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Project consultant:	None
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Authentication

I declare this work was carried out 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

31 July 2005

Grower summary

Headline

- Based on current information the storage temperature for air and CA-stored fruit should be 0-0.5°C and 1.5-2°C respectively.

- Based on current information, the most appropriate CA regime comprises <1% CO_2 + 2% O_2. This should be established 3 weeks after loading to avoid potential injury to the fruit.

- Provisional termination months for air and CA-stored fruit are December and late February - early March respectively. The development of scald or core flush will determine the duration of storage that is possible in any particular year.

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 prior to this project FAST Ltd and Worldwide Fruit (WWF) assessed harvest maturity in relation to eating quality of stored fruit on behalf of certain multiple retailers. Results of work carried out 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 three-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 six commercial orchards were used in the study. There were two orchards for each of the three clones (Hillwell, Lochbuie and Schneider) currently favoured by UK growers. These were the same orchards that were used in the first year of the project. Samples of fruit for maturity assessment and storage tests were picked on four occasions at weekly intervals beginning on 1 October 2004.

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 22 November 2004 and 24 January 2005, and from CA storage on 31 January and 22 April 2005. 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^{o}C. Samples previously stored at 1.5-2^{o}C were removed after four days and a few apples were used for sensory evaluation by representatives of WWF, FAST Ltd and EMR. The remainder of the samples were placed back into 20^{o}C. Samples previously stored at both temperatures were removed after 7 days at 20^{o}C for an assessment of external and internal condition.

Air storage

For storage in air until late November, there were no constraints imposed by the development of disorders. This was consistent with results obtained in the previous year. Consequently, picking date could be directed to achieving the desired appearance, optimum eating quality and minimum greasiness of the skin. On the basis of appearance and eating quality, pick 1 was clearly too immature. Pick 4 often gave the poorest sensory response and gave the most greasiness. This suggests an optimum period of 8-15 October for short-term air storage. Fruit benefited from the lower storage temperature particularly as regards reduced weight loss and higher firmness.

For storage in air until late January, core flush and scald development were major and minor constraints respectively. Although scald could be avoided by picking on 8 October or later and storing at 0-0.5°C, it was not possible to avoid core flush by modifying harvest date or storage temperature. Late January was not achievable in air storage in 2004. Generally, on the basis of optimising appearance and eating quality, pick 2 (October 8) was the optimum date. Earlier harvesting was not possible due to scald development and later harvesting was associated with a general loss of visual and eating quality but did not promote physiological disorders.

CA storage

For CA storage until late January, core flush was a minor constraint since it developed to a slight extent during shelf life. There were insufficient numbers of affected fruit to give reliable indications of treatment effects but there appeared to be little influence of harvest date, clone or storage temperature. Consequently, consideration of optimum harvest dates and storage temperatures for CA storage until late January was mainly concerned with physical and sensory assessments of quality. On this basis, 8-15 October 200 appeared to be the best period for harvesting.

For storage in CA until late April, core flush and internal breakdown were major and minor constraints respectively. Clearly, late April was not achievable in CA storage in 2004. Core flush was also evident in commercial fruit marketed late in the season. Late picking (pick 4) and storage at low temperature (0-0.5°C) exacerbated the problem, but the problem could not be ameliorated by earlier harvesting and storing at higher temperatures. On the basis of physical and sensory assessments of quality, it appeared that the first two picks (1-8 October) were appropriate for longer storage in CA. It is commonly expected that longer storage requires harvesting at a less mature stage. Core flush development in the 2004 crop dictated a shorter period of storage, where it is assumed that a pick date around 8 October might be ideal.

Harvest maturity

Harvest maturity parameters associated with optimum storage performance in 2004 were as follows:

Storage details	Harvest date	Harvest maturity parameters		
		Firmness (kg)	Starch (% black)	Streif index
Air late Nov.	8 October	8.2	61	0.18
	15 October	7.8	49	0.13
Air late Jan.	8 October	8.2	61	0.18
CA late Jan.	8 October	8.2	61	0.18
	15 October	7.8	49	0.13
CA late April	1 October	8.6	74	0.31
	8 October	8.2	61	0.18

Maturity parameters associated with optimum storage in 2003 and 2004 can be compared as follows:

Storage details	Year	Harvest maturity parameters		
		Firmness (kg)	Starch (% black)	Streif index
Air late Jan.	2003	9.0	63	0.18
	2004	8.2	61	0.18
CA late April	2003	9-9.5	63-67	0.18-0.22
	2004	8.2-8.6	61-74	0.18-0.31

It was reassuring that in the two years the starch iodine test and Streif Index could be used to indicate optimum time of harvest. Firmness was too variable between the two years to be of use as a guide to harvest date. Picking earlier than indicated by starch and Streif index is likely to lead to loss of eating quality, but more importantly to wastage due to scald development. Later harvesting will lead to loss appearance and eating quality and is only appropriate for shorter-term storage.

