Grower Summary

TF 221

Extend the marketing period of Gala apples. Phase II: Orchard and storage management practices to optimise flavour during long-term storage.

Final 2015

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GROWER SUMMARY

Headline

- The best controlled atmosphere regimes have been identified for storing Gala through to April and June.

Background and expected deliverables

UK production of Gala is expected to increase by 40% over the next three to four years. To provide a market for this fruit there is a need to extend the marketing period of UK Gala into April/ May. The challenge facing growers storing Gala beyond late March/early April is to compete with new season imports from the Southern hemisphere which are perceived to have superior quality at this stage of the season.

For Gala a number of storage regimes are currently being used; a regime of <1% CO_2, 1% O_2 at 0.5°C will allow storage up to February. Extending storage into March or early April requires the use of 5% CO_2, 1% O_2 at 1.5°C to prevent the development of scald and loss of firmness during shelf-life. There have been several reports that after long-term controlled atmosphere (CA) storage Gala apples have less flavour, relating to a decrease in flavour volatiles. Low oxygen concentrations and high carbon dioxide concentrations both contribute to this effect. Work funded by APRC (Stow and Genge, 2000) looking at storage in a range of CO_2 (0, 2.5 and 5% CO_2) and O_2 (1, 1.5 and 2%) conditions reported that flavour production in general declined after 110 days of storage, and that where CO_2 was present in the atmosphere, flavour volatile production was suppressed. The highest flavour production was reported at the highest oxygen concentration tested (2%).

With the advent of alternative strategies to reduce softening and control scald synthesis (SmartFresh™, ethylene scrubbing, ultra-low oxygen storage such as used with dynamic controlled atmosphere - DCA technologies), the need to incorporate 5% CO_2 in the storage atmosphere may be avoided or at least reduced for longer term storage. It is now vital that we define the best storage regimes for long-term storage of UK Gala where flavour production can be maintained for longer.

There have been many studies to identify volatiles in terms of their contribution to apple flavour. Methods for volatile capture by Solid Phase Micro extraction (SPME), or Thermal Desorption techniques followed by analysis using Gas Chromatograph with Mass spectroscopy (GC-MS) are currently under investigation at NRI.

A number of studies have charted the fall in volatile production during CA and air storage, and, as mentioned above, it is well documented that CA storage suppresses production of flavour production with time. However, some studies (Stow and Genge, 2000; Plotto *et al.,* 1999) have

found a poor correlation between ester flavour volatile decline and taste panel assessments of good eating quality, which suggests other attributes such as sweetness, acidity and texture (crispness) are also essential for the overall sensory perception of fruit quality. This underlines the importance of including the full range of characteristics in any assessment of eating quality of flavour

This project seeks to define a practical protocol for assessing Gala flavour that can be used to optimise pre and postharvest practices to maintain flavour, whilst identifying orchards with fruit suitable for long-term storage. A preliminary study will be undertaken on the effects of picking date, storage regime and SmartFresh™ application on the flavour retention of long-term stored fruit.

Summary of the project and main conclusions

Gala from six orchards (A-F) across Kent were harvested on two picking dates (8/9th and 12/13th September 2014). The rapidly changing maturity of Gala in the 2014 season resulted in Picks 1 and 2 being harvested only three to four days apart. Fruits were cooled for 24 hours to store holding temperature (1.5°C or 0.5°C) and a subset of samples were treated with SmartFresh™ (625 ppb) for 24 hours before atmospheres were exhausted. Controlled atmosphere regimes were established by automatic injection of nitrogen to reach 1% O_2. In addition to the AHDB-funded CA regime trial, International Controlled Atmosphere ltd (ICA) funded additional treatments (3% CO_2, 0.8,.0.6 and 0.4% O_2) Where Gala was stored below 1% O_2, fruit was held at 1% O_2 for a week before re-establishing conditions of 0.8, 0.6.or 0.4% O_2 by fruit respiration. CO_2 was added by automatic injection during the initial CA pull down phase. The CA regimes assessed are detailed below in the Table 1.

