Project title	Effects of store oxygen concentration and rate of establishment of low oxygen conditions on the quality of 'Braeburn' apples
Project number:	TF175
Project leader:	David Johnson, EMR
Report:	Annual report, May 2008
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Key staff:	David Johnson Clare Hopson
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Project co-ordinator:	Andrew Tinsley, HDC
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Date project completed (or expected completion date):	30 June 2008
Key words:	apple, storage, 'Braeburn', CA

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The results and conclusions in this report are based on an investigation 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.

AUTHENTICATION

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

David Johnson
Project Leader
East Malling Research

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Report authorised by:

Dr Christopher Atkinson
Head of Science
East Malling Research

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Grower Summary

Headline

- A three-fold reduction in core flush was achieved by sealing CA stores immediately after loading

- There were quality benefits from storing in oxygen levels lower than currently recommended

Background and expected deliverables

Previous research funded by the HDC (TF152), and carried out in collaboration with Worldwide Fruit and FAST Ltd under the auspices of the Quality Fruit Group (supported by English Apples and Pears Ltd), established the minimum storage temperature for 'Braeburn' and the maximum duration of storage in air and controlled atmosphere (CA) conditions of 2% O_2 and <1% CO_2. In addition, maturity parameters were established for the harvesting of 'Braeburn' at a stage that maximized visual and eating quality and avoided the development of superficial scald. Clonal differences in storage behaviour were also described.

Within the three years of project TF152 it was not possible to fully evaluate the effects of storing 'Braeburn' apples in 1.2% O_2 as opposed to 2% O_2, or the consequences of sealing CA stores immediately after loading as opposed to a 3-week delay as recommended in countries abroad for the avoidance of 'Braeburn' Browning Disorder (BBD).

Growers are concerned about the time taken to establish CA conditions where stores are sealed three weeks after loading. Since the majority of growers do not have nitrogen gas available for flushing stores to rapidly achieve low oxygen conditions, the low respiration rate of 'Braeburn' apples held at 1.5-2^{o}C may reduce store oxygen by less than 1% per day and some loss of quality and storage life may be expected as a consequence. More importantly the impact of slow establishment of CA conditions on the development of core flush is unknown. The occurrence of this disorder currently limits the storage of 'Braeburn' to March which is well short of commercial marketing targets of April and possibly May. Any change in the protocol for storing UK 'Braeburn' that minimizes the risk of core flush would be welcomed by growers and marketing organizations.

Without nitrogen flushing the reduction in store oxygen concentration in commercial stores will depend on the innate respiration of the consignments and the gas tightness of the stores. The research in this project aims to determine positive and negative effects of establishing low oxygen conditions immediately after cooling by nitrogen flushing or gradually by respiration. Different rates of oxygen reduction by respiration were established to accommodate the likely range in establishment times achieved in commercial stores. Different rates of oxygen 'pull-down' were compared on stores sealed immediately after cooling and after a 3-week delay. Final oxygen concentrations were maintained at the recommended 2% O_2 and at 1.2% O_2. It was important to investigate possible interactions between the delay and rate of CA establishment and the oxygen concentration used for storage of the fruit.

It is intended that the research will provide clear guidelines to growers on how to establish CA conditions in stores of 'Braeburn' and to alleviate current concerns about the time taken to establish CA using current best practice.

Summary of the project and main conclusions

A 3-year-old commercial 'Braeburn' orchard (Hillwell clone) in West Kent was selected for the study. Samples of fruit for storage were picked on the 4 and 10 October 2007. At each pick 70 fruits were selected at random from each of 30 trees. After picking all fruit was transported immediately to the Jim Mount Building at EMR. Sixty four 30-fruit samples were formed by placing into a net one fruit from each of the 30 boxes and repeating the exercise. In this way each sample had a fruit from each of the 30 trees sampled in the orchard. All nets were labeled and weighed and placed into a store at 1.5ºC to cool overnight. The next day samples were allocated to 360 L storage containers (8 samples to each of 8 containers). Four containers were sealed immediately and the remaining four after 21 days (current recommended practice). For containers sealed immediately and after 21 days there were four rates of CA establishment. Nitrogen was injected into the containers at rates that lowered the oxygen concentration to 2% in 1 hour or within 7, 10 or 14 days. When 2% O_2 was reached half of the samples were transferred to a lower oxygen (1.2% O_2) atmosphere whilst the remaining samples continued in a 2% O_2 regime. The entire exercise was repeated for the second pick of fruit. The treatments applied in 2007 are summarized as follows:

