HORTICULTURE RESEARCH INTERNATIONAL

EFFORD

Report to:

Horticultural Development Council
18 Lavant Street
PETERSFIELD
Hampshire GU32 3EW

Tel: 01730 263736
Fax: 01730 265394

HRI Contract Manager:

Dr D J Hand
HRI Efford
LYMINGTON
Hampshire SO41 0LZ

Tel: 01590 673341
Fax: 01590 671553

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FINAL CONTRACT REPORT

Vine-ripe tomatoes: Optimising the picking colour stage and storage conditions of tomatoes to maximise flavour at the point of consumption

HDC PC109
1994/95

PRINCIPAL WORKERS

HRI EFFORD

Mr M Fussell BSc (Hons)	Technical Officer (Author of Report)
Mrs S Foster	Scientific Officer
Miss J Basham	Scientific Officer
Miss S Williams BSc	Assistant Scientific Officer
Mr C Vigor	Nursery Staff
Mr P DeVries	Nursery Staff
Mr K Herridge	Nursery Staff
Mr M Reay	Computer Systems Maintenance

HRI LITTLEHAMPTON

Mr R H Edmondson MSc	Statistician

AUTHENTICATION

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

Signature ..... Dr D J Hand
Head of Protected Crops

Date: 23-4-96

Report Authorised by ..... Dr M R Shipway
Head of Station

HRI Efford
Lymington
Hants
SO41 0LZ

Date: 24.4.96

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Mr M Fussell
HRI Efford

Co-ordinator: Dr N O Dungey

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RELEVANCE TO GROWERS AND PRACTICAL APPLICATION

APPLICATION

The objectives of this project were to quantify any yield losses associated with harvesting tomatoes vine-ripe and to investigate what fruit quality benefits might result from vine-ripening and how any quality improvements could be maximised. Vine-ripe harvesting resulted in an ongoing yield reduction simply as a result of delay in harvesting ripe fruit but at the end of the season when remaining fruit had been harvested to the same colour only a small reduction of less than 3% was observed which was not statistically significant. Freshly harvested vine-ripe fruit tasted slightly sweeter and had more tomato flavour than fruit ripened in store but after a 6 day shelf-life period at 20°C fruit harvested vine-ripe was softer, less shiny, had lower acidity, less tomato flavour and more off flavours. Holding fruit at 10°C for short periods showed some promise as a method of maintaining the quality of vine-ripe fruit.

SUMMARY

Growers considering harvesting tomatoes vine-ripe need to know if doing so results in any reduction in yield. One objective of this trial was to quantify any such loss of yield. There is a perception held by the consumer that vine-ripened tomatoes taste better than tomatoes harvested less ripe. It is important that a vine-ripe product meets the expectations of the consumer. Therefore experiments were designed to assess the effects of vine-ripe harvesting on quality and in particular the effects of picking colour on quality after a period of shelf-life and also the effects of temperature in store on quality.

Yield

Throughout the season a crop of Solairo and Ferrari were harvested to ATB Colour Stage 4, 6 or 8. Harvesting tomatoes at ATB Colour Stage 8 resulted in an ongoing yield reduction as a result of the delay of a few days in harvesting ripe fruit. At the end of the season fruit remaining on the plants was harvested to the same colour stage, removing the effect of this delay. After this final harvest the marketable yield from the Colour Stage 8 treatment remained 4% lower than that for the Colour Stage 4 treatment. There was a small reduction in % Class I fruit for tomatoes harvested ripe as a result of increased softness. The difference in yield between the picking colour stages was small in comparison with the difference in yield between the two varieties. Ferrari produced 13% less yield than Solairo. The premium that would be required to cover the costs of lower yield due to harvesting vine-ripe was calculated as 19 pence per 6 kg box. However a much higher premium would be required if harvesting vine-ripe necessitated growing a lower yielding variety.

Quality

Freshly harvested vine-ripe fruit were found to be slightly sweeter and to have more tomato flavour than fruit that had been harvested earlier and ripened in store at 20°C.

After a period of shelf-life at 20°C vine-ripened tomatoes remained sweeter than ones harvested less ripe but their acidity declined during shelf-life to the extent that after 6 days they were perceived less sharp than fruit harvested less ripe. This lack of sharpness appears to have had a major effect on tomato flavour because, despite vine-ripe tomatoes being sweeter, they had less tomato flavour than fruit harvested less ripe. A number of taste panellists also detected a metallic taste or off flavour which was associated with the vine-ripened fruit after shelf-life. The shininess and firmness of the vine-ripe fruit was also lower than for the other harvesting treatments.

Holding vine-ripened fruit at low temperatures was evaluated in this trial as a potential means of maintaining their quality. It has been demonstrated elsewhere that temperatures below 9°C can cause physical damage to tomatoes harvested during early stages of ripening and that ripe fruit are less sensitive to chilling injury than less ripe fruit. Long periods of storage at 5°C failed to produce obvious symptoms of chilling damage in fruit harvested at ATB Colour Stages 4, 6 or 8. Holding vine-ripe fruit for short periods at 10°C seemed to slow down the decline in acidity and also to maintain fruit firmness. However holding fruit at 5°C rather than 10°C while improving fruit shininess did not result in increased firmness or acidity. The data suggests that the improved flavour of vine-ripe tomatoes may be preserved provided that adequate attention is given to storage temperatures after harvest and that lower temperatures than previously considered acceptable may be appropriate.

The economics of growing a vine-ripe tomato crop will clearly depend upon what premium can be obtained for the product. The yield reduction due to harvesting vine-ripe is small. However the yield reduction that might result from the choice of a variety is potentially large. The quality of the vine-ripe product will have much to do with the time delay between harvesting and consumption and the temperature at which the fruit is held during that time.

EXPERIMENTAL SECTION

Introduction

The development of new tomato varieties which combine good flavour with long shelf-life have made vine-ripe harvesting a commercial possibility. Previously, tomatoes harvested ripe would not stand up to grading, distribution and shelf-life before becoming soft. The perception of the consumer is that a tomato harvested red is a tastier tomato. There is evidence from field grown crops in the USA which demonstrates that tomatoes harvested ripe are sweeter and more tomato-like and with less off flavour than ones harvested green (Kader 1977). However these experiments compared ripe harvested fruit with fruit that was very under-ripe relative to UK glasshouse crops and vine-ripe fruit was assessed fresh, not after a period of shelf-life. It is important that a vine-ripe product meets the expectations of the consumer. Gaur and Bajpai (1982) found that fruit picked 'pink' retained better flavour after 4-12 days at room temperature than either fruit picked 'turning' or 'red'. The colour stage at which fruit is harvested may be critical in determining the quality when fruit is consumed and there is a is possibility that fruit might be harvested over-ripe.

Temperatures below 9°C can cause physical damage to tomatoes by disrupting the ripening process leading to soft fruit and reduced shelf-life (Hobson, 1987). However partial ripening has been shown to reduce sensitivity to chilling injury (Whitaker, 1994). Holding fruit at low temperatures may therefore be more appropriate for fruit harvested at more advanced colour stages. However little is known about the effects of temperature during storage on the flavour of tomatoes.

Sweet peppers harvested red rather than green incur a significant reduction in yield. Unlike peppers, round tomatoes have stopped growing once they start to ripen but the respiration of ripening fruit may result in a reduction in the amount of assimilates available to other fruits and hence cause a yield reduction. Growers need to know the scale of any such yield reduction.

MATERIALS AND METHODS

Site details

The trial was done at HRI Efford utilising part of the B-Block venlo glasshouse facility. The layout of the trial is illustrated in Appendix I.

Treatments

The main treatments comprised three picking colour stages taken from the ATB Colour Chart:

ATB Colour Stage 4 (CS4)
ATB Colour Stage 6 (CS6)
ATB Colour Stage 8 (CS8)

These harvesting treatments were imposed from the first pick in February up to the penultimate harvest in October. For the final harvest at the end of October all plots were harvested to Colour Stage 4.

Two varieties were grown as subtreatments:

Solairo
Ferrari

The trial consisted of 24 plots with each treatment/subtreatment combination replicated four times and arranged in four blocks as illustrated in Appendix I. In addition to the replicated treatments three other varieties were included in single plots for observation:

3186 (Pinetree De Ruiter)
72-36 (Rijk Zwaan)
3209 (Pinetree De Ruiter)

Cultural techniques

Seeds of tomato (*Lycopersicon esculentum Mill*) varieties Solairo, Ferrari, 3186, 72-36 and 3209 were sown on 25 October 1994, in rockwool multiblocks (40 x 40 x 40mm) which had been wetted up the day before using a feed solution with a pH of 5.2 and an EC of 1,500 μS. Following germination on 28 October the EC was raised to 2,500 μS coincident with expansion of the cotyledons. Prior to blocking on, the 0.65 litre rockwool blocks were wetted up with a feed at pH 5.0 and an EC of 2,500 μS on 1 November 1994, the aim being to achieve a stable block pH of circa 6.0.

From blocking on to the time taken for the third true leaf to reach 10mm in length, the EC of the applied feed was raised from 2,500 to 3,500 μS. The EC was then raised to 5,000 μS before plants were moved into B-Block on 21 November.

Plants were raised under lights for 16 hours per day from 28 October-18 November and for 12 hours a day from 18 November to 21 November.

Modified 'Blueprint' temperatures were applied throughout propagation.

The 'Blueprint regime'

Date	Temperature Day °C	Temperature Night °C
25 October	24	24
28 October	20	20
30 October	24	24
3 November	22	22
5 November	20	20
9 November	20	18

Slab contact was made on 12 December 1994.

The CO_2 level during propagation and in the B-Block was raised from ambient to a target 1,000 vpm (sunrise to sunset; using pure CO_2) during the winter period and circa 450 vpm was achieved in the summer.

Plants were grown in the 'V'-System on Grodan 90 x 15 x 15cm rockwool slabs with 3 plants to a slab. A total of 9 slabs were laid end to end in each plot. The plot area was 14.66m^2 based on a plot width of 1.62m (including pathway) and length of 9.05m (excluding concrete headland but including turning space). The initial plant density was therefore 1.84 plants/m^2 or 7,443/acre.

One in two sideshoots were taken in week 2 increasing the plant density to 2.76 plants/m^2 or 11,165/acre. Due to poor light conditions the first truss on each of these sideshoots was removed at anthesis. A further 2 in 3 sideshoots were taken on the remaining single stems in week 9 bringing the final density up to 3.38 plants/m^2 or 13,663/acre.

Records

Total and graded yield was recorded throughout the season.

Monetary returns based on weekly prices (from MAFF) for Class I and Class II fruit.

Fruit Quality Experiments

1. Effects of Vine/Room ripening on quality

This experiment was carried out on three occasions. On the first occasion in week 17 ten Class I size D fruit per CS4 plot were placed in a shelf-life room at 20°C and 50-60% Relative Humidity. Once these fruits ripened sufficiently for the majority to be at Colour Stage 6 a further ten fruit from each CS6 plot were harvested and placed in the shelf-life room. When the majority of these fruit were at Colour Stage 8 a further ten fruit from each CS8 plot were harvested (Figure 1).