Table 1. Controlled Atmosphere, Temperature and SmartFresh treatments

Funder	Treatment	CA regime	Temp	Pick	SmartFresh
AHDB	T1	5%CO2, 1%O2	1.5°C	Pick 1	SF
AHDB	T2	5%CO2, 1%O2	1.5°C	Pick 1	
AHDB	T3	5%CO2, 1%O2	0.5°C	Pick 1	SF
AHDB	T4	5%CO2, 1%O2	0.5°C	Pick 1	
AHDB	T5	3%CO2, 2 %O2	0.5°C	Pick 1	SF
AHDB	T6	5%CO2, 0.4 %O2	0.5°C	Pick 1	
ICA	T7	3%CO2, 0.8%O2	0.5°C	Pick 1	
ICA	T8	3%CO2, 0.6 %O2	0.5°C	Pick 1	
ICA	T9	3%CO2, 0.4%O2	0.5°C	Pick 1	
AHDB	T10	5%CO2, 1%O2	0.5°C	Pick 2	SF
AHDB	T11	3%CO2, 2%O2	0.5°C	Pick 2	SF

Harvest Maturity

In 2014, changes in Gala harvest maturity progressed rapidly. Fruit firmness in Pick 1 ranged from 8.6-10.2 kg, but dropped to 7.8-9.5 kg in the second pick only four days later. Internal ethylene concentrations in fruit from orchards A, D, E and F increased rapidly between the two picks (Table 2). Fruit respiration by the second pick had increased significantly between the two picks and starch profiles of fruit at harvest ranged from 76-90% for Pick 1 and 85% to 63 % by Pick 2. In orchards A, D, E and F, starch loss increased over the four day period between picks in line with increased internal ethylene production. Dry matter content in orchards sampled in Pick 1 ranged from 12.2% to 15.6%. A similar profile of dry matter was recorded in fruit from the second pick.

Table 2. Harvest maturity measurements of 6 Gala orchards Harvested on the 8/9th and 12/13th September 2014

		Firmness	% Brix	Starch	Internal ethylene	Dry Matter	Respiration
Pick	Orchard	N		Ctifl (%)	(ppb)	%	ml-kg-h^{-1}
1	A	8.4	9.9	4.7 (75.7 %)	392.1	12.2	0.57
1	B	8.9	10.9	3.8 (74.8 %)	222.9	14.6	0.79
1	C	9.8	11.6	3.1(87.4 %)	430.3	15.6	0.84
1	D	9.0	11.0	3.6 (84.4 %)	328.0	15.0	0.90
1	E	8.3	10.9	4.3 (79.3 %)	202.3	14.0	0.79
1	F	8.9	10.6	2.6 (91.6%)	162.0	13.7	0.68
2	A	7.5	10.6	7.4 (56.6 %)	1025.7	12.7	1.73
2	B	8.9	11.2	3.5 (85 %)	101.9	14.7	1.73
2	C	9.1	12.0	3.7 (83.5 %)	398.7	16.1	2.17
2	D	8.6	11.8	4.9 (73.9 %)	637.8	15.5	2.24
2	E	8.1	11.6	5.9 (69.6 %)	574.9	14.4	2.80
2	F	8.4	10.9	4.9 (73.9%)	416.1	13.9	1.81

Storage trials

Apples from each orchard were randomly placed into grey plastic crates with damaged and misshapen fruits discarded. Apples were cooled to store temperature 1.5 or 0.5°C within 24 hours. SmartFresh^{TM} (625 ppb) was applied to selected treatments for 24 hours before exhausting the cabinets. CA regimes of 5% CO_2 and 1% O_2 or 3% CO_2 and 2% O_2 were established immediately by injection of nitrogen and CO_2. Where treatments involved O_2 concentrations below 1%, CA regimes were adjusted to either 5% or 3% CO_2 and 1% O_2 for 7 days by manual adjustment, before allowing O_2 to drop to the set point by fruit respiration.

Quality Assessment, volatile collection and analysis: April/June

Fruit samples were sent to technologists and advisors in a number of Producer Organisations and allied industries. Gala from each orchard x storage regime combination was tasted by at least six people, with a total of 96 fruit being sent to each organisation for tasting by a panel of people.