Pick	Delay to seal (days)	Days to establish 2% O_2				Store oxygen conc.	
1 (4.10.07)	0	0	7	10	14	2% O_2	1.2% O_2

	21	0	7	10	14	2% O_2	1.2% O_2
2 (10.10.07)	0	0	7	10	14	2% O_2	1.2% O_2
	21	0	7	10	14	2% O_2	1.2% O_2

Throughout CA establishment and storage the CO_2 concentration was maintained below 1% by the use of hydrated lime scrubbers. Oxygen concentrations were maintained at 1.2 or 2% by automated injection of compressed air and fruit temperature was maintained at 1.5-2^{o}C. Gas measurement and control was achieved using an ICA 66 system (International Controlled Atmosphere Ltd).

Fruit was removed from the containers for quality assessment on 21 and 22 January and 7 and 9 April 2008. Quality was assessed immediately ex-store and again after a further 7 days at 20^{o}C.

There was no tissue damage in the fruit regardless of when the CA containers were sealed or how quickly the CA conditions were established. Clearly, further work will need to be done in 2008 in order to confirm these results but it appears that UK-grown 'Braeburn' is not as susceptible to BBD as those grown abroad.

The ability to seal stores after loading and cooling rather than after a three-week delay conferred advantages in terms of fruit quality. Firmness and green background colour was maintained more effectively by sealing the storage containers immediately after cooling, as opposed to delaying sealing by 21 days. More importantly, there was a three-fold reduction in the amount of core flush by immediate sealing of the CA containers compared with a three-week delay. This is particularly important since the development of core flush currently determines March as the termination date of 'Braeburn'. There is a major commercial incentive to extend the marketing of 'Braeburn' into April and possibly May. The different rates of CA establishment had little effect on the storage quality of 'Braeburn' in 2007-08. It was anticipated that more rapid establishment of CA conditions would be beneficial to retention of green colour and firmness but this was not the case.

As expected, fruits from the second harvest were softer and more yellow than those from the first harvest, even though fruit at both picks were at a slightly less mature stage than is considered ideal. The overall quality of fruit from both picks was more than acceptable in April with firmness 7.8 (pick 1) and 7.6 kg (pick 2) and greenness of 1.8 and 2.0 respectively (commercial colour chart where 1 is green and 4 is yellow).

Storing in 1.2% O_2 as opposed to 2% O_2 reduced weight loss and stickiness of fruit and provided greener, firmer fruit compared with 2% O_2.

Conclusions

The protocol being developed for UK 'Braeburn' requires that stores are sealed immediately after loading and that CA conditions are generated by fruit respiration in the normal way. Carbon dioxide concentrations should be maintained below 1% during establishment of low oxygen conditions and throughout the storage period. A store oxygen concentration of 1.2% is preferred to 2% in order to maximise retention of firmness and greenness in the fruit. This protocol is likely to optimise fruit quality and minimise the development of core flush in the fruit. Further work is proposed for 2008-09 to test the robustness of the protocol on different consignments of commercial fruit and on fruit harvested at different maturity stages.

Financial benefits

Improvement in the storage quality of 'Braeburn' will consolidate the position of UK fruit in the market place and will give UK growers a strong competitive edge against imports, particularly from Italy and France. With increasing production (estimates of 20,000 tonnes by 2010) it will be vital to extend the marketing period into March and April in order to control the market and stabilise prices. This research to optimise quality and extend the period of storage has important financial implications to UK 'Braeburn' growers and the UK fruit industry in general.

