones and picking dates on the firmness (kg) of Braeburn apples stored in air and controlled atmosphere conditions (<1% CO_2 + 2% O_2). Dates for picks 1, 2, 3, 4, 5, and 6 were 25 September and 2, 9, 16, 23 and 30 October 2003 respectively.

	Air		CA	
	24.11.03	26.1.04	2.2.04	26.4.04
0-0.5°C	8.3	7.0	7.8	7.2
1.5-2°C	7.9	6.9	7.9	7.1
SED (30 df)	0.10	0.11	0.10	0.09
Schneider	7.9	6.7	7.7	7.0
Hillwell	7.9	6.7	7.7	6.9
Lochbuie	8.5	7.4	8.2	7.5
SED (30 df)	0.12	0.14	0.12	0.11
Pick 1	8.7	7.5	8.4	8.1
Pick 2	8.1	7.0	8.1	7.5
Pick 3	8.1	6.9	7.8	7.3
Pick 4	8.0	6.9	7.8	7.1
Pick 5	7.7	6.7	7.5	6.6
Pick 6	7.9	6.6	7.4	6.5
SED (30 df)	0.17	0.20	0.17	0.16

Table 4. The effects of storage temperature, clones and picking dates on the soluble solids concentration (%) of Braeburn apples stored in air and controlled atmosphere conditions (<1% CO_2 + 2% O_2). Dates for picks 1, 2, 3, 4, 5, and 6 were 25 September and 2, 9, 16, 23 and 30 October 2003 respectively.

	Air		CA	
	24.11.03	26.1.04	2.2.04	26.4.04
0-0.5°C	14.8	14.4	14.3	14.0
1.5-2°C	14.5	14.6	13.9	14.1
SED (30 df)	0.25	0.34	0.33	0.35
Schneider	14.7	14.4	14.2	14.1
Hillwell	14.7	14.3	14.2	14.0
Lochbuie	14.6	14.7	14.0	14.1
SED (30 df)	0.31	0.42	0.40	0.43
Pick 1	15.0	14.5	13.8	14.0
Pick 2	14.3	14.4	14.0	14.0
Pick 3	14.5	14.5	14.1	13.9
Pick 4	14.8	14.6	14.3	14.1
Pick 5	14.3	14.1	14.1	13.9
Pick 6	15.1	14.7	14.5	14.4
SED (30 df)	0.44	0.60	0.57	0.61

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Table 5. The effects of storage temperature, clones and picking dates on the weight loss (%) of Braeburn apples stored in air and controlled atmosphere conditions (<1% CO_2 + 2% O_2). Dates for picks 1, 2, 3, 4, 5, and 6 were 25 September and 2, 9, 16, 23 and 30 October 2003 respectively.

	Air		CA	
	24.11.03	26.1.04	2.2.04	26.4.04
0-0.5ºC	0.49	1.09	0.52	0.70
1.5-2ºC	0.45	1.18	0.62	0.90
SED (30 df)	0.029	0.077	0.039	0.055
Schneider	0.44	1.09	0.51	0.72
Hillwell	0.44	1.06	0.53	0.72
Lochbuie	0.55	1.26	0.67	0.97
SED (30 df)	0.036	0.095	0.047	0.068
Pick 1	0.44	1.03	0.54	0.68
Pick 2	0.64	1.32	0.62	0.83
Pick 3	0.36	1.01	0.44	0.59
Pick 4	0.45	1.26	0.54	0.81
Pick 5	0.35	0.82	0.54	0.79
Pick 6	0.61	1.37	0.74	1.11
SED (30 df)	0.051	0.134	0.067	0.096

Table 6. The effects of storage temperature, clones and picking dates on the incidence (%) of superficial scald in Braeburn apples stored in air and controlled atmosphere conditions (<1% CO_2 + 2% O_2). Dates for picks 1, 2, 3, 4, 5, and 6 were 25 September and 2, 9, 16, 23 and 30 October 2003 respectively.