Gala samples were simultaneously assessed for fruit firmness and % Brix. Juice samples were collected and frozen (-20°C) for acid analysis by HPLC and inspected for external and internal disorders. Gala samples for volatile analysis were taken from store and placed in shelf-life conditions (18°C) for 48 hours. Samples of six fruits were cut into four quarters and placed inside air-tight 5L glass jars. Volatiles were collected using porapack columns. After sampling, columns were sealed and wrapped in aluminium foil, and stored at 4.5°C before analysis.

Results

First assessment – April 2015

For the purposes of identifying the optimum CA regime required for maintaining the quality of Gala into April, data from Orchard A was excluded from the analysis, due to significant internal breakdown. Taste panel assessment of overall acceptability averaged across 5 orchards ranged from 5.3-6.1 (Table 3). Fruit stored in 5/1 at 1.5°C or 5/1 at 0.5°C + SF produced fruit with an overall acceptability similar to imported fruit in April (6-6.1). There was no clear distinction between the optimum storage temperature and the effect of SF in the April assessment. It is important to note that CA's in this trial were generated within 24 hours of fruit reaching store temperature using nitrogen flushing and CO_2 injection. Rapid establishment of CA for Gala has the potential to improve ex-store quality of the fruit in long-term storage.

Table 3. Taste panel results April 2015- data averaged across five orchards

CA regime	Temperature	SmartFresh	Overall Acceptability	Aroma	Flavour	Sweetness	Acidity	Firmness
imported 2	n/a		6.1	5.2	5.7	5.6	3.2	6.9
5%CO2, 1%O2	1.5°C	-SF	6.1	5.3	5.6	5.4	3.9	7.1
imported 1	n/a		6.0	5.4	5.8	5.9	3.1	7.4
5%CO2, 1%O2	0.5°C	+SF	6.0	5.0	5.5	5.6	3.6	7.4
3%CO2, 0.4%O2	0.5°C	-SF	6.0	5.4	5.4	5.4	3.5	7.5
3%CO2, 2%O2	0.5°C	+SF	5.6	5.1	5.3	5.4	3.9	7.3
3%CO2, 0.6 %O2	0.5°C	-SF	5.6	5.4	5.4	5.3	4.1	7.2
3%CO2, 2 %O2	0.5°C	+SF	5.5	5.0	5.1	5.2	3.7	7.5
3%CO2, 0.8%O2	0.5°C	-SF	5.5	5.4	5.2	5.2	4.2	7.1
5%CO2, 1%O2	1.5°C	+SF	5.4	4.7	5.0	4.8	3.7	7.2
5%CO2, 0.4 %O2	0.5°C	-SF	5.4	5.4	4.9	5.5	3.4	7.0
5%CO2, 1%O2	0.5°C	+SF	5.3	4.3	5.2	5.2	3.7	6.9
5%CO2, 1%O2	0.5°C	-SF	5.3	4.9	5.1	5.2	3.9	7.0

In comparing firmness, % Brix, acidity and flavour profiles of Gala samples in April, it was found that UK Gala was over 2 kg firmer than imported fruit at the beginning of the Southern Hemisphere season (Table 4). Southern Hemisphere fruit in April had a higher acetate ester profile providing a 'fruity' aroma to apples with approximately 10 fold higher content of 2-methylbutyl acetate, 15-20 fold higher hexyl acetate and 4 fold increase in butyl acetate. However, UK Gala was firmer and had a higher background acidity after seven months storage. This in part countered the lower volatile profiles and emphasises the importance of texture and acid/sugar profile when considering overall acceptability (Table 4).

A new DCA monitored regime of 3% CO_2 and 0.4% O_2 produced fruit with taste panel overall acceptability scores of 6.0 in April when averaged over 5 orchards. The quality of fruit was equal to imported Gala and Gala stored in 5/1 regimes.

Taste panel assessment of individual orchard consignments in CA regimes

When the storage behaviour of individual orchard consignments was examined under different CA regimes, Gala stored in 5% CO_2, 1% O_2 (1.5°C) without SmartFresh and 5% CO_2,1% O_2 (0.5°C) with SmartFresh provided the highest number of orchard consignments where overall acceptability equalled imported fruit (Table 4). Gala from orchard C stored in 3% CO_2 and 0.8% O_2 produced the highest overall acceptable scores (6.7) of all fruit tasted (Table 4). Gala from orchard C was the highest ranked orchard providing fruit with the best overall eating acceptability scores and yielded the highest number of consignments (5/15) where

acceptability scores were equal or exceeded the scores (5.9-6.6) recorded for imported fruit. Gala from this orchard (Mondial) had the highest dry matter content and % Brix at harvest and was the orchard where fruit was consistently ranked with the highest concentration of volatiles.