Action points for growers

- It is premature for growers to make changes to the methods of storing 'Braeburn' in 2008
- It is anticipated that major changes will be made to the storage protocol for the 2009 crop of 'Braeburn' subject to a successful outcome of trials proposed for 2008

Science Section

Introduction

Previous research funded by the HDC (TF152), and carried out in collaboration with Worldwide Fruit and FAST Ltd under the auspices of the Quality Fruit Group (supported by English Apples and Pears Ltd), established the minimum storage temperature for 'Braeburn' and the maximum duration of storage in air and controlled atmosphere (CA) conditions of 2% O_2 and <1% CO_2. In addition, maturity parameters were established for the harvesting of 'Braeburn' at a stage that maximized visual and eating quality and avoided the development of superficial scald. Clonal differences in storage behaviour were also described.

Within the three years of project TF152 it was not possible to fully evaluate the effects of storing 'Braeburn' apples in 1.2% O_2 as opposed to 2% O_2 or the consequences of sealing CA stores immediately after loading as opposed to a 3-week delay, as recommended in countries abroad for the avoidance of 'Braeburn' Browning Disorder (BBD).

Growers are concerned about the time taken to establish CA conditions where stores are sealed three weeks after loading. Since the majority of growers do not have nitrogen gas available for flushing stores to rapidly achieve low oxygen conditions, the low respiration rate of 'Braeburn' apples held at 1.5-2^{o}C may reduce store oxygen by less than 1% per day and some loss of quality and storage life may be expected as a consequence. More importantly, the impact of slow establishment of CA conditions on the development of core flush is unknown. The occurrence of this disorder currently limits the storage of 'Braeburn' to March, which is well short of commercial marketing targets of April and possibly May. Any change in the protocol for storing UK 'Braeburn' that minimizes the risk of core flush would be welcomed by growers and marketing organizations.

Without nitrogen flushing the reduction in store oxygen concentration in commercial stores will depend on the innate respiration of the consignments and the gas tightness of the stores. The research in this project aims to determine the positive and negative effects of establishing low oxygen conditions immediately after cooling by nitrogen flushing or gradually by respiration. Different rates of oxygen reduction by respiration were achieved to accommodate the likely range in establishment times achieved in commercial stores. Different rates of oxygen 'pull-down' were compared in stores sealed immediately after cooling and after a 3-week delay. Final oxygen concentrations were maintained at the recommended 2% O_2 and at 1.2% O_2. It was important to investigate possible interactions

between the delay and rate of CA establishment and the oxygen concentration used for storage of the fruit.

It is intended that the research will provide clear guidelines to growers on how to establish CA conditions in stores of 'Braeburn' and to alleviate current concerns about the time taken to establish CA using current best practice.

Materials and methods

A three-year-old commercial 'Braeburn' orchard (Hillwell clone) in West Kent was selected for the study. Samples of fruit for maturity assessment were picked on 20 and 27 September and on 3 October 2007 (Table 1). On the basis of these tests it was decided to harvest fruit for storage on the 4 October 2007. The intention was to carry out the first pick at 80% starch and the second pick at 75% starch in accordance with the recommendations from HDC project TF152. However, the need to obtain two picks of fruit within the growers' intended picking programme resulted in the first pick being slightly less mature than ideal. The second pick on 10 October coincided with the grower harvesting for storage, but even then the fruit was slightly less mature than recommended for storage.