Clonal differences

Orchards of all three clones were present on one of the farms used in the study, but the remaining three orchards were on different farms and, as a consequence, any potential clonal differences were likely to be confounded by effects of orchard location.
In sensory tests Lochbuie scored highest for texture, which is consistent with results obtained with the penetrometer tests. Hillwell was greasiest, sweetest and most aromatic. These effects may relate to differences in harvest maturity parameters. At harvest, Hillwell had the most yellow background colour and contained the highest concentration of soluble solids, whilst Lochbuie was firmest.

In air storage, Schneider apples developed more core flush than Hillwell or Lochbuie. There was insufficient scald to determine any clonal differences. Hillwell apples had a more yellow background colour and were greasier than either Schneider or Lochbuie. Lochbuie apples were the firmest and Schneider apples were softest with least soluble solids. Lochbuie apples lost most weight during storage. The higher firmness and weight loss associated with Lochbuie was consistent with results obtained in the previous year.

In CA storage in 2003 and 2004, Lochbuie was more affected by core flush and low temperature breakdown than Schneider or Hillwell.

Financial benefits

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

Action points

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

- Provisional maturity criteria for picking for storage are: starch cover of 50-60 (% black) for air storage and 60-70% for CA storage. Picking at the higher end of these ranges for starch is likely to provide the longest storage potential.

- 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.

- Based on current information the storage temperature for air and CA-stored fruit should be 0-0.5ºC and 1.5-2ºC respectively.

- Based on current information, the most appropriate CA regime comprises <1% CO_2 + 2% O_2 and should be established 3 weeks after loading to avoid potential injury to the fruit. Refer also to the Defra Best Practice Guide for UK Apple Production for further advice on storage recommendations.

- Avoid storing too long. Provisional termination months for air and CA-stored fruit are December and late February - early March respectively. The development of scald or core flush will determine the duration of storage that is possible in any particular year.

- Monitor fruit condition regularly and include a simulated marketing test in order to detect the first signs of scald and core flush development. Refer also to the Defra Best Practice Guide for UK Apple Production for further advice on monitoring the condition of fruit in store.

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 two years prior to the start of this project, FAST Ltd and Worldwide Fruit (WWF) assessed 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.

Aims of the Project

The aim of this three-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.

Materials and Methods

Braeburn apples from six commercial orchards were used in the study. These were the same orchards that were used in the first year of the project. There were two orchards for each of the three clones (Hillwell, Lochbuie and Schneider) currently favoured by UK growers. Orchards of all three clones were present on one of the farms used in the study, but the remaining three 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 four occasions at weekly intervals beginning on 1 October 2004. Fruits above 65 mm diameter were selected at random from trees reserved for the study. At one site it was only possible to take samples of Lochbuie apples on the first two occasions. There were insufficient trees left by the picking staff to complete the sampling as planned. After picking, all fruit was transported immediately to the Jim Mount Building at EMR.

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°C and 1.5-2°C. Storage samples were weighed and 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 EMR experimental procedures and protocols. Smith (1985) has described many of the objective methods used for the assessments of quality in apples.

<u>Internal ethylene concentration (IEC)</u>. IEC was measured on five 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.

<u>Background colour</u>. 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 four 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 & 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 22 November 2004 and 24 January 2005, and from CA storage on 31 January and 22 April 2005. 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 four 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 seven 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 after four or seven 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.

Results and Discussion

Harvest maturity (Table 1)

On the basis of calendar date picks 1-4 in 2004 can be compared with picks 2-5 in 2003. The more restricted picking period (three-week) in 2004 may explain the generally less marked effect of harvest delay on maturity parameters compared with the more extended (five-week) period in 2003. Delay in picking was associated with a progressive decline in starch cover, although differences between consecutive picks were not always statistically significant. On the basis of starch pattern, it appeared that the fruit in 2004 matured one-two weeks earlier than in 2003. The Streif maturity index changed in a manner similar to that described for starch cover. There was no significant change in background colour or concentration of soluble solids over the four picks. Pick 1 fruit was firmest and significantly firmer than fruit from pick 3.

As in 2003, ethylene concentration in the fruit (IEC) remained low over the entire sampling period. However, there was a progressive increase in IEC with harvest delay although the only statistical difference was between the first and last picked fruit. Ripening is considered to be underway when the IEC is above 100 ppb ($\text{Log}_{10}2.0$) and on a sustained increase. Only pick 4 fruit exceeded the ripening threshold, but further picks would be required to establish whether ripening was underway. In 2003, IEC remained just above 100 ppb for the entire six-week sampling period.

Storage behaviour in air and CA

Susceptibility to rotting and physiological disorders normally determines the maximum period of storage that is possible for any particular variety in any given storage environment. Within the period that apples remain in a sound condition the eating quality of the fruit will dictate the period of storage that provides acceptable commercial quality.