Table 4. Individual treatment x orchard combinations producing fruit with an overall eating quality equal to or exceeding imported Gala in April 2015

Pick	Storage atmosphere	Temp.	SF?	Orchard	Overall acceptability	SE
1	3%CO2, 0.8%O2	0.5°C	-SF	C	6.7	0.4
1	5%CO2, 1%O2	1.5°C	-SF	E	6.6	0.6
imported 2					6.6	0.4
1	5%CO2, 1%O2	1.5°C	-SF	B	6.5	0.6
1	5%CO2, 1%O2	0.5°C	+SF	F	6.5	0.5
1	3%CO2, 2 %O2	0.5°C	+SF	D	6.3	0.7
1	3%CO2, 0.6 %O2	0.5°C	-SF	C	6.3	0.7
1	5%CO2, 1%O2	1.5°C	-SF	F	6.2	0.7
2	3%CO2, 2%O2	0.5°C	+SF	D	6.1	0.6
1	5%CO2, 1%O2	0.5°C	+SF	C	6.1	0.8
1	3%CO2, 0.6 %O2	0.5°C	-SF	E	6.1	0.7
1	5%CO2, 0.4 %O2	0.5°C	-SF	C	6	0.8
1	5%CO2, 1%O2	0.5°C	+SF	B	6	0.7
1	5%CO2, 1%O2	0.5°C	+SF	C	6	0.4
imported 1					5.9	0.6

Compositional and flavour profiles of Gala orchard consignments- April

Overall, orchard C provided fruit with the highest firmness values (92.9 N). The fruit had softened by only 5 N (~0.5 kg) since harvest (Table 5). Orchard C (Mondial Gala) contained the highest dry matter content over both picks (15.6%-16.1%) and % Brix in fruit sampled in April (13.4%) and was equal to the consignment of imported Gala. Imported Gala was 20 N (2 kg) softer than UK Gala stored for 7 months under CA conditions. Malic acid, the major contributor to fruit acidity, was significantly higher in 4 out of 6 Gala orchards compared to imported Gala. Comparison of major volatile components of Gala flavour showed imported fruit to have a higher acetate volatile profile, with significantly higher 2-butyl-acetate (ripe banana), amyl acetate, hexyl acetate (pear/banana flavour), compared to UK Gala in April, providing fruit with distinctive Gala apple flavour (Table 5). Moreover, imported fruit had a higher content of hexanol which provides sharp 'fusel' note to apple flavour. Hexanol is readily converted (esterified) into hexyl acetate. The conversion of hexanol to hexyl acetate is suppressed by high CO_2 in the storage atmosphere. Despite the difference in volatile aroma profiles, the overall acceptability scores of UK fruit in some cases was equal to imported fruit

based on better texture and higher ratios of acidity to sugar content. Butyrate esters were low across all orchard and imported fruit. The hexanal content of orchards B, C and E were higher than imported fruit. This compound is often associated with green- unripe flavour. A more extensive profile of volatiles can be found in the science section.

Table 5. The overall effect of orchard consignments on quality attributes and major volatiles of Gala (averaged across all CA regimes) April 2015.

Orchard	A	B	C	D	F	G	Imported	**Fprob**	**$LSD_{0.05}$**
Firmness (kg)	7.5	8.7	**9.3**	**9.0**	8.3	8.6	6.7	**<.001**	**1.37**
% Brix	10.7	12.5	**13.4**	12.7	12.3	12.2	**13.4**	**<.001**	**0.24**
Malic acid (µL/µL)	4.5	**6.3**	**5.2**	**6.4**	**5.7**	4.8	4.9	**<.001**	**0.30**
Acetate esters									
isobutyl acetate	1.6	2.1	2.3	3.5	2.2	2.1	**30.0**	**0.392**	**1.75**
Amyl acetate	0.05	0.07	0.08	**0.23**	0.05	0.06	**5.12**	**0.537**	**0.22**
Hexyl acetate	1.08	1.27	1.53	**2.39**	1.29	1.33	**36.89**	**0.627**	**1.58**
Aldehyde									
Hexanal	19.3	**25.2**	**25.5**	23.0	21.7	**25.8**	14.7	**<.001**	**3.01**
2-Hexonal	4.9	**6.1**	**6.4**	5.6	5.7	**6.1**	**8.8**	**0.081**	**1.08**
Alcohols									
Hexanol	2.8	3.2	3.7	2.8	3.2	3.2	**6.3**	**0.09**	**0.66**