Table 1. Maturity parameters of 'Braeburn' (Hillwell) apples sampled from a commercial orchard in 2007. Figures for the first three picks are mean values for 20-fruit samples (1 fruit selected at random from 20 trees within a row). Figures for the picks for storage (4 and 10 October) are means values for 30-fruit samples randomized from the picked crop

Pick date	Mean Fruit Weight (g)	Firmness (kg)	Soluble solids (%)	Starch cover	
				Ctifl	% black
20.9.07	130	10.8	10.0	1.9	95
27.9.07	146	10.2	10.6	2.4	92
3.10.07	148	9.8	10.5	2.8	89
4.10.07	151	9.7	10.4	2.9	88
10.10.07	148	9.7	11.2	3.2	87

Seventy fruits were selected at random from each of 30 trees. After picking all fruit was transported immediately to the Jim Mount Building at EMR. Sixty-four 30-fruit samples were formed by placing into a net one fruit from each of the 30 boxes and repeating the exercise. In this way each sample had a fruit from each of the 30 trees sampled in the orchard. All nets were labeled and weighed and placed into a store at 1.5ºC to cool overnight. The next day samples were allocated to 360 L storage containers (8 samples to each of 8 containers). Four containers were sealed immediately and the remaining four after 21 days (current recommended practice). For containers sealed immediately and after 21 days there were four rates of CA establishment. Nitrogen was injected into the containers at rates that lowered the oxygen concentration to 2% in 1 hour or within 7, 10 or 14 days. When 2% O_2 was reached half of the samples were transferred to a lower oxygen (1.2% O_2) atmosphere

whilst the remaining samples continued in a 2% O_2 regime. The entire exercise was repeated for the second pick of fruit. The treatments applied in 2007 are summarized as follows:

Pick	Delay to seal (days)	Days to establish 2% O_2				Store oxygen conc.	
1 (4.10.07)	0	0	7	10	14	2% O_2	1.2% O_2
	21	0	7	10	14	2% O_2	1.2% O_2
2 (10.10.07)	0	0	7	10	14	2% O_2	1.2% O_2
	21	0	7	10	14	2% O_2	1.2% O_2

Throughout CA establishment and storage CO_2 concentrations were maintained below 1% by the use of hydrated lime scrubbers. Oxygen concentrations were maintained at 1.2 or 2% by automated injection of compressed air and fruit temperature was maintained at 1.5-2^{o}C. Gas measurement and control was achieved using an ICA 66 system (International Controlled Atmosphere Ltd).

Fruit was removed from the containers for quality assessment on 21 and 22 January and 7 and 9 April 2008. Quality was assessed immediately ex-store and again after a further 7 days at 20^{o}C.

Measurements on samples taken at harvest for maturity assessment included 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.

Fruit firmness. Two measurements were made on the opposite sides of each fruit using an LRX (Lloyd Instruments) materials testing machine fitted with an 11 mm probe. Measurements were made in the equatorial region after removal of the peel. Firmness was the maximum force (N) recorded during the insertion of the probe to a depth of 8 mm.

Soluble solids concentration. Juice was extracted from each apple using a 'Chylofel' (Copa - Technologie S.A.) apparatus and mixed to form a composite sample. Soluble solids concentration (%) was measured using a PR-32a digital refractometer (Atago Ltd).

Starch test. Half of each apple cut for internal examination was dipped in a solution containing 0.1% w/v iodine and 4% w/v potassium iodide. Dipped sections were left for at least an hour before being assessed. Each apple was scored (1-slight central discoloration to10-no peripheral discoloration) using the starch conversion chart for apples (circular type)

issued by Ctifl, France. An average score was calculated for each sample and an approximation made of the percentage of the surface stained black.

Background colour. The colour of the non-blush side of the fruit was assessed using commercial (Worldwide 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.

On removal from store each sample was weighed and each fruit was examined externally for the presence of rotting and external physiological disorders such as superficial scald. In January only a subjective assessment was made of the greasiness of the skin. Background colour was assessed on as many of the fruits in the sample as possible. On some fruits the extent of the red coloration was such that no measurement of background colour was possible. Firmness was measured on10 fruits per sample and these were then cut and examined for internal physiological disorders. The remaining fruit (20) in each sample were placed into 20^{o}C and examined after 7 days.