At each new introduction of fruit into the shelf-life room the following records were taken on both the freshly harvested fruit and the fruit in shelf-life already:

- Fruit weight (per plot of 10)
- Colour Stage
- Shininess (0 - very dull, 1 - dull, 2 - moderately shiny, 3 - very shiny)
- Calyx Condition (0 - absent, 1 - Very shrivelled, 2 - Slightly shrivelled or kinked, 3 - straight)

At the time of harvest from CS8 plots the following records were taken on both the freshly harvested fruit and the fruit in shelf-life already:

- Compression (mm)
- Fresh weight of sample slices for dry matter determination
- Remaining fruit was frozen for soluble solids and acid determinations

Details of methods used in shelf-life and internal composition determinations are listed in Appendix II.

On the remaining two occasions in weeks 26 (Solairo) and 41 (Ferrari) ten fruit per experimental block (fruit taken from CS4, CS6 and CS8 plots) were harvested at Colour Stage 2 (CS2) and placed into shelf-life and when these fruit reached Colour Stage 4 the above procedure was followed.

Taste panel assessments (see Appendix III) were carried out at the end of the same experiment on Solairo in weeks 19, 29 and 41 and on Ferrari in week 33.

2. Effect of Picking Colour Stage on quality after shelf-life

In this experiment five tomatoes per plot were harvested at CS4, CS6 and CS8 all on the same day and placed in a shelf-life room at 20°C and 50-60% Relative Humidity for 6 days

Figure 1. Vine versus Room-Ripening Experimental Treatments

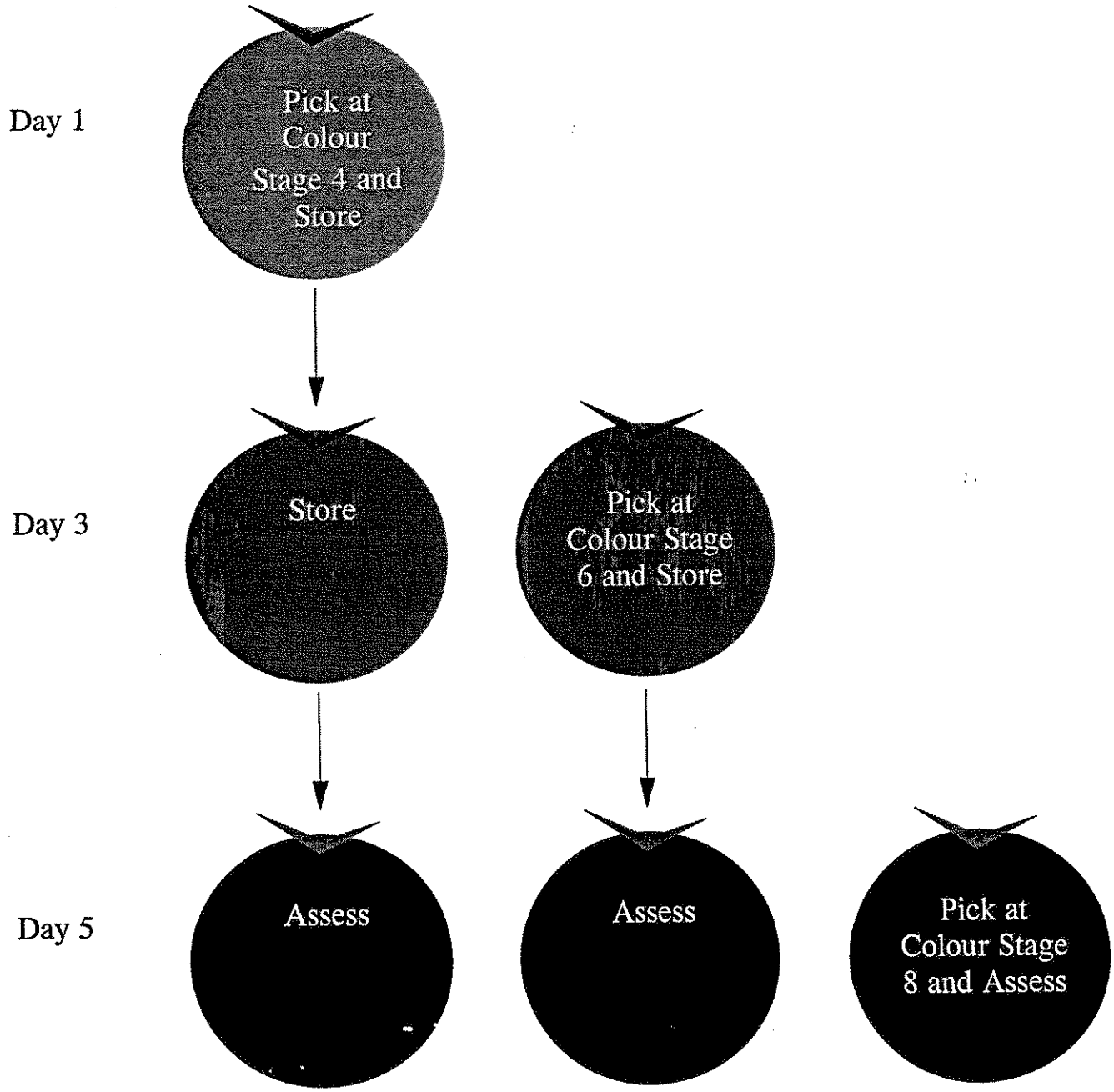
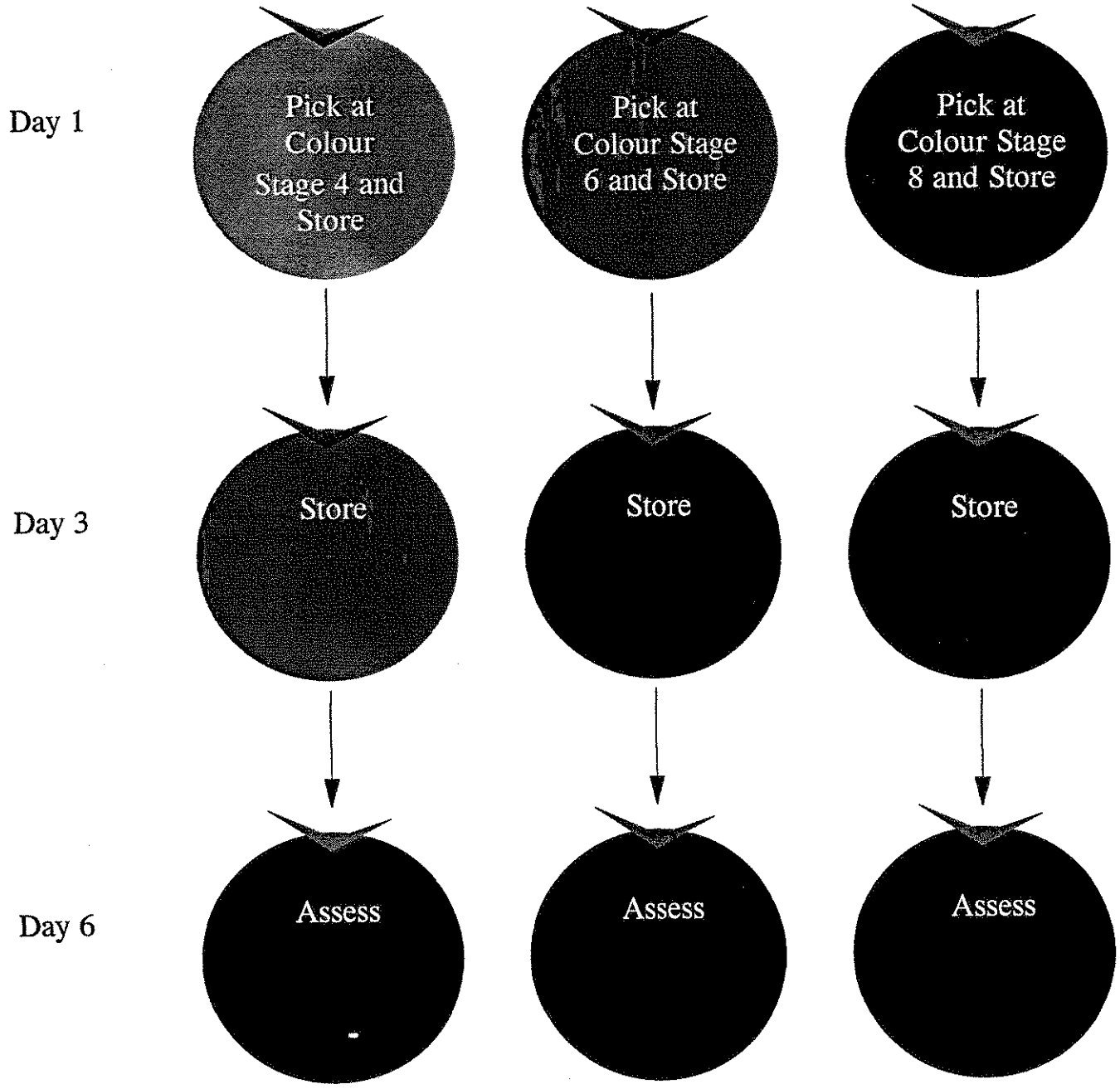


Figure 2. Vine-Ripening plus Shelf-life Experimental Treatments



(Figure 2). At the end of this period the following assessments were made:

- Colour Stage
- Weight Loss during shelf-life
- Compression (mm)
- Calyx Condition
- Shininess
- Soluble Solids and Acid determinations
- Dry Matter Content
- Taste panel assessments

The incidence of physical disorders were recorded where appropriate.

Shelf-life and internal composition assessments were made on fruit of Ferrari harvested in weeks 19 and 36 and on Solairo harvested in week 31. Taste panel assessments were made on fruit of Ferrari harvested in weeks 22, 31 and 37 and on Solairo harvested in weeks 32 and 36. A taste panel held in week 17 assessed fruit that had been held at 5°C for 2 days followed by 3 days at 20°C. In addition to taste assessments by the members of the Efford panel which comprised a maximum of 12 individuals, a larger number of individuals were asked to express a preference for coded samples of Ferrari harvested at CS4, CS6 or CS8 in this experiment at the Growers Walks at Stockbridge House on 21 June and at Efford on 11 July 1995.

Fruit from this experiment was also sent to supermarket technology departments for taste assessment.

3. Effects of Picking Colour Stage, Storage Time and Temperature on quality

a) Long periods of storage

In addition to fruit harvested in Experiment 2 five fruit per plot were harvested as above and stored at 10°C for 13 days and a further five fruit at 5°C for 21 days. At the end of the storage time shelf-life and internal composition assessments were made as in Experiment 2 and assessments of the incidence of any storage rots were also recorded.

b) Short periods of storage

The effects of a 48hr period in store at 5°,10°C or 20°C followed by 3 days at 20°C on fruit from CS4, CS6 and CS8 were investigated for Ferrari in week 14 and Solairo in week 22. The sample for each plot in each temperature treatment consisted of five tomatoes. At the end of the period shelf-life and internal composition assessments were made as in Experiment 2.