The effect of CA regime on composition and flavour profile

Evaluation of CA regimes averaged across all orchards found that early harvested Gala (Pick 1) stored in 5/1 regime at 1.5°C and treated with SF provided the firmness fruit in April (Table 6). % Brix during storage was not affected by CA regime, temperature or SF. However, malic acid content was higher in Pick 2 fruit stored in 5/1 or 3/2 (Table 6) and early picked fruit stored under the DCA regime (5% CO_2 and 0.4% O_2). Moreover, fruit stored in 3/2 treated with SF provided fruit with higher apple volatile esters: isobutyl, amyl and hexyl acetate. Overall, orchard effect had a bigger influence than storage regime on ex-store quality in April (Table 6).

Table 6. The overall effect of CA regime on quality attributes and major volatiles of Gala (averaged across 5 orchards- excluding Orchard A) April 2015.

CA Regime (%CO_2/%O_2)	5/1	5/1	5/1	5/1	5/0.4	5/1	3/2		
Storage Temperature	1.5°C	1.5°C	0.5°C	0.5°C	0.5°C	0.5°C	0.5°C		
Pick (+/-SmartFresh)	1(+)	1(-)	1(+)	1(-)	1(-)	2(+)	2(+)	Fprob	$LSD_{0.05}$
Firmness (kg)	**8.9**	8.7	8.6	8.4	8.7	8.3	8.5	**<.001**	**1.851**
% Brix	12.5	12.3	12.1	12.4	12.2	12.5	12.5	**0.065**	**0.325**
Malic acid µL/µL	5.8	5.7	5.8	5.0	**6.5**	**6.4**	**6.6**	**<.001**	**0.407**
Acetate ester									
Isobutyl acetate	1.7	1.9	1.9	2.2	2.5	2.1	1.8	**0.364**	**2.36**
Amyl acetate	0.03	0.04	0.08	0.07	0.07	0.06	0.05	**0.377**	**0.29**
Hexyl acetate	1.21	1.05	1.35	1.45	1.44	1.15	1.03	**0.439**	**2.14**
Aldehyde									
Hexanal	24.0	21.5	20.8	23.3	24.0	24.6	21.4	**0.067**	**4.07**
2-hexonal	5.9	5.1	5.0	6.5	6.6	5.9	4.7	**0.045**	**1.46**
Alcohol									
Hexanol	3.2	2.6	2.9	**3.7**	**3.8**	2.9	2.6	**0.038**	**0.89**

Table 6-continued The overall effect of CA regime on quality attributes and major volatiles of Gala (averaged across 5 orchards- excluding Orchard A) April 2015.

CA Regime (CO_2/O_2)	3/2	3/0.8	3/0.6	3/0.4		
Temperature	0.5°C	0.5°C	0.5°C	0.5°C	Fprob	$LSD_{0.05}$
Pick (+/-SmartFresh™)	1(+)	1(-)	1(-)	1(-)		
Firmness (kg)	8.6	8.6	8.4	8.5	**<.001**	1.851
% Brix	12.3	12.3	12.1	12.2	**0.065**	0.3253
Malic acid µL/µL	4.7	4.6	4.5	4.9	**<.001**	0.4075
Acetate ester						
isobutyl acetate	**4.9**	2.1	2.4	2.0	**0.364**	2.36
Amyl acetate	**0.41**	0.07	0.07	0.05	**0.377**	0.29
Hexyl acetate	**3.74**	1.35	1.34	1.18	**0.439**	2.14
Aldehyde						
Hexanal	21.1	**26.6**	25.6	24.8	**0.067**	4.07
2-Hexonal	5.3	6.9	5.5	6.4	**0.045**	1.46
Alcohol						
Hexanol	2.9	**3.7**	3.0	**3.6**	**0.038**	0.89