Statistical analysis

All data were subjected to an analysis of variance (ANOVA) using a treatment structure to compare the effects of the treatments and any possible interactions. The overall effects of picking date, delay to seal and store oxygen concentration can be compared using the least significant differences given in the tables. The standard errors of the difference between means (s.e.d.) and degrees of freedom (df) are given for completeness.

Results

Firmness (Table 2)

Firmness was maintained more effectively by sealing the storage containers immediately after cooling as opposed to delaying sealing by 21 days. Delaying harvest and maintaining a higher store oxygen concentration resulted in softer fruit but there was no effect of the rate at which store oxygen concentrations were achieved. Overall firmness declined from January to April by 8.7 N (0.9 kg). In April the firmest fruit was that picked on the first occasion that was not subjected to delay in sealing and was stored in 1.2% O_2.

Table 2. Effect of harvest date, delay in sealing CA containers, store oxygen concentration and storage duration on the firmness (N) of 'Braeburn' apples. Data are mean values for fruit subjected to four different rates of establishment of CA conditions (see text)

Harvest date	Delay in sealing storage containers	Firmness (N)			
		2% O_2		1.2% O_2	
		January	April	January	April
4.10.07	0 days	86.2	78.9	87.5	80.2
	21 days	82.4	72.1	84.0	75.0
10.10.07	0 days	85.2	73.1	86.6	80.0
	21 days	81.3	71.8	82.0	74.4
s.e.d. (32 df)		0.70	0.91	0.70	0.91
l.s.d. (32 df)		1.42	1.86	1.42	1.86

Weight loss (Table 3)

The weight loss of fruits stored until January was highest in fruits from the second pick and was reduced by storing in 1.2 as opposed to 2% O_2. However, there was a strong interaction between these treatments whereby 1.2% O_2 reduced weight loss only in fruit from the second pick. Average weight loss increased from January to April by 0.6% and again higher weight loss was recorded in the later harvested fruit and in fruit stored in 2% O_2. Unlike in January there was no significant interaction between harvest date and store oxygen concentration.

Table 3. Effect of harvest date, delay in sealing CA containers, store oxygen concentration and storage duration on the weight loss (%) of 'Braeburn' apples. Data are mean values for fruit subjected to four different rates of establishment of CA conditions (see text)

Harvest date	Delay in sealing storage containers	Weight loss (%)			
		2% O_2		1.2% O_2	
		January	April	January	April
4.10.07	0 days	0.7	1.6	0.6	0.9
	21 days	0.7	1.6	0.7	1.1
10.10.07	0 days	1.3	2.0	1.0	1.3
	21 days	1.4	2.1	1.0	1.3
s.e.d. (32 df)		0.04	0.16	0.04	0.16
l.s.d. (32 df)		0.09	0.34	0.09	0.34

Background colour (Table 4)

Although there were some highly significant treatment effects on the background colour of the fruits, the differences were likely to be regarded as slight from a commercial perspective. Delaying the sealing of the CA containers resulted in a more yellow background of fruits removed from store in January and April. The second harvest of fruit was more yellow than the first and storing in 1.2% O_2 resulted in greener fruit compared with 2% O_2.

Table 4. Effect of harvest date, delay in sealing CA containers, store oxygen concentration and storage duration on the background colour (1, green to 4, yellow) of 'Braeburn' apples. Data are mean values for fruit subjected to four different rates of establishment of CA conditions (see text)

Harvest date	Delay in sealing storage	Background colour (1, green to 4, yellow)	
		2% O_2	1.2% O_2

	containers	January	April	January	April
4.10.07	0 days	1.7	1.8	1.6	1.7
	21 days	1.8	2.0	1.8	1.9
10.10.07	0 days	1.8	2.1	1.7	1.8
	21 days	2.0	2.0	1.9	2.0
s.e.d. (32 df)		0.04	0.05	0.04	0.05
l.s.d. (32 df)		0.09	0.11	0.09	0.11

Core Flush (Tables 5-8)