Fruit of Ferrari harvested at CS4, CS6 and CS8 in week 16 was stored for two days at 5˚C followed by 3 days at 20˚C and then assessed by the taste panel in week 17.

The effects of storing CS8 fruit for 2 days at 5˚C, 10˚C and 20˚C and then equilibrating to room temperature on taste were assessed by the panel for Solairo in weeks 24 and 39 and for Ferrari in week 35.

Explanation of statistical terms

Throughout the main body of this report and selected appendices a number of statistical terms are referred to; these are:

SED	=	The standard error of the difference when comparing two means in that column of data.

A statistical term easier to interpret:

LSD 5%	=	The least (minimum) difference when comparing two means within a given column that is required for the means to be statistically different.
N.S.	=	Not Significant
*	=	$P<0.05$, i.e. the probability of this result occurring by chance is equal to or less than 1 in 20 (0.05 = 5%)
**	=	$P<0.01$, i.e. the probability of this result occurring by chance is equal to or less than 1 in 100 (0.01 = 1%)
***	=	$P<0.001$, i.e. the probability of this result occurring by chance is equal to or less than 1 in 1000 (0.001 = 0.1%)

RESULTS

Yield and gradeout

Monthly yield figures showed higher yields from the plots harvested at CS4 than at CS8 (Table 1). To the end of October, but excluding the final harvest, CS4 yielded 4.1% more than CS8, a significant difference. However after the final harvest when all fruit of marketable colour had been picked, including fruit at ATB Colour 4 or redder in the CS6 and CS8 plots, the yield penalty was less than 3% and not statistically significant (Table 2).

Table 1. Effects of Colour Stage at Picking on monthly total yield ($kg.m^{-2}$)

ATB Colour Stage	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (exc final harvest)
4	0.90	2.79	4.89	8.64	8.25	8.54	8.18	6.80	5.05	54.03
6	0.80	2.64	4.68	8.40	8.22	8.30	8.33	6.34	4.91	52.61
8	0.82	2.61	4.57	8.64	7.71	7.98	8.36	6.33	4.80	51.81
SED (14 d.f.)	*0.030*	*0.051*	*0.117*	*0.143*	*0.131*	*0.144*	*0.134*	*0.066*	*0.153*	*0.598*
LSD (5%)	*0.06*	*0.11*	*0.25*	-	*0.28*	*0.31*	*0.29*	*0.14*	-	*1.28*
Significance	*	**	*	*N.S.*	**	**	*N.S.*	***	*N.S.*	**

Table 2. Effects of Colour Stage at Picking and Variety on total yield ($kg.m^{-2}$) to the end of October (including final harvest when all plots were picked to Colour Stage 4)

ATB Colour Stage	Variety		
	Ferrari	Solairo	Mean
4	50.26	58.30	54.28
6	49.85	56.65	53.25
8	48.85	56.74	52.80
SED (14 d.f.)			*0.603*
LSD (5%)			-
Significance			*N.S.*

The tables shown above refer to total yield including Class II and Waste. When considering marketable yield there was a significantly lower yield (4%) for the CS8 treatment because of a slightly higher percentage of Class II and Waste fruit. To the end of October the CS8 treatment

produced nearly 2% less Class I fruit compared with CS4 (Table 3). The commonest reason for downgrading was fruit softness. As might have been expected this was slightly less of a problem for Ferrari than for Solairo. Even so Solairo was able to achieve 88.9% Class I fruit when picked at CS8 (Table 4).

Table 3. **Effects of Colour Stage at Picking on total marketable yield ($kg.m^{-2}$), percentage Class I, II and waste fruit to the end of October (including final harvest when all plots were picked to Colour Stage 4)**

ATB Colour Stage	Marketable Yield	% Class I	% Class II	% Waste
4	52.92	91.16	6.34	2.50
6	51.80	90.72	6.56	2.71
8	50.90	89.34	7.08	3.58
SED (14 d.f.)	*0.584*	*0.379*	*0.271*	*0.182*
LSD (5%)	*1.25*	*0.81*	*0.58*	*0.39*
Significance	*	***	*	***

Table 4. **Effects of Variety and Colour Stage at Picking on percentage Class I fruit to the end of October (including final harvest when all plots were picked to Colour Stage 4)**

Variety	ATB Colour Stage 4	6	8	Mean
Ferrari	91.52	91.10	89.74	90.79
Solairo	90.80	90.35	88.93	90.03
SED (14 d.f.)				*0.310*
LSD (5%)				*0.66*
Significance				*

There was a small effect of colour stage at picking on fruit size such that harvesting at CS4 resulted in larger fruit (Table 5).

Table 5. **Effects of Colour Stage at Picking on fruit size to the end of October (including final harvest when all plots were picked to Colour Stage 4)**

ATB Colour Stage	Percentage of Class I fruit in size grade		
	C (>57mm)	D (47-57mm)	E (40-47mm)
4	18.5	77.0	4.1
6	16.5	78.5	4.7
8	14.7	80.3	4.6
SED (14 d.f.)	*1.08*	*0.92*	*0.31*
LSD (5%)	*2.3*	*2.0*	-
Significance	*	*	*N.S.*

The monetary value of the crop calculated from the yield and gradeout figures (not size gradeout) indicate that harvesting at CS8 represents a loss of £15,900/ha compared to harvesting at CS4. This difference is small in comparison with the difference in return between the two varieties, £41,900/ha (Table 6).

Table 6. **Effects of Variety and Colour Stage at Picking on monetary returns to the end of October (including final harvest when all plots were picked to Colour Stage 4)**

Variety	ATB Colour Stage	£s/m^2
Ferrari	**4**	31.28
	6	30.77
	8	29.97
Solairo	**4**	35.93
	6	34.57
	8	34.08
Variety	**Ferrari**	30.67
	Solairo	34.86
SED (14 d.f.)		*0.312*
LSD (5%)		*0.67*
Significance		***
ATB Colour Stage	**4**	33.61
	6	32.67
	8	32.02
SED (14 d.f.)		*0.383*
LSD (5%)		*0.82*
Significance		**

Yield and gradeout from the numbered varieties are listed in Appendix 4.

Fruit quality

1. Effects of Vine/Room ripening on quality

In this experiment freshly harvested CS8 tomatoes were compared with CS2, CS4 and CS6 fruit which had ripened to the same colour in storage. As might be expected the freshly harvested CS8 fruit were generally firmer than fruit that had been in store for a period of days. However there were no significant effects of colour stage at picking on internal composition that were consistently recorded (Appendix V).

Fruit appearance was affected by the treatments. Table 7 shows how fruit shininess was higher for CS8 only early in the season (April) but not in the summer or at the end of the season when the freshly harvested CS8 fruit was less shiny.

Table 7. Effect of vine/room ripening on shininess

Week/Variety	17 (Ferrari)	26 (Solairo)	33 (Ferrari)	41 (Solairo)
CS2	-	1.93	1.10	2.53
CS4	1.40	1.80	1.25	2.53
CS6	1.63	1.55	1.28	2.23
CS8	1.88	1.53	1.13	1.88
SED (9(8) d.f.)	*(0.0835)*	*0.105*	*0.152*	*0.135*
LSD (5%)	*0.19*	*0.24*	-	*0.31*
Significance	**	*	*N.S.*	**

Calyx condition was also recorded in this experiment and as might be expected the freshly picked CS8 fruit had fewer kinked or shrivelled calyces than other treatments (Table 8). The changes in calyx condition occurring in store for CS2 fruit is illustrated in Appendix *.

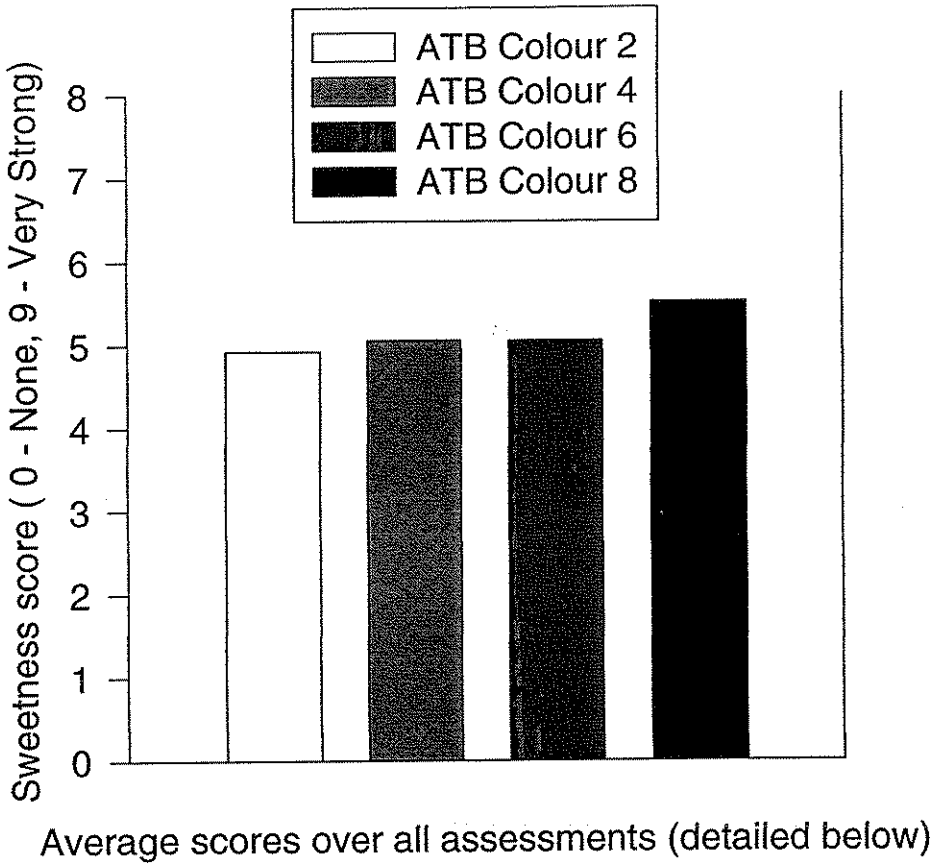
Table 8. **Effect of vine/room ripening on the percentage of fruit with unkinked/shrivelled calyces**