	Air		CA	
Removal date	26.1.04		26.4.04	
Days at 20ºC	4	7	4	8
0-0.5ºC	-	8.0	-	2.9
1.5-2ºC	-	7.6	-	13.4
SED (30 df)		3.67		3.57
Schneider	5.8	7.1	9.6	11.7
Hillwell	4.2	3.7	1.8	4.6
Lochbuie	12.9	12.7	7.1	8.2
SED (30 df)	5.12	4.50	5.26	4.38
Pick 1	40.0	41.0	22.5	23.7
Pick 2	4.2	4.5	14.4	13.1
Pick 3	1.6	1.5	0	2.5
Pick 4	0	0	0	0.4
Pick 5	0	0	0	4.4
Pick 6	0	0	0	5.0
SED (30 df)	7.24	6.36	7.44	6.19

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Table 7. The effects of storage temperature, clones and picking dates on the incidence (%) or severity (max. 4 or 5) of greasiness in Braeburn apples stored in air and controlled atmosphere conditions (<1% CO_2 + 2% O_2). Assessments made by EMR or WWF staff. Dates for picks 1, 2, 3, 4, 5, and 6 were 25 September and 2, 9, 16, 23 and 30 October 2003 respectively.

	Air			CA		
Removal date	24.11.03	26.1.04		2.2.04	2.2.04	26.4.04
Days at 20ºC	7	4	4	0	4	8
	EMR	WWF	EMR	EMR	EMR	EMR
	%	0-5	0-4	0-4	0-4	0-4
0-0.5ºC	70.1	-	-	0.9	-	0.9
1.5-2ºC	61.7	-	-	0.9	-	1.2
SED (30 df)	5.79			0.13		0.15
Schneider	67.1	1.3	1.1	1.1	1.4	1.0
Hillwell	77.0	2.0	1.0	1.1	1.7	1.3
Lochbuie	53.6	1.3	0.3	0.5	1.3	0.8
SED (30 df)	7.09	0.35	0.24	0.16	0.21	0.18
Pick 1	7.1	0.3	0	0.1	0	0.1
Pick 2	28.2	0.7	0.2	0.3	0.7	0.3
Pick 3	71.4	1.3	0.2	0.3	1.3	0.8
Pick 4	93.8	1.8	1.2	1.3	1.7	1.3
Pick 5	94.9	2.5	1.3	1.6	2.2	1.7
Pick 6	100.0	2.3	2.0	1.8	2.8	1.9
SED (30 df)	10.02	0.49	0.35	0.23	0.29	0.26

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Table 8. The effects of storage temperature, clones and picking dates on the incidence (%) of core flush in Braeburn apples stored in air and controlled atmosphere conditions (<1% CO_2 + 2% O_2) followed by 7 days at 20°C. Dates for picks 1, 2, 3, 4, 5, and 6 were 25 September and 2, 9, 16, 23 and 30 October 2003 respectively.

	Air		CA	
Inspection date	1.12.03	2.2.04	9.2.04	4.5.04
0-0.5°C	0	2.1	0	13.3
1.5-2°C	0	6.7	0	11.1
SED (30 df)		1.29		4.03
Schneider	0	2.2	0	5.0
Hillwell	0	1.3	0	5.0
Lochbuie	0	9.7	0	26.5
SED (30 df)		1.58		4.94
Pick 1	0	0.4	0	8.5
Pick 2	0	1.3	0	16.0
Pick 3	0	3.5	0	6.9
Pick 4	0	4.6	0	8.2
Pick 5	0	3.9	0	11.2
Pick 6	0	12.7	0	22.2
SED (30 df)		2.24		6.99

Table 9. The effects of picking date on the incidence of physiological disorders in Braeburn apples stored controlled atmosphere conditions (<1% CO_2 + 2% O_2) until 26 April 2004 followed by 7 days at 20°C. Dates for picks 1, 2, 3, 4, 5, and 6 were 25 September and 2, 9, 16, 23 and 30 October 2003 respectively.