Air storage

Physiological disorders and rotting

Fruit stored in air was virtually free of fungal rots, with an average of 0.2% of fruit affected after storage until 24 January followed by a further seven days at 20°C (data not presented). There were no disorders in fruit examined immediately after storage in air until 22 November 2004 and none developed during a further seven days at 20°C. However, where air storage was extended until 24 January 2005 core flush affected 5.2% of fruit immediately ex-store and an average of 30.4% after a further seven days at 20°C. A low percentage (1.2%) of fruit stored for a further seven days at 20°C were affected by scald.

Scald developed only in fruit from picks 1 and 2 (Table 19). Fruit picked on an equivalent calendar date in 2003 or earlier were also the only fruit to develop scald. Scald could be avoided by picking on 15 or 22 October 2004. Core flush was a far more serious problem than scald and dictated that the 2004 crop could not be stored in air until late January. A possible limit to air storage in 2004 would have been December, although no fruit was inspected in that month.

Storing at 0-0.5°C as opposed to 1.5-2°C prevented core flush in fruit stored until 24 January 2005 and reduced by 50% the incidence of core flush in fruit after seven days at 20°C. The lower storage temperature also tended to reduce scald incidence and is consistent with the effect of temperature on scald in CA-stored fruit in the previous year.

Schneider apples developed more core flush than Hillwell or Lochbuie. There was insufficient scald to determine any clonal differences.

There was no significant effect of picking date on the incidence of core flush.

Fruit quality measurements

In addition to the affects on core flush development there were additional benefits of storing Braeburn apples at 0-0.5ºC as opposed to 1.5-2ºC. These included higher firmness and lower weight loss (Tables 16 and 18).

Hillwell apples had a more yellow background colour and were greasier than either Schneider or Lochbuie (Tables 15 and 20). Lochbuie apples were the firmest and Schneider fruit were softest with least soluble solids (Tables 16 and 17). Lochbuie apples lost most weight during storage. The higher firmness and weight loss associated with Lochbuie was consistent with results obtained in the previous year.

Background colour was progressively more yellow with delay in picking and earlier picked fruit (picks 1 and 2) lost more weight in store than that picked later (picks 3 and 4).

CA storage

Physiological disorders and rotting

There was a low incidence of rotting in fruit stored in CA until 22 April 2005 (overall average of 1.4%). Rot incidence tended to be lower in fruit stored at 0-0.5ºC (0.7%) than in that stored at 1.5-2ºC (2.1%). The average incidence of rotting increased to 2.5% during a further seven days at 20ºC but there were no effects of storage temperature, picking date or clone (Table 22, 24 and 25).

Scald did not develop in CA-stored fruit. This contrasts with the situation in the previous year when fruits from all picking dates were affected by scald to some extent when stored until April and subjected to a further seven days at 20ºC. The development of core flush was the limiting factor in the CA storage of Braeburn in 2003. Core flush was not evident in fruit removed from CA storage at the end of January although a low incidence of the disorder (average 3.7%) was recorded in fruit after a further seven days at 20ºC. It is unlikely that such a slight amount of core flush would have any commercial significance. However, by the 22 April 2005 the average incidence of core flush had increased to 19.6% immediately ex-store and to 43.7% after a further seven days at 20ºC. Clearly in seasons such as 2004 when there is a high potential for core flush, storage until April using the current CA conditions (<1% CO_2 + 2% O_2) and establishment protocol (three weeks before sealing) is not attainable. Although core flush could be reduced by avoiding late picking (22 October 2004) and storing at the higher temperature (Table 21) there would still be a commercial problem. Since there were no examinations of fruit between 31 January and 22 April it is impossible to indicate when the level of core flush became unacceptable. Breakdown affected an average of 6.1% of fruits stored in CA until 22 April and subjected to after a further seven days at 20^{o}C. Breakdown was restricted mainly to Lochbuie picked on the first or final occasion. In both 2003 and 2004 Lochbuie was more affected by core flush and low temperature breakdown than Schneider or Hillwell.

Fruit quality measurements

There was no change in the quality (colour, firmness and soluble solids) of CA-stored fruit from 31 January to 22 April 2005, despite the increased development of core flush during that period.

The lower storage temperature resulted in a lower weight loss in fruits stored in CA, as was the case in air-stored fruit (Table 18). However, there were no benefits of the lower storage temperature on fruit colour, firmness or soluble solids concentration (Tables 15, 16 and 17). In view of the worsening effect of the lower storage temperature on core flush and the lack of any benefits on quality attributes it appears that a temperature of 1.5-2^{o}C is more appropriate for CA storage.

Clonal differences in fruit firmness and soluble solids concentration noted at harvest and in air storage persisted during CA storage. Lochbuie fruits were the firmest and Schneider the softest (Table 16). Schneider fruits were lowest in soluble solids (Table 17). As in air storage, Lochbuie apples lost most weight during CA storage and Hillwell apples were most greasy (Tables 18 and 20).