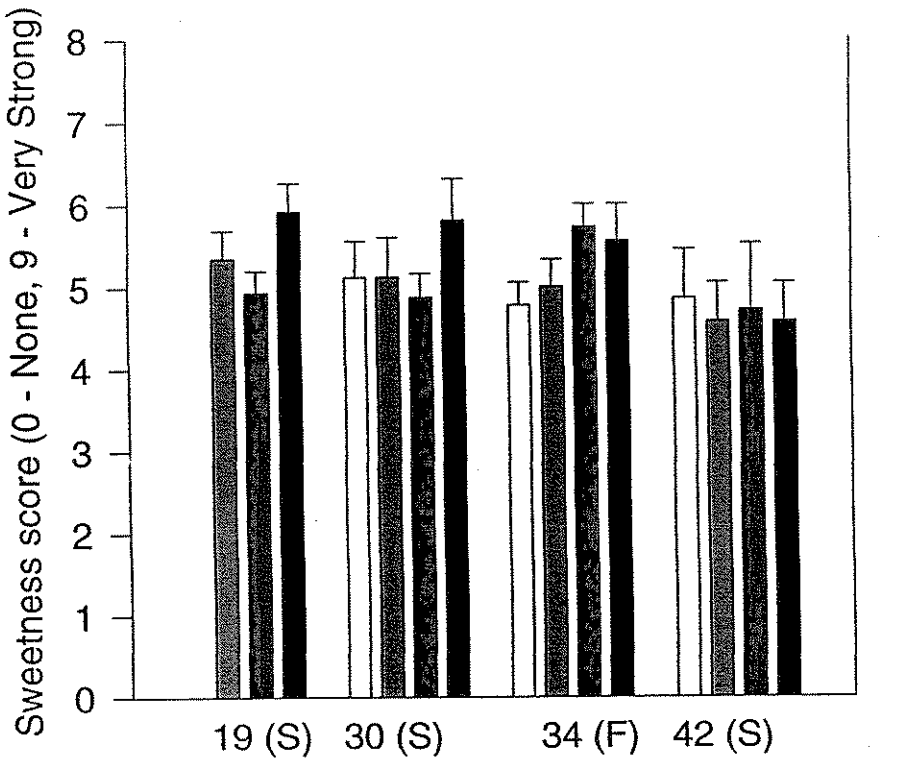
Week/Variety	17 (Ferrari)	26 (Solairo)	33 (Ferrari)	41 (Solairo)
CS2	-	0	0	0
CS4	0	0	50	0
CS6	0	0	0	0
CS8	20	100	53	97.5
SED (9(8) d.f.)	*(5.95)*	-	*32.50*	*1.78*
LSD (5%)	*13.5*	-	-	*4.1*
Significance	*	-	*N.S.*	***

Taste panel assessments indicated that fresh ripe fruit was generally sweeter than fruit harvested earlier and stored apart from at the end of the season (Fig. 3). CS8 fruit was sweetest in weeks 19 and 30 but not in weeks 34 and 42. While CS8 fruit was clearly sweeter in the first two assessments there was no apparent trend of increasing sweetness from CS2 through CS4 to CS6. The CS8 fruit was also found to have more 'tomato flavour' than other colour stages, again apart from at the end of the season (Fig. 4). There was a clear trend of increasing tomato flavour with colour stage at harvest in week 30 but this was not repeated in other weeks. Other flavour and texture attributes were unaffected by the harvesting/storage treatments (see Appendix VI).

In addition to the taste panel assessments undertaken at Efford fruit was sent for assessment by supermarket technology departments. The results of these assessments are listed in Appendix VII. Two of the four supermarkets found the freshly harvested CS8 fruit to be sweeter as in the Efford taste panels. However the results from the other two supermarkets were not consistent perhaps as a result of the delay between despatching fruit and the assessments which was up to four days in one instance.

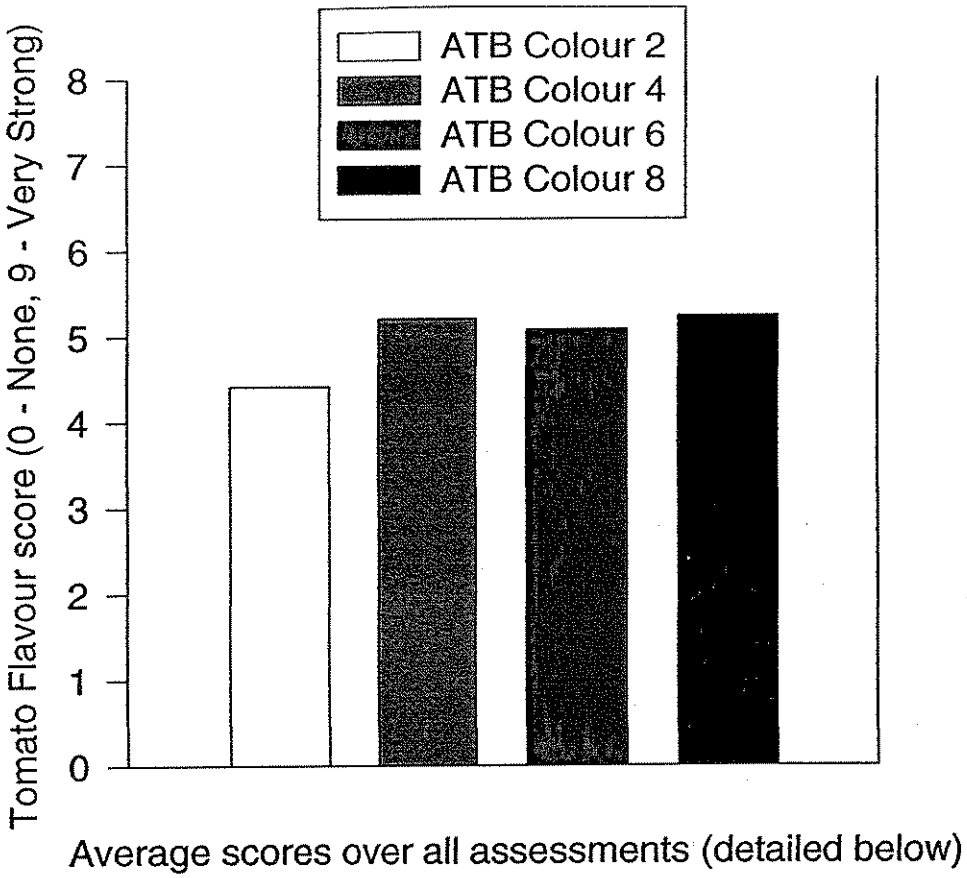
Figure 3. Effect of Vine versus Room Ripening on Taste Panel Assessments of Sweetness

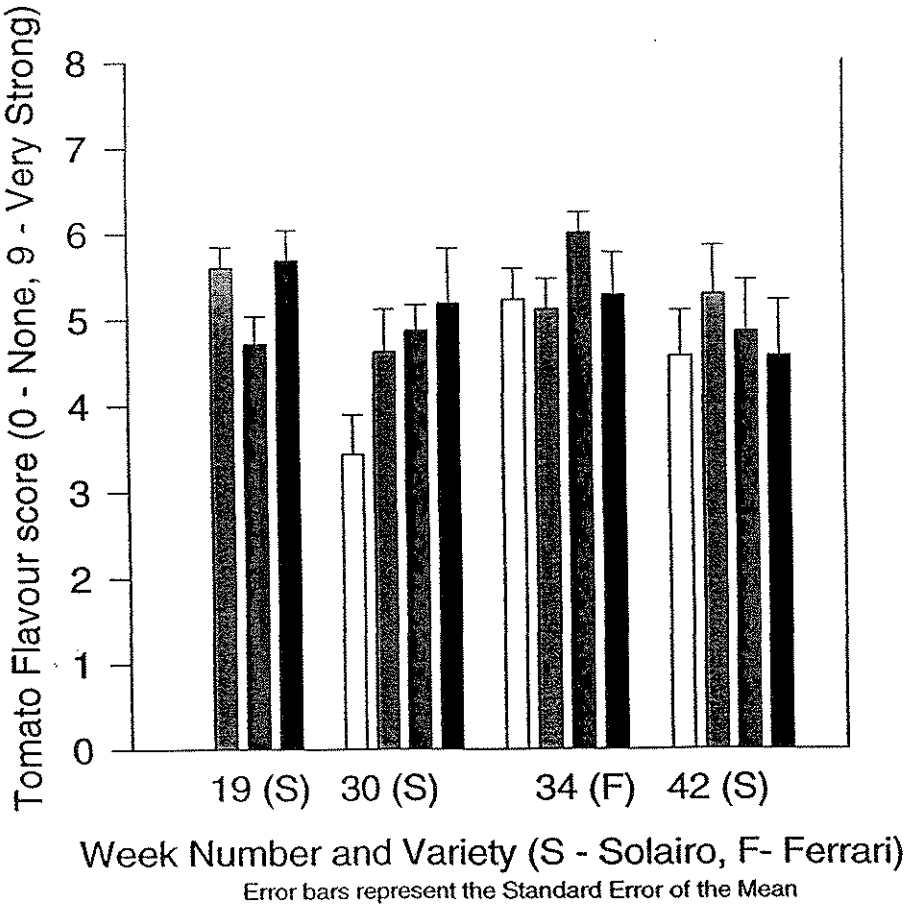




Error bars represent the Standard Error of the Mean

Figure 4. Effect of Vine versus Room Ripening on Taste Panel Assessment of Tomato Flavour





Error bars represent the Standard Error of the Mean

2. Effect of Picking Colour Stage on quality after shelf-life

Tomatoes harvested at CS8 and then held for six days under shelf-life conditions were consistently softer than fruit harvested less ripe (Table 9).

Table 9. Effects of Colour Stage at Picking on fruit softness (mm Compression) after 6 days shelf-life

ATB Colour Stage	Week 19	31	36
4	2.37	2.10	1.87
6	2.73	2.34	2.07
8	2.95	2.62	2.20
SED (14 d.f.)	*0.104*	*0.158*	*0.084*
LSD (5%)	*0.24*	*0.36*	*0.19*
Significance	**	*	*

Despite this clear effect on softness there were no significant effects on percentage weight loss during shelf-life (Appendix VIII).

CS8 fruit was less shiny than fruit harvested less ripe after the six days shelf-life in every assessment although the differences were never great enough to be statistically significant (Table 10).

Table 10. Effect of colour stage at picking on shininess after 6 days shelf-life

Week/Variety	19 (Ferrari)	26 (Solairo)	36 (Ferrari)
CS4	1.90	1.70	1.70
CS6	1.75	1.50	1.80
CS8	1.65	1.45	1.60
SED (9(8) d.f.)	*0.241*	*0.327*	*0.260*
LSD (5%)	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*

The calyx condition of nearly all of the fruit, irrespective of the colour stage at picking, was poor (shrivelled or severely kinked) after 6 days shelf-life and therefore these data are not presented.

There were no measurable effects of the picking colour plus shelf-life on the dry matter or soluble solids content of fruit (Appendix VIII) but there was a consistent trend of decreasing acidity with ripeness at harvest (Table 11). The differences in pH after neutralisation with a fixed quantity of alkali between CS4, CS6 and CS8 were statistically significant only for Ferrari in week 19 but CS8 fruit was the least acidic in every assessment.