Core flush was not present in fruit removed from store in January although the disorder developed to a slight extent (average 3%) during 7 days at 20ºC. The greater incidence and severity of core flush in fruit removed in April provides a more substantial data set to test the effects of the various treatments. Consequently only the effects of treatments on core flush incidence and severity at the April examination will be reported here. The only significant effect on core flush incidence was the three-fold increase due to the 21-day delay in sealing the CA containers. The delay also increased the average severity of core flush from 1.8 to 4.8. After 7 days at 20ºC the average incidence and severity of core flush had risen from 15 to 20% and the severity index from 3.3 to 4.3. Delay in sealing the CA containers resulted in a two-fold increase in core flush incidence and the number of fruit affected by the disorder was also increased in fruit from the first pick. Effects of treatments on core flush severity were similar to those described for core flush incidence. There was no effect of rate of CA establishment or store oxygen concentration on the incidence and severity of core flush.

Table 5. Effect of harvest date, delay in sealing CA containers, store oxygen concentration and storage duration on the incidence (%) of core flush in 'Braeburn' apples immediately ex-store. Data are mean values for fruit subjected to four different rates of establishment of CA conditions (see text)

Harvest date	Delay in sealing storage containers	Core flush (%)			
		2% O_2		1.2% O_2	
		January	April	January	April
4.10.07	0 days	0.0	8.8	0.0	12.5
	21 days	0.0	31.3	0.0	17.5
10.10.07	0 days	0.0	5.0	0.0	3.8
	21 days	0.0	17.5	0.0	23.8
s.e.d. (32 df)		-	6.2	-	6.2
l.s.d. (32 df)		-	12.7	-	12.7

Table 6. Effect of harvest date, delay in sealing CA containers, store oxygen concentration and storage duration on the severity of core flush (max. 60) in 'Braeburn' apples immediately ex-store. Data are mean values for fruit subjected to four different rates of establishment of CA conditions (see text)

Harvest date	Delay in sealing storage containers	Core flush (severity index max. 60)			
		2% O_2		1.2% O_2	
		January	April	January	April
4.10.07	0 days	0.0	2.3	0.0	2.5
	21 days	0.0	7.0	0.0	3.5
10.10.07	0 days	0.0	1.3	0.0	1.0

	21 days	0.0	3.8	0.0	5.0
s.e.d. (32 df)		-	1.32	-	1.32
l.s.d. (32 df)		-	2.70	-	2.70

Table 7. Effect of harvest date, delay in sealing CA containers, store oxygen concentration and storage duration on the incidence (%) of core flush in 'Braeburn' apples subjected to 7 days at 20ºC after storage. Data are mean values for fruit subjected to four different rates of establishment of CA conditions (see text)

Harvest date	Delay in sealing storage containers	Core flush (%)			
		2% O_2		1.2% O_2	
		January	April	January	April
4.10.07	0 days	3.1	20.0	1.9	15.3
	21 days	6.3	35.2	1.9	32.4
10.10.07	0 days	1.3	13.1	1.9	7.5
	21 days	5.0	16.3	3.1	20.3
s.e.d. (32 df)		1.79	2.78	1.79	2.78
l.s.d. (32 df)		3.65	5.66	3.65	5.66

Table 8. Effect of harvest date, delay in sealing CA containers, store oxygen concentration and storage duration on the severity (max. 60) of core flush in 'Braeburn' apples subjected to 7 days at 20ºC after storage. Data are mean values for fruit subjected to four different rates of establishment of CA conditions (see text)

Harvest date	Delay in sealing storage containers	Core flush (severity index max. 60)			
		2% O_2		1.2% O_2	
		January	April	January	April
4.10.07	0 days	0.6	4.3	0.4	3.6
	21 days	1.3	7.6	0.4	7.2
10.10.07	0 days	0.3	2.6	0.4	1.5
	21 days	1.0	3.4	0.6	4.2
s.e.d. (32 df)		0.35	0.62	0.35	0.62
l.s.d. (32 df)		0.73	1.26	0.73	1.26

Greasiness (Table 9)

None of the apples were considered greasy either in January or April even when subjected to a 7 day period at 20ºC. However, some of the fruits felt slightly sticky and an assessment was made of the 'feel' of the fruit. This was only carried out on fruit stored until January and subjected to a further 7 days at 20ºC. Fruit from the second pick was stickier than that from the first pick. Storing in 1.2% O_2 as opposed to 2% O_2 reduced stickiness of fruit from the first pick only.