There was a progressive effect of delayed picking on background colour (Table 15) and fruit from the final pick (4) were softer than those from the first 3 harvests (Table 16). There were no sign ificant effects of harvest date on weight loss (Table 18) although greasiness increased progressively with harvest delay (Table 20).

Sensory assessment of air and CA-stored fruit

Overall, there was no significant difference in the sensory quality of air and CA-stored fruit except that the latter were considered juicier. Air-stored fruit assessed in January 2005 were considered sweeter and more aromatic than those assessed in November (Tables 6, 4 and 14). On the basis of these attributes the quality of air and CA-stored fruit in late January was comparable. Prolonged storage in CA (late April) resulted in lower scores for aroma and sweetness and for visual appearance (Tables 4, 6, 3 and 14). Extending storage in air and CA resulted in lower scores for firmness and texture (Tables 9, 10 and 14). Greasiness was similar in air and CA storage and did not get worse with time in store.

Pick 4 fruit generally scored lowest for visual quality, acidity, juiciness, firmness, texture and overall acceptability (Table 13). Conversely, pick 1 fruit scored lowest for aroma and sweetness. This suggests that picks 2 and 3 provided the best sensory quality in 2004. However, where storage was extended the second harvest gave higher scores for texture and overall quality. Overall, pick 2 provided the highest total quality score, with pick 4 fruit by far the lowest. Greasiness increased progressively with harvest delay but it is difficult to establish at what point on a scale of 0-5 the greasiness score is commercially significant.

Lochbuie scored highest for texture, which is consistent with results obtained with the penetrometer tests (Table 12). Hillwell was greasiest, sweetest and most aromatic. These effects may relate to differences in harvest maturity parameters. At harvest, Hillwell had the most yellow background colour and contained the highest concentration of soluble solids whilst Lochbuie was firmest (harvest maturity data not presented for individual orchards).

Conclusions

For storage in air until late November, there were no constraints imposed by the development of disorders. This was consistent with results obtained in the previous year. 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 was clearly too immature. Pick 4 often gave the poorest sensory response and the most greasy fruit. This suggests an optimum period of 8-15 October for short-term air storage. Fruit benefited from the lower storage temperature particularly as regards reduced weight loss and higher firmness.

For storage in air until late January, core flush and scald development were major and minor constraints respectively. Although scald could be avoided by picking on 8 October or later, and storing at 0-0.5°C, it was not possible to avoid core flush by modifying harvest date or storage temperature. Late January was not achievable in air storage in 2004. Generally, on the basis of optimising appearance and eating quality pick 2 (October 8) was the optimum date. Earlier harvesting was not possible due to scald development and later harvesting was associated with a general loss of visual and eating quality but did not promote physiological disorders.

For CA storage until late January, core flush was a minor constraint since it developed to a slight extent during shelf life. There were insufficient numbers of affected fruit to give reliable indications of treatment effects but there appeared to be little influence of harvest date, clone or storage temperature. Consequently, consideration of optimum harvest dates and storage temperatures for CA storage until late January was mainly concerned with physical and sensory assessments of quality. On this basis, 8-15 October 2004 appeared to be the best period for harvesting.

For storage in CA until late April, core flush and internal breakdown were major and minor constraints respectively. Clearly, late April was not achievable in CA storage in 2004. Core flush was also evident in commercial fruit marketed late in the season. Late picking (pick 4) and storage at low temperature (0-0.5°C) exacerbated the problem, but the problem could not be ameliorated by earlier harvesting and storing at higher temperatures. On the basis of physical and sensory assessments of quality, it appeared that the first two picks (1-8 October) were appropriate for longer storage in CA. It is commonly expected that longer storage requires harvesting at a less mature stage. Core flush development in the 2004 crop dictated a shorter period of storage, where it is assumed that a pick date around 8 October might be ideal.

Harvest maturity parameters associated with optimum storage performance in 2004 were as follows:

Storage details	Harvest date	Harvest maturity parameters Firmness (kg)	Starch (% black)	Streif index
Air late Nov.	8 October	8.2	61	0.18
	15 October	7.8	49	0.13
Air late Jan.	8 October	8.2	61	0.18
CA late Jan.	8 October	8.2	61	0.18
	15 October	7.8	49	0.13
CA late April	1 October	8.6	74	0.31
	8 October	8.2	61	0.18

Maturity parameters associated with optimum storage in 2003 and 2004 can be compared as follows:

Storage details	Year	Harvest maturity parameters Firmness (kg)	Starch (% black)	Streif index
Air late Jan.	2003	9.0	63	0.18
	2004	8.2	61	0.18
CA late April	2003	9-9.5	63-67	0.18-0.22
	2004	8.2-8.6	61-74	0.18-0.31

It was reassuring that in the two years of the project to date the starch iodine test and Streif Index could be used to indicate optimum time of harvest. Firmness was too variable between the two years to be of use as a guide to harvest date. Picking earlier than indicated by starch and Streif index is likely to lead to loss of eating quality but more importantly to wastage due to scald development. Later harvesting will lead to loss appearance and eating quality and is only appropriate for shorter-term storage.