Table 11. Effects of Colour Stage at Picking on fruit acidity (endpoint pH) after 6 days shelf-life (Low endpoint pH = high acidity)

ATB Colour Stage	Week 19	31	36
4	7.78	8.38	8.66
6	8.54	8.20	8.87
8	8.69	8.61	9.29
SED (14 d.f.)	*0.295*	*0.404*	*0.454*
LSD (5%)	*0.68*	-	-
Significance	*	*N.S.*	*N.S.*

The increased sweetness of CS8 fruit detected by the taste panel in the first experiment was also evident in this experiment. Taste panellists found fruit harvested at CS8 to be consistently sweeter than fruit harvested less ripe (Fig. 5) even though the fruit had been in shelf-life for 6 days. In fact the sweetness differences were more marked in this experiment and there were trends of increasing sweetness from CS4 to CS8 in weeks 17, 32 and 37. (It should be noted that in week 17 fruit was stored at 5°C for 2 days prior to spending 3 days under shelf-life conditions rather than undergoing 6 days at 20°C.)

While CS8 fruit were sweeter than other fruit they were also less sharp. Figure 6 shows how CS8 fruit were found to be less sharp in weeks 17, 23, 32 and 37 although not in weeks 33 and 38. There were trends of decreasing sharpness with increasing colour stage at picking in weeks 17, 32 and 37. The lower sharpness of CS8 fruit is consistent with the acidity measurements made in weeks 19, 31 and 36 and reported on above.

The reduced sharpness appears to have had a considerable effect on the taste panel's assessment of tomato flavour. Whereas in the first experiment increased sweetness was accompanied by increased tomato flavour, in this experiment the increased sweetness did not have this effect at all. In fact tomato flavour was generally lower for CS8 than the other colour stages (Fig. 7) presumably as a result of lower sharpness.

In order to establish that fruit acidity was in fact declining during shelf-life some measurements

of acidity (endpoint pH) were made on a small batch of CS8 fruit. Figure 8 shows how rapidly acidity declines at 20˚C.

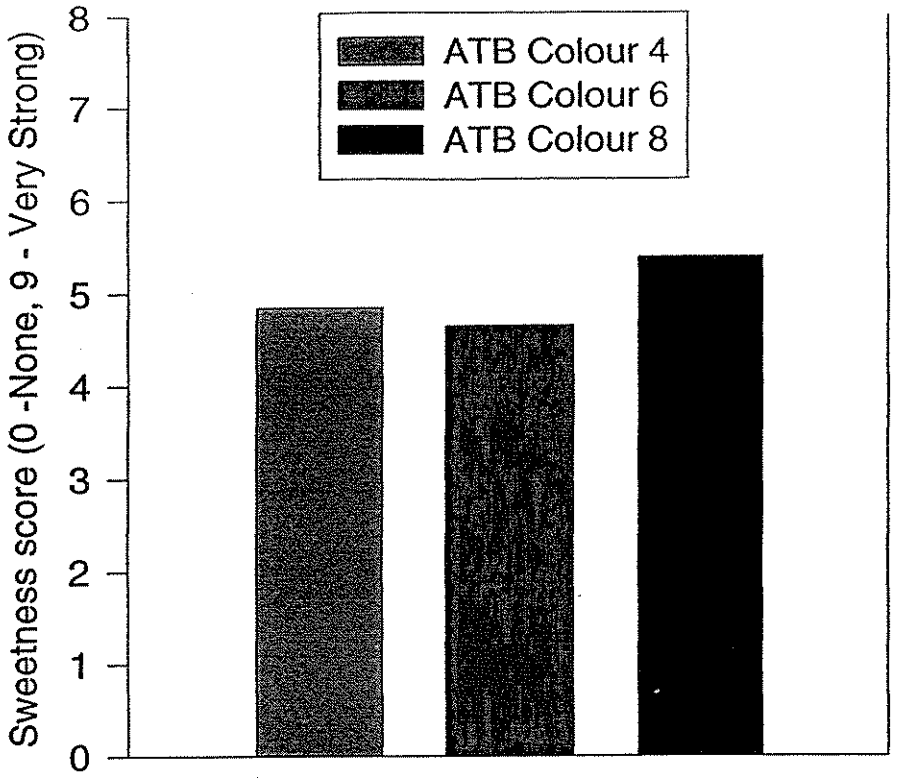
Some taste panel members detected a 'metallic' taste in some samples of tomatoes and we have called this an 'off flavour'. Although levels were never very high and some panel members did not detect them there appeared to be a trend of increasing levels of off flavours with ripeness at harvest (Fig. 9). This seemed to be particularly true in week 37. Appendix IX provides a comprehensive list of results of these taste panels.

In order to gather evidence of any preference for fruit harvested at either CS4, CS6 or CS8 after a period of shelf-life, participants at the Grower Walks at Efford and Stockbridge House were asked to taste coded samples of each and rank them in order of preference. The results were not conclusive but more participants (approximately 50%) preferred fruit harvested at CS6 to fruit harvested at other colour stages (Figure 10).

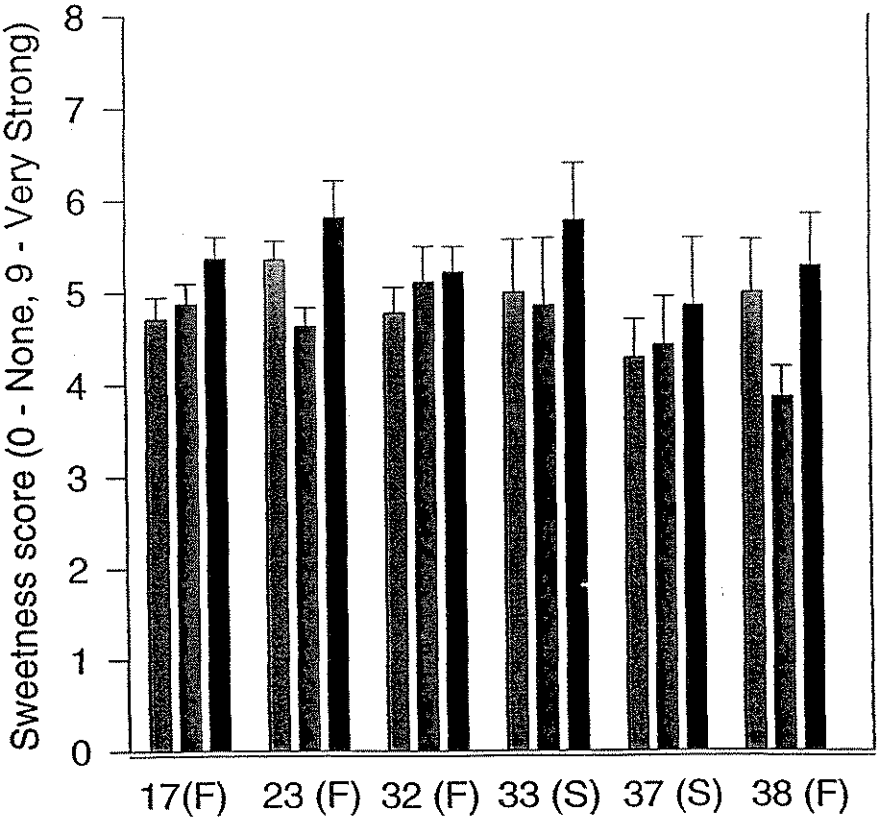
In addition to these taste assessments fruit were also sent to supermarkets for assessments (Appendix X). Again these assessments were not very consistent. They did not show any clear evidence for a reduction in acidity from CS4 to CS8 and where preferences were shown they were given in favour of CS8.

Besides Solairo and Ferrari three other varieties were grown in single rows to assess their suitability for harvesting as vine-ripe tomatoes. The quality characteristics of CS4, CS6 and CS8 fruit were assessed for fruit harvested in week 19 (Table 12). 3209 had higher soluble solids content than Ferrari and had good levels of acidity and high dry matter content. However it was the softest variety and therefore was not well suited to harvesting at CS8. 3186 had low dry matter content, similar soluble solids content to Solairo but lower acidity and therefore would not be worth harvesting vine-ripe on grounds of taste. 3186 has since been withdrawn by the seed company. 72-36 had levels of soluble solids comparable with Ferrari and higher acidity. 72-36 was firm like Ferrari but also had a greater shininess than Ferrari. These attributes made it a promising variety for vine-ripe harvesting.

Figure 5. Effect of Vine versus Room Ripening on Taste Panel Assessment of Sweetness after shelf-life



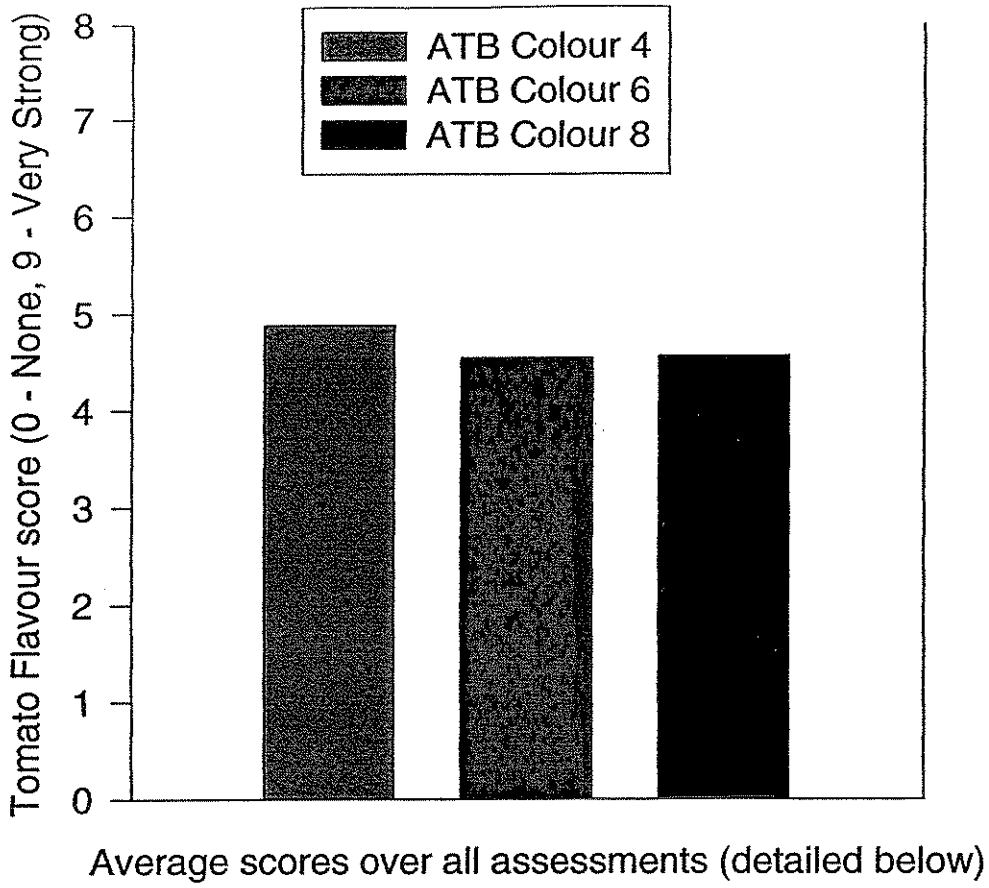
Average scores over all assessments (detailed below)