Second Assessment- June 2015

Taste panel assessment

In general, the overall acceptability scores for UK Gala dropped slightly from April to June, with only one UK sample exceeding a score of 6. The highest ranking imported Gala in June produced an overall acceptability score of 7.3. SF-treated Gala stored in 3/2 (0.5°C) from Picks 1 and 2 were the most favoured UK Gala with overall acceptability scores of 6.2 and 5.8 respectively. Interestingly, Gala stored in DCA regimes where oxygen was lowered to between 0.6-.0.4% and 3-5% CO_2 was the next most favoured fruit. In general, taste panel perception of sweetness and flavour were the two attributes that most correlated with perception of overall acceptability, while poor texture and a lack of acidity experienced with imported 2 Gala led to low overall acceptability scores (Table 7).

Table 7. Taste Panel assessment of UK stored and imported Gala: June 2015

CA/Temp/SF/Pick	Overall Acceptability	Aroma	Flavour	Sweetness	Acidity	Firmness	Crispness
imported 1	7.3	5.6	6.1	6.0	4.0	7.0	6.8
3/2, 0.5°C, SF, P1	6.2	5.4	5.7	5.3	4.4	7.3	7.3
3/2, 0.5°C, SF, P2	5.8	4.7	5.0	5.2	4.4	7.0	7.0
5/0.4, 0.5°C P1	5.7	5.0	5.3	4.9	4.9	7.0	7.1
3/0.6, 0.5°C P1	5.6	4.6	5.1	4.8	4.6	6.9	6.7
3/0.4, 0.5°C P1	5.6	5.0	5.5	5.3	4.3	6.7	6.9
5/1, 0.5°C, SF P1	5.5	4.8	4.8	4.9	4.3	7.1	6.9
5/1, 1.5°C, SF P1	5.5	4.5	4.9	4.9	4.4	7.0	6.8
3/0.8, 0.5°C P1	5.4	4.9	4.9	4.8	4.2	6.9	6.7
5/1, 0.5°C, SF P1	5.4	4.4	4.9	4.6	4.0	7.0	6.9
5/1, 0.5°C P1	5.3	4.3	4.6	5.0	4.3	6.9	6.9
5/1, 1.5°C P1	5.2	4.7	4.8	4.9	4.5	7.1	7.1
imported 2	4.1	4.3	5.0	6.3	1.9	3.0	3.1

The poor firmness rating of the second batch of imported Gala fruit was confirmed by penetrometer readings of 49.9 N. Interestingly, the most preferred batch of imported fruit firmness measured only 58.5 N but was perceived to have ample firmness and crispness in the taste panel assessment and was considered equal to UK Gala where firmness ranged from 71.8-91.9N.

Gala from orchard C maintained high % Brix in CA storage until June and was sweeter than imported fruit (Table 8). Malic acid concentrations in imported fruit were generally low while UK Gala from 3 orchards maintained significantly higher acid profiles despite the length of CA storage. In terms of flavour production, imported fruit was higher in the acetate esters isobutyl acetate and hexyl acetate, but lower in 2-methylbutyl acetate (Table 8). Moreover, imported fruit had higher undecanal which produces a fatty citrus waxy-floral refreshing flavour bouquet, but significantly lower content of hexanal which is responsible for green- unripe flavours