Based on current information the storage temperature for air and CA-stored fruit should be 0-0.5°C and 1.5-2°C respectively. The CA conditions should remain at <1% CO_2 + 2% O_2 for the time being and CA conditions should be established 3 weeks after loading to avoid potential injury to the fruit. The length of storage that is possible will depend on the growing conditions in any particular season and it appears that in years such as 2003 the main risk will be scald, whilst in other years such as 2004 the main risk will be core flush. From current information, it is suggested that air storage should be terminated by the end of December and

CA storage by the end of February or early March. Further years of storage data would be required in order to be able to predict the risk of core flush and scald using weather data.
There may be scope for reducing the main storage disorders of Braeburn, i.e. scald and core flush, by the use of lower store oxygen concentrations and by shortening the delay before establishing CA conditions. It is hoped that these aspects can be investigated in the final year of the project.

Technology transfer

Data from the project were used to formulate picking date advice provided by the Quality Fruit Group (QFG) in 2004 and the second year of data will strengthen advice provided by QFG in 2005. Reference has been made to the study at various conferences in 2005 such as the FAST Conference held at EMR in February and at the EMRA/MFSS Storage Day held at EMR in April.

References

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Table 1. **The effects of picking dates and clones on maturity parameters of Braeburn apples in 2004. Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively**

	Colour 1, green - 4, yellow	**Firmness (kg)**	**S. Solids (%)**	**Starch (% black)**	**Streif Index**	**IEC (Log_{10} ppb)**
Schneider	1.3	7.9	11.1	53	0.17	1.86
Hillwell	1.5	8.2	11.8	56	0.18	1.76
Lochbuie	1.3	8.6	11.6	66	0.25	1.96
SED (8 df)	0.92	0.22	0.33	5.8	0.031	0.147
Pick 1	1.3	8.6	11.2	74	0.31	1.65
Pick 2	1.3	8.2	11.5	61	0.18	1.72
Pick 3	1.4	7.8	11.7	49	0.13	1.83
Pick 4	1.5	8.2	11.5	45	0.13	2.18
SED (8 df)	0.09	0.22	0.35	6.0	0.032	0.152

Table 2. **The effects of picking date on the visual (greasiness) quality of Braeburn apples stored at 1.5-2ºC in air until 22 November 2004 and 24 January 2005 and in CA until 31 January and 22 April 2005. Fruit was assessed after 4 days at 20ºC. Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively**

	Pick 1	**Pick 2**	**Pick 3**	**Pick 4**
Air November	0.5	1.2	1.8	2.2
Air January	0.6	1.0	1.8	2.4
CA February	0.4	0.9	1.7	2.3
CA April	0.6	0.8	1.3	1.9
SED 32 d.f.		0.65		

Table 3. **The effects of picking date on the visual quality of Braeburn apples stored at 1.5-2ºC in air until 22 November 2004 and 24 January 2005 and in CA until 31 January and 22 April 2005. Fruit was assessed after 4 days at 20ºC. Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively**

	Pick 1	**Pick 2**	**Pick 3**	**Pick 4**
Air November	2.9	3.4	3.3	2.9
Air January	3.6	3.6	3.3	2.8
CA February	3.6	3.6	3.6	3.1
CA April	2.9	3.1	2.9	2.3
SED 32 d.f.		0.30		

Table 4. The effects of picking date on the sensory (aroma) quality of Braeburn apples stored at 1.5-2ºC in air until 22 November 2004 and 24 January 2005 and in CA until 31 January and 22 April 2005. Fruit was assessed after 4 days at 20ºC. Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively

	Pick 1	**Pick 2**	**Pick 3**	**Pick 4**
Air November	1.8	1.9	2.0	2.1
Air January	2.6	2.9	2.7	2.7
CA February	2.4	2.6	2.7	2.8
CA April	1.9	2.1	2.4	2.3
SED 32 d.f.			0.26	

Table 5. The effects of picking date on the sensory (acidity) quality of Braeburn apples stored at 1.5-2ºC in air until 22 November 2004 and 24 January 2005 and in CA until 31 January and 22 April 2005. Fruit was assessed after 4 days at 20ºC. Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively

	Pick 1	**Pick 2**	**Pick 3**	**Pick 4**
Air November	2.5	2.3	2.2	2.1
Air January	2.8	2.7	2.4	2.4
CA February	3.4	3.3	2.7	2.5
CA April	2.3	2.2	2.0	1.7
SED 32 d.f.			0.26	