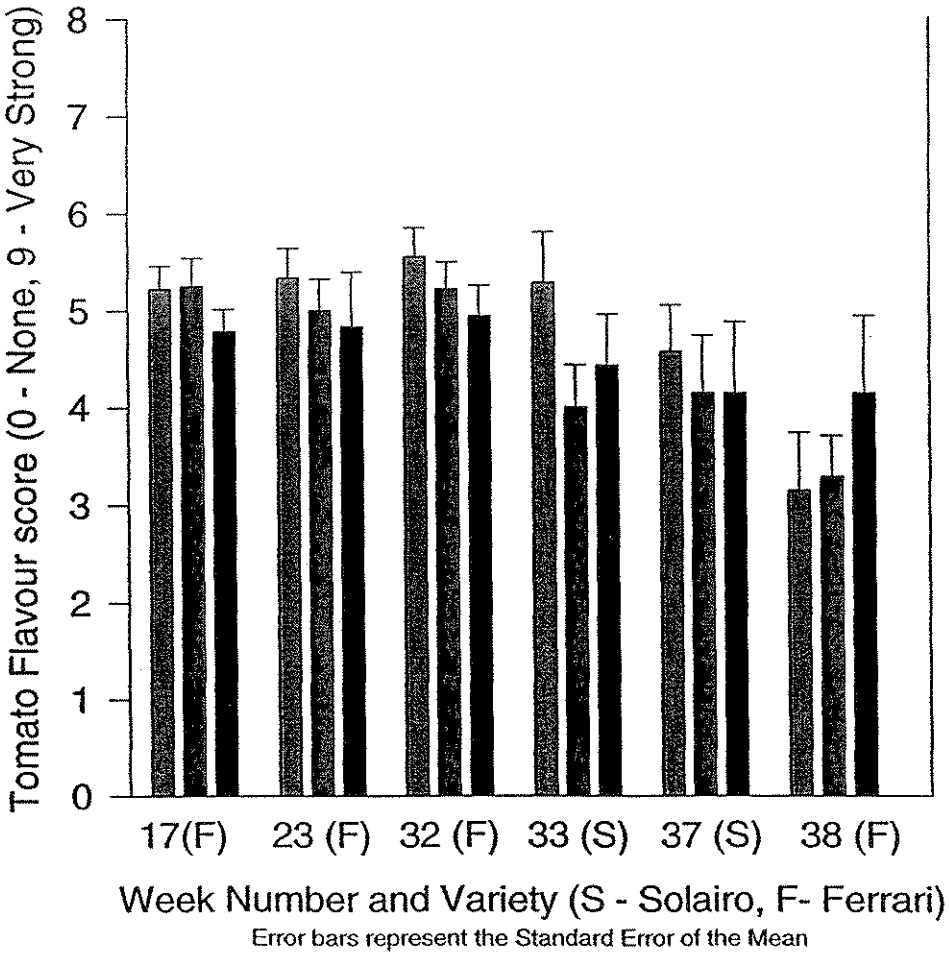


Week Number and Variety (S - Solairo, F - Ferrari)

Error bars represent the Standard Error of the Mean

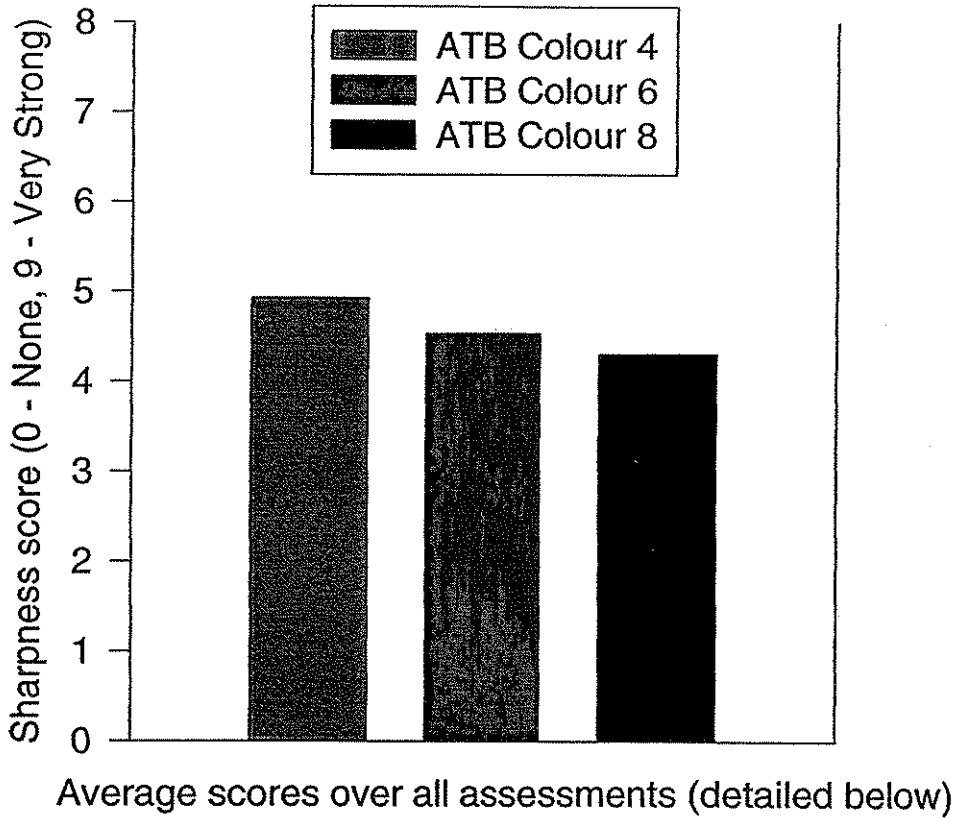
Figure 7. Effect of Vine versus Room Ripening on Taste Panel Assessment of Tomato Flavour after Shelf-life

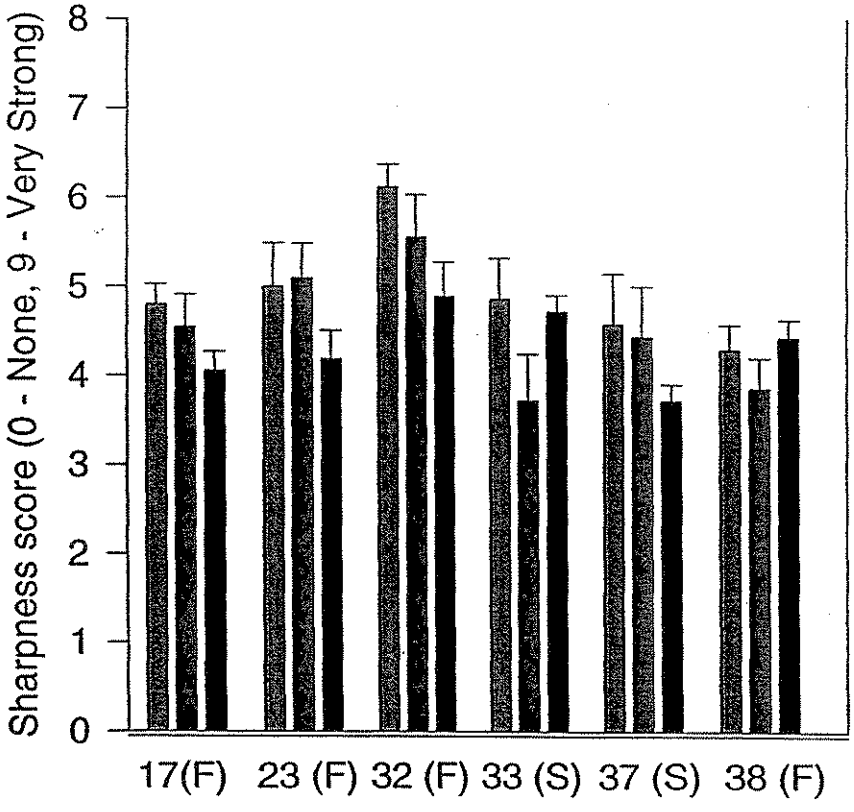




Error bars represent the Standard Error of the Mean

Figure 6. Effect of Vine versus Room Ripening on Taste Panel Assessment of Sharpness after Shelf-life