Table 9. Effect of harvest date, delay in sealing CA containers and store oxygen concentration on the 'stickiness' of 'Braeburn' subjected to 7 days at 20ºC after storage. Data are mean values for fruit subjected to 4 different rates of establishment of CA conditions (see text)

Harvest date	Delay in sealing storage containers	Greasiness			
		2% O_2		1.2% O_2	
		January	April	January	April
4.10.07	0 days	0.4	-	0.1	-
	21 days	0.3	-	0.1	-
10.10.07	0 days	0.5	-	0.5	-
	21 days	0.5	-	0.4	-

s.e.d. (32 df)	0.08	-	0.08	-
l.s.d. (32 df)	0.18	-	0.18	-

Superficial scald and rotting

None of the fruit was affected by superficial scald and there were only seven rotted fruits out of 3840 fruits that were stored.

Discussion

The current recommendation to wait for 21 days before sealing CA stores of 'Braeburn' is based on international experience and is intended to prevent CA injury problems such as 'Braeburn' Browning Disorder (BBD). The current HDC storage recommendations wall chart refers to the Best Practice Guide for UK apples which stipulates the 21-day delay. The objective of the 2007 trial was to investigate the possible injurious effects of sealing CA containers immediately after loading as opposed to delay of 21 days and the effects of different rates of establishing low oxygen conditions on the development of tissue damage. There was no tissue damage in the fruit regardless of when the CA containers were sealed or how quickly the CA conditions were established. Clearly, further work will need to be done in 2008 in order to confirm the results obtained in 2007-8 but it appears that UK-grown 'Braeburn' is not as susceptible to BBD to those grown abroad.

The ability to seal stores after loading and cooling rather than after a three-week delay conferred advantages in terms of fruit quality. Firmness and green background colour was maintained more effectively by sealing the storage containers immediately after cooling as opposed to delaying sealing by 21 days. More importantly there was a three-fold reduction in the amount of core flush by immediate sealing of the CA containers compared with a three-week delay. This is particularly important since the development of core flush currently determines March as the termination date of 'Braeburn'. There is a major commercial incentive to extend the marketing of 'Braeburn' into April and possibly May.

The different rates of CA establishment had little effect on the storage quality of 'Braeburn' in 2007-8. It was anticipated that more rapid establishment of CA conditions would be beneficial to retention of green colour and firmness but this was not the case.

As expected, fruits from the second harvest were softer and yellower than those from the first harvest even though fruit at both picks were at a slightly less mature stage than is considered ideal. The overall quality of fruit from both picks was more than acceptable in April with firmness 7.8 (pick 1) and 7.6 kg (pick 2) and greenness of 1.8 and 2.0.

Storing in 1.2% O_2 as opposed to 2% O_2 reduced stickiness of fruit (first pick) and provided greener, firmer fruit compared with 2% O_2.

Conclusions

The protocol being developed for UK 'Braeburn' requires that stores are sealed immediately after loading and that CA conditions are generated by fruit respiration in the normal way. Carbon dioxide concentrations should be maintained below 1% during establishment of low oxygen conditions and throughout the storage period. A store oxygen concentration of 1.2% is preferred to 2% in order to maximise retention of firmness and greenness in the fruit. This protocol is likely to optimise fruit quality and minimise the development of core flush in the fruit. Further work is required to test the robustness of the protocol on different consignments of commercial fruit and on fruit harvested at different maturity stages.

Technology transfer

None

References

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Appendices

None