Table 8. Quality assessment and volatile profile of UK Gala June 2015

Orchard	A	B	C	D	E	F	Import 1	Import 2	Fprob	LSD
Firmness (kg)	7.2	8.5	**9.2**	**8.9**	8.1	8.4	5.8	5.0	**<.001**	1.397
% Brix	10.2	12.4	**13.5**	12.6	12.1	12.0	12.6	12.9	**<.001**	0.150
Malic acid **(µg µL^{-1})**	5.2	**6.8**	5.6	**7.1**	**6.4**	5.4	5.3	4.4	<.001	0.282
Acetate esters(ng g^{-1}h^{-1})										
Isobutyl acetate	2.5	8.1	8.1	5.9	4.7	5.5	**11.8**	**14.8**	0.455	6.158
2-Methylbutyl acetate	1.70	3.70	9.10	7.20	4.00	3.00	0.02	0.01	0.289	7.000
Hexyl acetate	0.19	0.56	0.59	0.45	0.54	0.61	1.86	2.41	**0.038**	0.277
Amyl acetate	0.02	0.03	0.19	0.07	0.02	0.02	0.21	0.01	0.441	0.195
Aldehydes										
Undecanal	0.14	0.41	0.43	0.49	0.16	0.02	**41.02**	**43.34**	0.131	0.407
Hexanal	23.30	41.10	**44.40**	38.20	30.90	31.90	0.91	0.97	**0.001**	10.270
Alcohols										
Hexanol	1.93	4.07	**4.88**	3.73	3.57	3.35	2.56	3.99	**0.013**	1.551
Alkanes										
Undecane	0.05	0.04	**0.08**	0.04	0.05	0.04	0.01	0.02	**0.017**	0.014

The effect of CA regime on fruit composition and flavour

The effect of CA regime on composition and volatile profile in fruit coming out of store in June was minimal (Table 9). Pick 1 fruit stored in 5/1 at 1.5°C with SF retained the highest firmness (87.1 N). Storage at 0.5°C did not improve firmness retention or acidity. Acidity retention was improved in early harvested fruit. Fruit stored in 3% CO_2, 2% O_2 with SF was generally considered to have better eating quality in June despite firmness and volatile profiles being non distinguishable from the other CA regimes. In general, fruit volatile profiles were similar for Gala stored in the CA regimes under test, with the exception of Gala stored under Dynamic CA regime of 3% CO_2, 0.8% O_2 where higher concentrations of 2-methylbutyl acetate (fruity, apple flavour) a volatile considered important in imparting characteristic 'Gala- apple flavour' was recorded. Fruit stored in 3% CO_2, 0.6% O_2 was higher in hexanal- which imparts 'green apple flavour'. A more extensive list of volatiles is detailed in the science section.

In these experiments, Gala CA regimes were established using nitrogen flushing and CO_2 injection; more pronounced differences in firmness and compositional analysis may be observed between temperature regimes where CA regimes are established through fruit respiration.

Table 9. Quality attributes and volatile profiles of Gala apples stored for 9 months (June) under a range of CA regimes

CA Regime ($\%CO_2/\%O_2$)	5/1	5/1	5/1	5/1	3/0.4	5/1	3/2		
Storage Temperature	1.5°C	1.5°C	0.5°C	0.5°C	0.5°C	0.5°C	0.5°C		
Pick (+/- SmartFresh™)	1(+)	1(-)	1(+)	1(-)	1(-)	2(-)	2(-)	Fprob	$LSD_{0.05}$
Firmness (kg)	**8.7**	8.5	8.4	8.2	8.3	8.2	8.3	**<.001**	**1.891**
%Brix	**12.34**	12.22	11.89	12.12	12.07	12.22	12.10	**<.001**	**0.203**
Malic acid	**6.10**	5.46	4.98	5.06	**6.43**	5.71	5.56	**<0.01**	**0.328**
Acetate esters									
Isobutyl acetate	10.21	7.12	8.40	0.43	5.59	3.46	7.16	**0.274**	**8.338**
2-Methylbutyl acetate	2.90	4.70	2.50	3.90	4.50	3.50	2.50	**0.052**	**9.480**
Amyl acetate	0.02	0.03	0.04	0.06	0.03	0.02	0.01	**0.253**	**0.264**
Hexyl acetate	0.49	0.61	0.39	0.33	0.30	0.76	0.68	**0.215**	**0.375**
Aldehydes									
Hexanal	34.80	37.30	36.80	39.40	37.80	29.90	26.90	**0.313**	**13.910**

Table 9 continued. Quality attributes and volatile profiles of Gala apples stored for 9 months (June 2015) under a range of CA regimes