Table 6. The effects of picking date on the sensory (sweetness) quality of Braeburn apples stored at 1.5-2ºC in air until 22 November 2004 and 24 January 2005 and in CA until 31 January and 22 April 2005. Fruit was assessed after 4 days at 20ºC. Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively

	Pick 1	**Pick 2**	**Pick 3**	**Pick 4**
Air November	2.5	2.8	2.8	2.7
Air January	3.0	3.2	3.2	3.0
CA February	2.7	2.9	3.0	3.2
CA April	2.7	2.9	2.8	2.5
SED 32 d.f.			0.29	

Table 7. The effects of picking date on the sensory (flavour) quality of Braeburn apples stored at 1.5-2ºC in air until 22 November 2004 and 24 January 2005 and in CA until 31 January and 22 April 2005. Fruit was assessed after 4 days at 20ºC. Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively

	Pick 1	**Pick 2**	**Pick 3**	**Pick 4**
Air November	2.6	3.0	3.0	2.9
Air January	3.0	3.1	3.0	2.7
CA February	3.1	3.0	3.2	3.0
CA April	2.7	2.9	2.8	2.4
SED 32 d.f.			0.30	

Table 8. **The effects of picking date on the sensory (juiciness) quality of Braeburn apples stored at 1.5-2ºC in air until 22 November 2004 and 24 January 2005 and in CA until 31 January and 22 April 2005. Fruit was assessed after 4 days at 20ºC. Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively**

	Pick 1	**Pick 2**	**Pick 3**	**Pick 4**
Air November	3.2	3.4	3.3	3.0
Air January	3.6	3.3	3.1	3.0
CA February	3.4	3.5	3.7	3.4
CA April	3.5	3.5	3.5	3.1
SED 32 d.f.			0.12	

Table 9. **The effects of picking date on the sensory (firmness) quality of Braeburn apples stored at 1.5-2ºC in air until 22 November 2004 and 24 January 2005 and in CA until 31 January and 22 April 2005. Fruit was assessed after 4 days at 20ºC. Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively**

	Pick 1	**Pick 2**	**Pick 3**	**Pick 4**
Air November	3.8	3.8	3.5	3.3
Air January	3.6	3.1	2.8	2.3
CA February	3.8	3.8	3.5	3.0
CA April	3.6	3.5	2.9	2.5
SED 32 d.f.			0.19	

Table 10. **The effects of picking date on the sensory (texture) quality of Braeburn apples stored at 1.5-2ºC in air until 22 November 2004 and 24 January 2005 and in CA until 31 January and 22 April 2005. Fruit was assessed after 4 days at 20ºC. Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively**

	Pick 1	**Pick 2**	**Pick 3**	**Pick 4**
Air November	3.7	3.8	3.6	3.2
Air January	3.6	3.3	2.9	2.4
CA February	3.4	3.5	3.6	3.4
CA April	3.4	3.4	2.8	2.3
SED 32 d.f.			0.23	

Table 11. **The effects of picking date on the sensory (overall) quality of Braeburn apples stored at 1.5-2ºC in air until 22 November 2004 and 24 January 2005 and in CA until 31 January and 22 April 2005. Fruit was assessed after 4 days at 20ºC. Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively**

	Pick 1	**Pick 2**	**Pick 3**	**Pick 4**
Air November	3.0	3.2	3.0	2.8
Air January	3.4	3.3	3.0	2.5
CA February	3.0	3.2	3.4	3.2
CA April	3.1	3.3	2.9	2.3
SED 32 d.f.	0.22			

Table 12. The overall effects of clones on the sensory quality of Braeburn apples stored at 1.5-2°C in air until 22 November 2004 and 24 January 2005, and in CA until 31 January and 22 April 2005. Fruit was assessed after 4 days at 20°C

	Lochbuie	**Hillwell**	**Schneider**	**SED**	**df**
Greasiness	0.9	2.2	0.9	0.28	36
Visual	3.1	3.3	3.1	0.30	36
Aroma	2.2	2.6	2.3	0.13	36
Acidity	2.2	2.5	2.7	0.23	36
Sweetness	2.9	3.0	2.7	0.19	36
Flavour	2.9	3.1	2.7	0.17	36
Juiciness	3.4	3.3	3.4	0.16	36
Firmness	3.5	3.2	3.2	0.33	36
Texture	3.5	3.2	3.1	0.30	36
Overall	3.1	3.1	2.9	0.24	36

Table 13. The overall effects of picking date on the sensory quality of Braeburn apples stored at 1.5-2°C in air until 22 November 2004 and 24 January 2005, and in CA until 31 January and 22 April 2005. Fruit was assessed after 4 days at 20°C. Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively

	Pick 1	**Pick 2**	**Pick 3**	**Pick 4**	**SED 32 df**
Greasiness	0.5	1.0	1.7	2.2	0.32
Visual	3.2	3.5	3.3	2.8	0.15
Aroma	2.2	2.4	2.5	2.5	0.13
Acidity	2.7	2.6	2.3	2.2	0.13
Sweetness	2.7	2.9	3.0	2.9	0.14
Flavour	2.8	3.0	3.0	2.8	0.15
Juiciness	3.4	3.4	3.4	3.1	0.06
Firmness	3.7	3.6	3.2	2.8	0.09
Texture	3.5	3.5	3.2	2.8	0.11
Overall	3.1	3.2	3.1	2.7	0.11

Table 14. The overall effects of storage conditions and duration on the sensory quality of Braeburn apples stored at 1.5-2°C in air until 22 November 2004 and 24 January 2005, and in CA until 31 January and 22 April 2005. Fruit was assessed after 4 days at 20°C. Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively

	Air 1	**Air 2**	**CA 1**	**CA 2**	**SED 32 df**
Greasiness	1.4	1.5	1.3	1.2	0.32
Visual	3.1	3.3	3.5	2.8	0.17
Aroma	2.0	2.7	2.6	2.2	0.07
Acidity	2.3	2.6	3.0	2.0	0.13
Sweetness	2.7	3.1	3.0	2.7	0.11
Flavour	2.9	3.0	3.1	2.7	0.10
Juiciness	3.2	3.3	3.5	3.4	0.09
Firmness	3.6	2.9	3.5	3.1	0.19
Texture	3.6	3.1	3.5	3.0	0.17
Overall	3.0	3.1	3.2	2.9	0.13

Table 15. 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 and 4 were 1, 8, 15 and 22 October 2004 respectively

Storage		**Air**		**CA**
Removal date	**22.11.04**	**24.1.05**	**31.1.05**	**22.4.05**
0-0.5°C	1.6	2.4	1.9	2.0
1.5-2°C	1.6	2.3	1.9	2.2
SED (20 df)	0.03	0.09	0.12	0.09
'Schneider'	1.6	2.3	1.9	2.1
'Hillwell'	1.7	2.5	2.1	2.2
'Lochbuie'	1.6	2.3	1.9	2.0
SED (20 df)	0.04	0.11	0.14	0.11
Pick 1	1.5	2.1	1.8	1.7
Pick 2	1.6	2.2	1.8	2.1
Pick 3	1.6	2.4	2.0	2.2
Pick 4	1.7	2.7	2.1	2.4
SED (20 df)	0.05	0.13	0.17	0.13

Table 16. 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 and 4 were 1, 8, 15 and 22 October 2004 respectively

Storage		**Air**		**CA**
Removal date	**22.11.04**	**24.1.05**	**31.1.05**	**22.4.05**
0-0.5°C	8.2	7.3	7.6	7.5
1.5-2°C	7.9	7.0	7.6	7.6
SED (20 df)	0.09	0.11	0.08	0.09
Schneider	7.8	6.8	7.3	7.2
Hillwell	8.0	7.0	7.6	7.5
Lochbuie	8.3	7.5	7.9	7.8
SED (20 df)	0.11	0.14	0.10	0.12
Pick 1	8.2	7.2	7.7	7.7
Pick 2	8.0	7.2	7.6	7.8
Pick 3	8.0	7.1	7.6	7.7
Pick 4	7.9	6.9	7.3	6.8
SED (20 df)	0.13	0.16	0.12	0.13

Table 17. **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 and 4 were 1, 8, 15 and 22 October 2004 respectively**

Storage		**Air**		**CA**
Removal date	**22.11.04**	**24.1.05**	**31.1.05**	**22.4.05**
0-0.5ºC	13.5	12.8	12.9	12.8
1.5-2ºC	13.8	12.8	12.8	12.8
SED (20 df)	0.20	0.22	0.23	0.22
Schneider	13.2	12.4	12.3	12.4
Hillwell	14.0	13.1	13.2	13.2
Lochbuie	13.7	13.0	13.0	12.8
SED (20 df)	0.25	0.27	0.29	0.27
Pick 1	13.6	12.8	12.8	12.7
Pick 2	13.5	12.6	12.6	12.6
Pick 3	13.9	13.0	13.0	13.0
Pick 4	13.6	12.9	13.0	12.9
SED (20 df)	0.29	0.32	0.33	0.31

Table 18. **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 and 4 were 1, 8, 15 and 22 October 2004 respectively**

Storage		**Air**		**CA**
Removal date	**22.11.04**	**24.1.05**	**31.1.05**	**22.4.05**
0-0.5ºC	0.46	1.02	0.71	0.99
1.5-2ºC	0.67	1.63	0.96	1.32
SED (20 df)	0.045	0.084	0.062	0.07
Schneider	0.48	1.18	0.71	0.98
Hillwell	0.46	1.12	0.71	1.04
Lochbuie	0.76	1.69	1.09	1.44
SED (20 df)	0.056	0.103	0.076	0.080
Pick 1	0.51	1.15	0.83	1.07
Pick 2	0.44	0.89	0.80	1.07
Pick 3	0.69	1.69	0.84	1.23
Pick 4	0.63	1.58	0.87	1.25
SED (20 df)	0.064	0.119	0.088	0.093