	Pick 1	Pick 2	Pick 3	Pick 4	Pick 5	Pick 6	SED	df
Greasiness (max. 5)	0.1	0.3	0.8	1.3	1.7	1.9	0.26	30
Superficial Scald (%)	23.7	13.1	2.5	0.4	4.4	5.0	6.19	30
Senescent scald (%)	0	0	0.8	0	1.8	0	1.02	30
Rotting (%)	1.3	4.0	3.0	3.5	5.8	4.4	2.48	30
Bitter pit (%)	0	0	0	0.6	0	0	0.37	30
Core flush (%)	8.5	16	6.9	8.2	11.2	22.2	6.99	30
Braeburn browning (%)	0.4	0	0.7	3.3	0	0	1.74	30
Low temp. breakdown (%)	0.6	7.6	2.3	1.7	3.9	6.9	3.68	30
Senescent breakdown (%)	0	0	0	1.3	1.8	0	1.13	30

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Table 10. The effects of clones on the incidence of physiological disorders in Braeburn apples stored controlled atmosphere conditions (<1% CO_2 + 2% O_2) until 26 April 2004 followed by 7 days at 20°C.

	Lochbuie	Hillwell	Schneider	SED	df
Greasiness (max. 5)	0.8	1.3	1.0	0.18	30
Superficial Scald (%)	8.2	4.6	11.7	4.38	30
Senescent scald (%)	0	1.3	0	0.72	30
Rotting (%)	3.1	4.5	3.4	1.75	30
Bitter pit (%)	0	0	0.3	0.26	30
Core flush (%)	26.5	5.0	5.0	4.94	30
Braeburn browning disorder (%)	0	1.7	0.6	1.23	30
Low temperature breakdown (%)	11.3	0	0.2	2.6	30
Senescent breakdown (%)	0	0.9	0.6	0.79	30

Table 11. The effects of storage temperature on the incidence of physiological disorders in Braeburn apples stored controlled atmosphere conditions (<1% CO_2 + 2% O_2) until 26 April 2004 followed by 7 days at 20°C.

	0-0.5°C	1.5-2°C	SED	df
Greasiness (max. 5)	0.9	1.2	0.15	30
Superficial Scald (%)	2.9	13.4	3.57	30
Senescent scald (%)	0.4	0.4	0.59	30
Rotting (%)	3.3	4.0	1.43	30
Bitter pit (%)	0	0.2	0.21	30
Core flush (%)	13.3	11.1	4.03	30
Braeburn browning disorder (%)	0.8	0.7	1.00	30
Low temperature breakdown (%)	4.9	2.7	2.12	30
Senescent breakdown (%)	0.3	0.7	0.65	30

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Conclusions

For storage in air until late November there were no constraints imposed by the development of disorders. Consequently picking date could be directed to achieving the desired appearance, optimum eating quality and least greasiness of the skin. On the basis of appearance and eating quality pick 1 (25 September 2003) was clearly too immature.

For storage in air until late January scald development was a constraint. Delay in picking until pick 4 was required to avoid scald although pick 3 (9 October 2003) may be considered an acceptable commercial risk. Pick 4 (16 October 2003) was also best for eating quality and had acceptable background colour (2.3) and firmness (6.9 kg). Starch cover (% black), firmness (kg) and soluble solids concentration (%) at pick 4 were 63, 9.0 and 13.5 respectively with a Streif index of 0.18.

For storage in CA until early February there were no constraints imposed by the development of disorders. Consequently picking date could be directed to achieving the desired appearance, optimum eating quality and least greasiness of the skin. Pick 1 fruit was too immature and picks 3 and 4 provided optimum eating quality. This is in accordance with the best stage to pick for optimum quality from air storage in late January.

For storage in CA until late April scald development was a constraint. Pick 4 was the best time to harvest for minimal scald but pick 3 may have provided an acceptable risk. Pick 1 fruit was also visually unacceptable and picks 5 (23 October 2003) and 6 (30 October 2003) produced an unacceptable texture in the fruit. None of the picks provided fruit free of all disorders with core flush development in shelf-life being the biggest problem. Fruit from picks 3 and 4 were still good for background colour (2-2.2) and firmness (7.1-7.3 kg).

Technology transfer

Growers who provided fruit for the experiment attended the examination of CA-stored fruit on 30 April 2004 and made their own assessments of the quality of the fruit and discussed the results with staff from WWF and EMR. Outline results were provided to Mr DonVaughan of FAST Ltd and these were used in his presentation to growers at the annual FAST Ltd conference. The source of the information and of the funding for the research was duly acknowledged.

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