CA Regime (CO_2/O_2)	3/2	3/0.8	3/0.6	3/0.4		
Temperature	0.5°C	0.5°C	0.5°C	0.5°C	**Fprob**	**$LSD_{0.05}$**
Pick (+/-SmartFresh™)	1(+)	1(-)	1(-)	1(-)		
Firmness (kg)	8.4	8.5	8.2	8.4	**<.001**	**1.891**
%Brix	11.92	12.28	12.12	12.08	**<.001**	**0.203**
Malic Acid	6.78	6.80	7.35	6.55	**<.001**	**0.328**
Acetate ester						
Isobutyl acetate	4.01	1.13	10.30	5.87	**0.274**	**8.338**
2-Methylbutyl acetate	1.90	**18.70**	3.50	4.00	**0.052**	**9.480**
Amyl acetate	0.02	0.38	0.02	0.02	**0.253**	**0.264**
Hexyl acetate	0.43	0.64	0.38	0.40	**0.215**	**0.375**
Aldehydes						
Hexanal	29.20	33.10	**46.10**	33.20	**0.313**	**13.910**

The interaction of orchard consignments in CA regimes

The quality and volatile profile of individual orchard consignments in each treatment that equalled or exceeded taste panel scores of 5.9 were compared with profiles of imported fruit (Table 10). A comparison of compositional analysis between consignments of Gala found no significant increase in firmness, % Brix, acidity or flavour profiles between the imported fruit and highest ranking UK Gala, even though the imported fruit was considered more acceptable.

In many cases, Gala from orchard C fruit had higher 2-methylbutyl acetate, a major component of Gala flavour, compared to other consignments. Due to the nature in which consignments were selected, there was a skew in the number of observations per orchard.

Table 10. Quality attributes and volatile profiles of orchard consignments that equalled or exceeded acceptability scores of 5.9 compared with imported fruit (June)

	Orchard B	Orchard C	Orchard D	Orchard E	Orchard F	Imported 1	Imported 2
Mean Overall Acceptability	6	6.4	6.2	6.2	6.2	7.1	4.1
Firmness (kg)	8.5	**9.2**	9.0	8.1	8.3	5.5	5.0
%Brix	12.3	13.5	12.2	12.1	11.8	12.4	12.6
Malic acid	**6.8**	5.6	**7.1**	**6.4**	5.4	5.3	4.4
Acetates							
Isobutyl acetate	3.79	**7.89**	**7.14**	3.49	**11.81**	**7.48**	**11.87**
Amyl acetate	0.02	**0.25**	0.03	0.01	0.02	0.01	0.03
2-Methylbutyl acetate	2.67	**11.11**	2.45	3.40	1.86	2.46	3.00
Hexyl acetate	0.73	0.49	0.33	0.66	0.21	0.42	0.43
2-Hexenyl acetate	0.07	0.42	0.80	0.22	0.02	0.40	0.38
Alcohols							
Hexanol	3.97	5.39	3.85	3.52	2.22	3.28	4.00
Aldehydes							
Hexanal	29.37	**43.13**	37.40	29.58	33.20	34.81	35.97
Undecanal	0.01	0.52	1.09	0.29	0.03	0.46	0.49
Substituted benzenes							
1,3-Diethylbenzene	0.71	**5.57**	0.35	0.25	0.44	0.47	0.51
Alkanes							
Dodecane	0.08	**1.23**	0.15	0.11	0.13	0.12	0.17
Hexadecane	1.96	**6.97**	2.80	1.99	2.24	1.90	2.94
Hexyl hexanoate	0.02	0.03	0.04	0.02	0.01	0.03	0.03
N^{o} of observations	3	8	2	3	1	1	1

Financial benefits

Some UK orchards are capable of producing fruit that maintains good eating quality in April and through to June, which is comparable with imported fruit. This could provide an additional marketing window for UK Gala.

Action points for growers

- Early harvesting and rapid establishment of CA conditions can help to maintain fruit quality into April and in some cases through to June.
- Orchards with high dry matter content (15.5-17%) generally produce fruit with better sweetness and firmness and are considered to have better eating quality and are more likely to maintain eating quality for longer
- The CA regimes of 5/1 (1.5°C) without SF and 5/1 (0.5°C) with SF and the DCA regime of 3% CO_2 and 0.4% O_2, provided fruit with the best eating quality in April which was as good as imported Gala.
- The CA regimes of 3% CO2 and 2% O2 + SF and the DCA regime 5% CO2 and 0.4% O2 were the highest ranked CA regimes for maintaining quality through to June.