Table 19. 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 and 4 were 1, 8, 15 and 22 October 2004 respectively

Storage	**Air**		**CA**	
Removal date	**24.1.05**		**22.4.05**	
Days at 20ºC	**0**	**7**	**0**	**8**
0-0.5ºC	0	0.2	0	0
1.5-2ºC	0	2.1	0	0
SED (20 df)		1.39		
Schneider	0	1.6	0	0
Hillwell	0	1.6	0	0
Lochbuie	0	0.3	0	0
SED (20 df)		1.71		
Pick 1	0	4.2	0	0
Pick 2	0	0.5	0	0
Pick 3	0	0	0	0
Pick 4	0	0	0	0
SED (20 df)		1.97		

Table 20. The effects of storage temperature, clones and picking dates on the 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 and 4 were 1, 8, 15 and 22 October 2004 respectively

Storage	**Air**			**CA**		
Removal date	**22.11.04**	**24.1.05**		**31.1.05**		**22.4.05**
Days at 20ºC	**4**	**4**	**7**	**4**	**7**	**4**
	WWF 0-5	WWF 0-5	EMR 0-4	WWF 0-5	EMR 0-4	WWF 0-5
0-0.5ºC	-	-	0.4	-	0.5	-
1.5-2ºC	-	-	0.5	-	0.6	-
SED (20 df)			0.15		0.12	
Schneider	0.5	0.8	0.3	1.5	0.4	0.9
Hillwell	1.0	1.9	0.9	1.9	0.9	1.7
Lochbuie	0.5	1.1	0.1	1.2	0.3	1.4
SED (10 df)	0.22	0.14	0.18	0.38	0.14	0.40
Pick 1	0.2	0.8	0.2	0.4	0	0.8
Pick 2	0.2	1.1	0.2	1.3	0.3	1.0
Pick 3	1.2	1.4	0.4	2.1	0.6	1.5
Pick 4	1.2	1.8	1.0	2.4	1.2	1.9
SED (10 df)	0.25	0.17	0.21	0.44	0.17	0.47

Table 21. 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). Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively

	Air		**CA**			
Removal date	**24.1.05**		**31.1.05**		**22.4.05**	
Days at 20°C	**0**	**7**	**0**	**7**	**0**	**7**
0-0.5°C	0	19.4	0	2.7	17.9	54.8
1.5-2°C	10.4	41.3	0	4.6	21.3	32.6
SED (20 df)	3.1	4.74		1.65	4.74	7.34
Schneider	7.5	42.0	0	4.5	23.1	38.4
Hillwell	5.6	24.2	0	2.2	13.8	36.8
Lochbuie	2.5	24.9	0	4.4	21.9	56.0
SED (20 df)	3.81	5.80		2.03	5.81	8.99
Pick 1	4.2	31.0	0	4.8	17.5	37.9
Pick 2	4.2	26.2	0	1.7	13.3	34.8
Pick 3	5.8	27.9	0	2.2	13.3	43.0
Pick 4	6.7	36.4	0	6.0	34.2	59.0
SED (20 df)	4.40	6.70		2.3	6.71	10.38

Table 22. The effects of picking date on the incidence of rotting and physiological disorders in Braeburn apples stored controlled atmosphere conditions (<1% CO_2 + 2% O_2) until 22 April 2005 followed by 7 days at 20°C. Dates for picks 1, 2, 3 and 4 were 1, 8, 15 and 22 October 2004 respectively

	Pick 1	**Pick 2**	**Pick 3**	**Pick 4**	**SED**	**df**
Rotting (%)	0.4	3.5	1.3	4.9	1.90	20
Core flush (%)	37.9	34.8	43.0	59.0	10.38	20
Internal breakdown (%)	6.5	1.4	4.7	11.4	3.23	20

Table 23. The effects of clones on the incidence of rotting and physiological disorders in Braeburn apples stored controlled atmosphere conditions (<1% CO_2 + 2% O_2) until 22 April 2005 followed by 7 days at 20°C

	Schneider	**Hillwell**	**Lochbuie**	**SED**	**df**
Rotting (%)	3.7	1.3	2.5	1.64	20
Core flush (%)	38.4	36.8	56.0	8.99	20
Internal breakdown (%)	1.2	2.6	14.2	2.79	20

Table 24. The effects of storage temperature on the incidence of rotting and physiological disorders in Braeburn apples stored controlled atmosphere conditions (<1% CO_2 + 2% O_2) until 22 April 2005 followed by 7 days at 20°C

	0-0.5°C	**1.5-2°C**	**SED**	**df**
Rotting (%)	2.7	2.3	1.34	20
Core flush (%)	54.8	32.6	7.34	20
Internal breakdown (%)	7.1	4.9	2.28	20