Error bars represent the Standard Error of the Mean

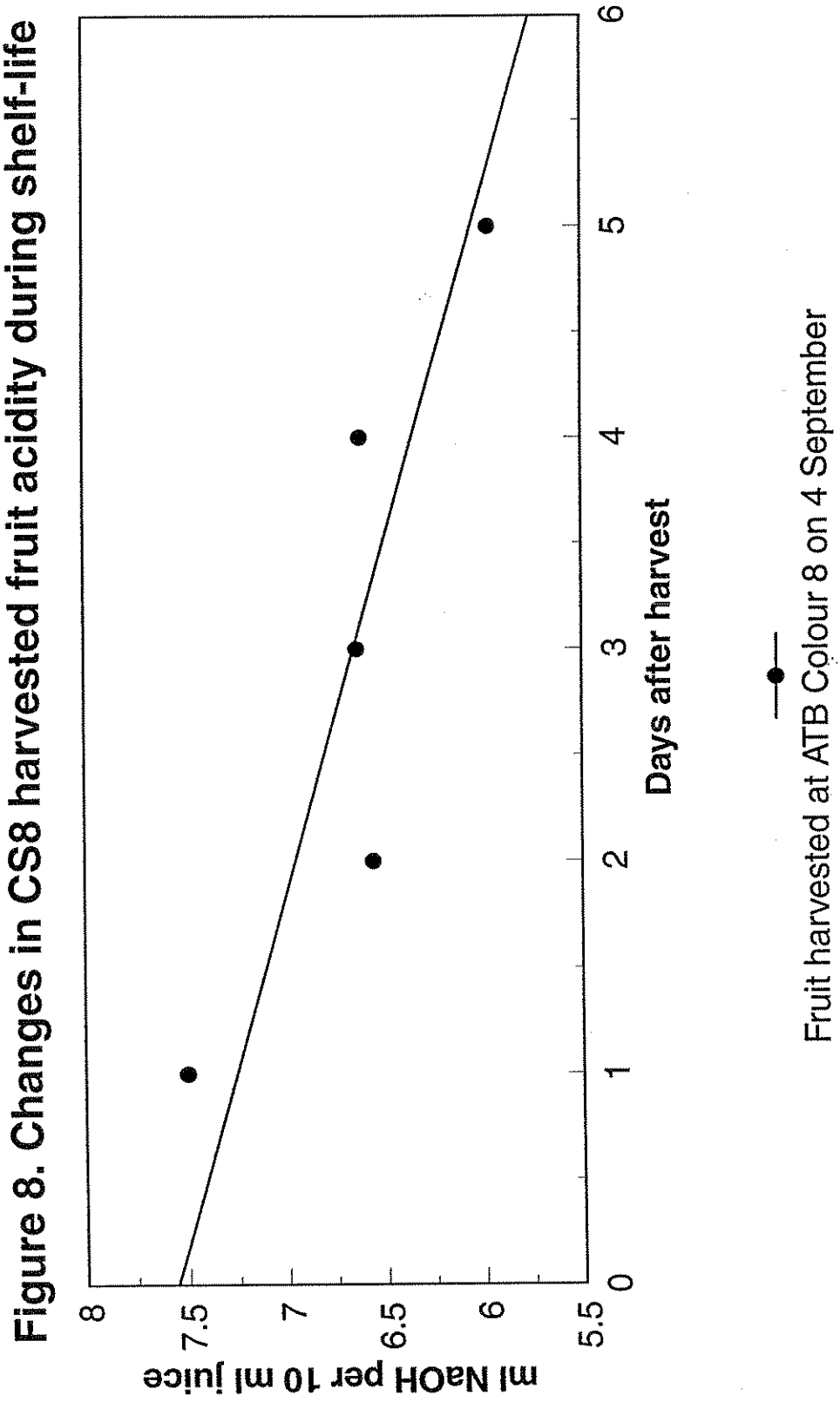
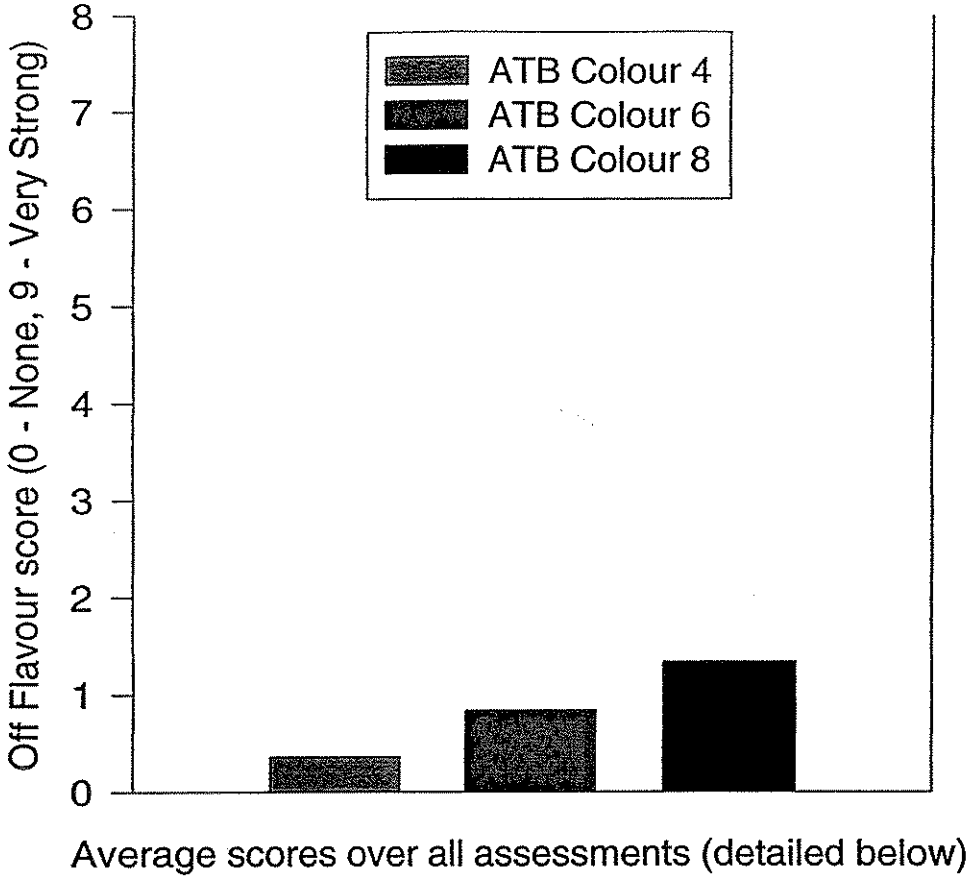


Figure 8. Changes in CS8 harvested fruit acidity during shelf-life
ml NaOH per 10 ml juice
8
7.5
7
6.5
6
5.5
0
1
2
3
4
5
6
Days after harvest
Fruit harvested at ATB Colour 8 on 4 September

Figure 9. Effect of Vine versus Room Ripening on Taste Panel Assessment of 'Off Flavour' after Shelf-life



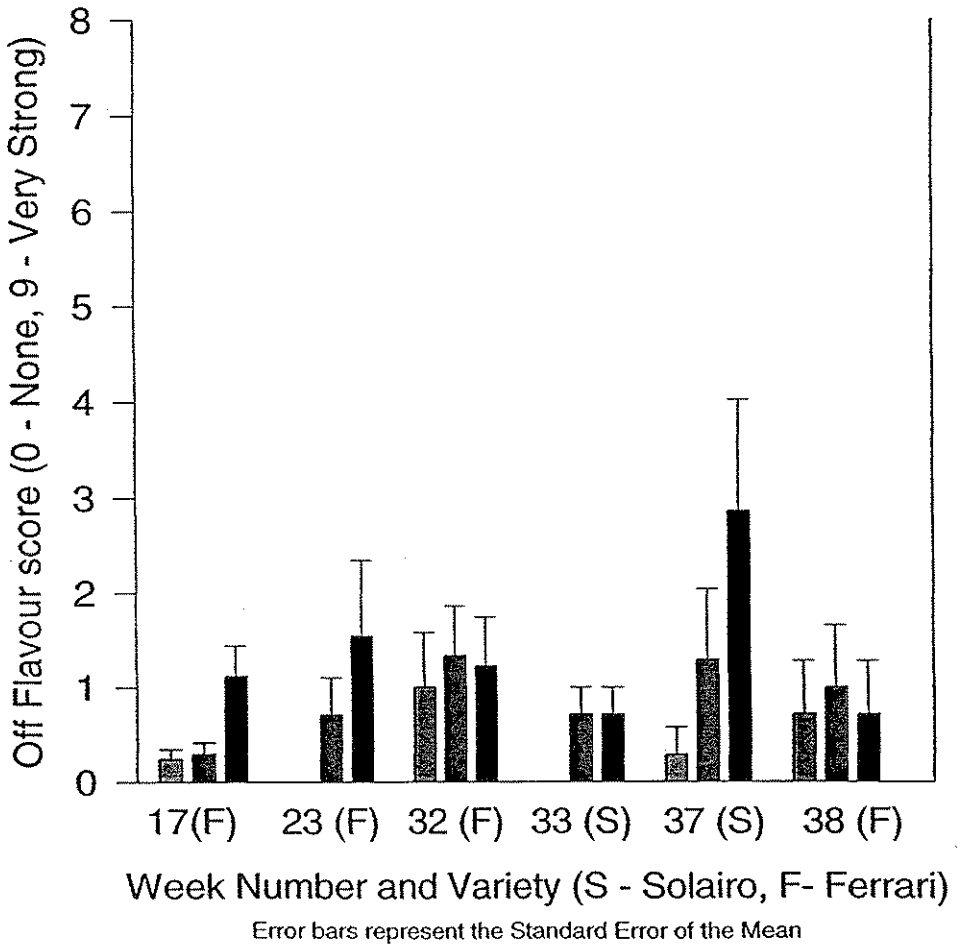


Figure 10. Percentage of Grower's Walk attendees preferring tomatoes harvested at ATB Colour Stage 4, 6 and 8 after shelf-life

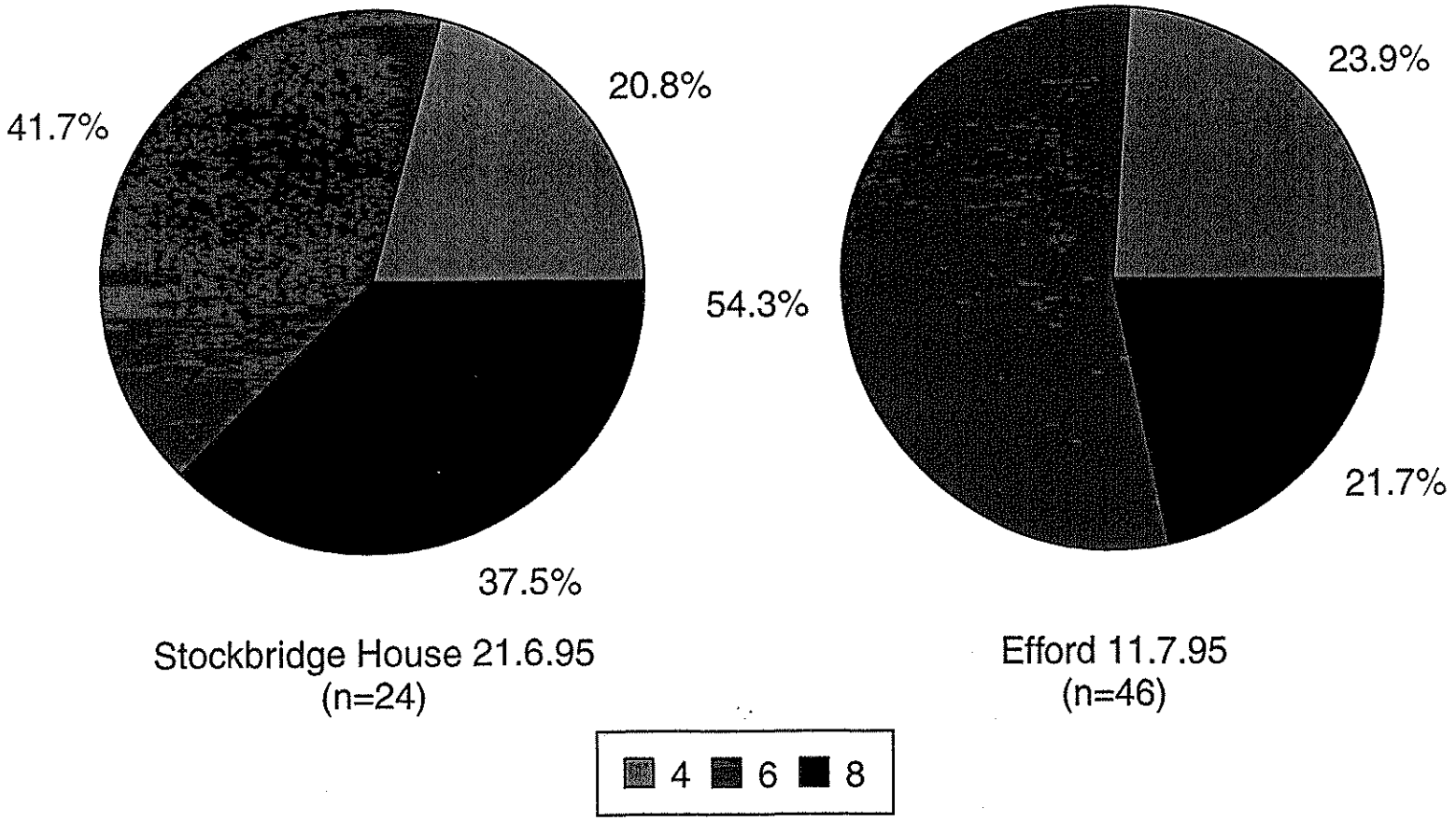


Table 12. **Effect of variety and colour stage at harvest on shelf-life, internal composition and appearance**

Variety	Colour Stage	% Soluble Solids	Endpoint pH	% Dry Matter	Compression	% Weight Loss	Shine	% Calyces Shrivelled
Ferrari	**4**	5.13	7.78	6.24	2.37	2.14	1.90	80
	6	5.15	8.54	6.26	2.73	2.28	1.75	70
	8	5.23	8.70	6.26	2.95	2.62	1.65	70
Solairo	**4**	4.6	7.81	6.07	2.21	1.93	2.8	100
	6	4.6	8.69	5.70	2.56	2.04	2.6	100
	8	4.7	9.13	5.89	2.95	2.49	2.4	100
3186	**4**	4.7	8.50	5.94	2.98	2.51	1.4	80
	6	4.6	9.61	5.53	3.20	2.32	2.4	60
	8	4.7	9.53	5.69	2.50	2.17	2.8	100
3209	**4**	5.3	7.9	6.42	2.90	2.33	1.4	80
	6	5.1	7.86	6.32	2.91	2.40	2.0	100
	8	5.4	8.22	6.24	3.16	2.52	2.4	100
72-36	**4**	5.1	8.19	6.35	2.43	2.32	2.0	100
	6	5.1	7.92	6.22	2.67	2.49	2.2	100
	8	5.3	8.09	6.39	2.85	2.43	2.6	100

Notes

Ferrari data are means from 4 reps, data for all other varieties are from single plots

Fruit were not passed through the handling simulator

3. Effects of Picking Colour Stage, Storage Time and Temperature on quality

a) Long periods of storage

Fruit from CS4, CS6 and CS8 were stored at 5°C for 20 days, 10°C for 13 days or 6 days at 20°C. The aim of this experiment was to determine what effects storage at low temperature might have on fruit quality.

The low temperature storage treatments were very effective at restricting the colour development of the fruit. In week 19 fruit were assessed at the end of the set storage period and there were very marked differences in colour between treatments. Table 13 shows how the 5°C treatment virtually prevented any progression up the ATB colour scale despite the storage period being 21 days.

Table 13. Effect of storage temperature and initial colour stage on ATB colour in week 19

	CS4	CS6	CS8
5°C for 20 d	5.15	6.25	7.70
10°C for 13 d	7.15	8.15	8.70
20°C for 6 d	8.75	9.00	8.95
SED (18 d.f.)			*0.278*
LSD (5%)			*0.584*
Significance			***

Assessments made in week 19 revealed a number of effects (Table 14) which are likely to be a result of the difference in stage of ripeness rather than the storage temperatures *per se*.

Table 14. Effect of storage temperature on shelf-life and internal composition in week 19

	% Weight Loss	Compression (mm)	Endpoint pH
5°C for 20 d	1.38	2.26	7.83
10°C for 13 d	1.54	2.25	7.70
20°C for 6 d	2.35	2.68	8.34
SED (18 d.f.)	*0.108*	*0.061*	*0.155*
LSD (5%)	*0.23*	*0.13*	*0.33*
Significance	***	***	**

In subsequent assessments fruit from the lower temperature treatments was allowed to colour up to ATB colour stage 8 at 20°C before assessment.

Interestingly all of the effects listed in Table 14 disappeared when fruit were assessed at the same colour stage and some effects were reversed. Table 15 shows how shelf-life can be maintained by holding fruit at 10°C. Weight loss and compression figures were lower for the 13 days at 10°C treatment than for the 20°C and 5°C treatments. Interestingly the figures for the 5°C treatment after colouring up were as bad or worse than the 20°C treatment. However it is unclear whether this might be due to the length of time in store or due to a temperature effect. In weeks 31 and 36 a few fruit developed storage rots. These took the form of dark, circular lesions and were identified as *Alternaria sp*. The number of lesions per fruit was recorded and as Table 16 shows, there were more lesions when fruit were held at low temperatures. However as with the shelf-life results it is unclear if this difference was due to temperature of length of time in store.

Table 15. Effect of storage temperature on fruit compression and percentage weight loss

	% Weight Loss		Compression (mm)	
Week	**31**	**36**	**31**	**36**
5°C for 20 d	2.34	2.57	2.69	1.98
10°C for 13 d	1.61	2.05	2.39	1.84
20°C for 6 d	2.01	2.47	2.35	2.04
SED (18 d.f.)	*0.164*	*0.094*	*0.086*	*0.042*
LSD (5%)	*0.34*	*0.20*	*0.18*	*0.09*
Significance	**	***	**	***

Table 16. **Effect of storage temperature and colour stage at picking on the mean number of *Alternaria* lesions per fruit**

Week	Week 31 CS4	CS6	CS8	Week 36 CS4	CS6	CS8
5°C for 20 d	0.25	0.45	0.10	0.15	0.45	0.30
10°C for 13 d	0.30	0.25	0.30	0.00	0.00	0.00
20°C for 6 d	0.00	0.00	0.00	0.00	0.00	0.00

b) Short periods of storage

The effects of holding fruit harvested at CS4, CS6 and CS8 at 5°C, 10°C or 20°C for 48 h and then 3 days at 20°C were investigated in weeks 14 (Ferrari) and week 22 (Solairo). The differences in colour stage at the end of the experiment were quite evident although all close to CS8 (Table 17). In week 22 a shortage of red fruit resulted in CS8 being harvested closer to CS6 than CS8.

Table 17. **Effect of initial 48 h storage temperature on ATB colour**

	Week 14 CS4	CS6	CS8	Mean	Week 22 CS4	CS6	CS8	Mean
5°C	7.20	8.20	8.60	8.00	6.60	7.55	6.85	7.15
10°C	7.30	8.20	8.65	8.05	7.45	8.00	7.35	7.75
20°C	7.65	8.35	8.80	8.27	8.25	8.45	8.45	8.52
SED (18 d.f.)				*0.144*				*0.207*
LSD (5%)				-				*0.43*
Significance				*N.S.*				***

A short period of storage at 5°C or 10°C improved the shelf-life of all colour stages in terms of % weight loss during storage and compression relative to the 20°C treatment (Table 18). However the differences in weight loss and compression between the 5°C and 10°C treatments were generally very small.

Table 18. **Effect of initial 48 h storage temperature on percentage weight loss and compression after 3 days at 20°C**

% Weight Loss	Week 14 CS4	CS6	CS8	Mean	Week 22 CS4	CS6	CS8	Mean
5°C	1.54	1.39	1.41	1.44	1.19	1.13	1.22	1.18
10°C	1.47	1.36	1.30	1.38	1.32	1.23	1.26	1.27
20°C	2.09	1.96	1.92	1.99	1.73	1.69	1.59	1.67
SED (18 d.f.)				*0.064*				*0.054*
LSD (5%)				*0.13*				*0.11*
Significance				***				***

Compression (mm)	Week 14 CS4	CS6	CS8	Mean	Week 22 CS4	CS6	CS8	Mean
5°C	2.27	2.17	2.51	2.32	2.30	2.39	2.34	2.34
10°C	2.20	2.29	2.45	2.32	2.38	2.60	2.44	2.47
20°C	2.40	2.55	2.75	2.57	2.62	2.74	2.61	2.66
SED (18 d.f.)				*0.054*				*0.056*
LSD (5%)				*0.11*				*0.12*
Significance				***				***

The storage treatments did not have any consistent effects on soluble solids content but they did affect the acidity of the fruit. Holding CS8 fruit at 10°C for 48 h had a significant effect in slowing down the decline in fruit acidity (Table 19). However it appeared that the 5°C treatment although resulting in higher acidity (lower endpoint pH) than the 20°C treatment, was no more effective than the 10°C treatment in slowing down the decline in acidity during storage.

Table 19. Effect of initial 48 h storage temperature on fruit acidity (Low endpoint pH = high acidity)

% Weight Loss	Week 14 CS4	CS6	CS8	Mean	Week 22 CS4	CS6	CS8	Mean
5°C	7.88	8.26	8.39	8.17	7.73	8.76	8.11	8.20
10°C	7.68	8.09	8.09	7.95	7.83	8.42	7.99	8.08
20°C	7.93	8.55	8.73	8.40	8.86	8.78	8.92	8.85
SED (18 d.f.)				*0.183*				*0.153*
LSD (5%)				*0.38*				*0.32*
Significance				*				***

Fruit appearance was affected by the storage conditions. Low temperature for 48 h had the effect of maintaining fruit shininess (Table 20).

Table 20. Effect of initial 48 h storage temperature on fruit shininess after 3 days at 20°C

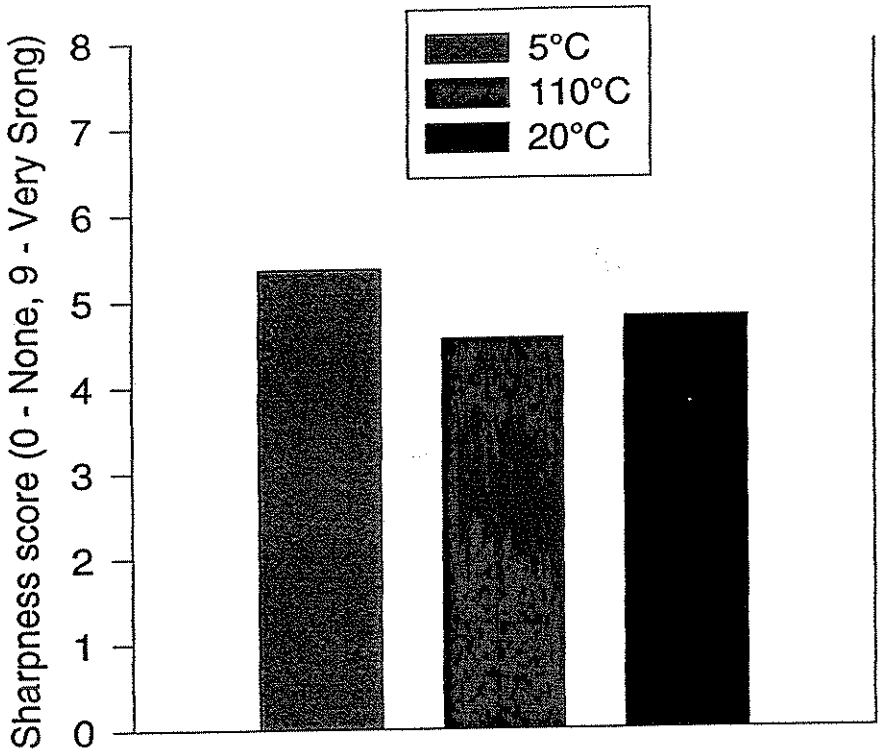
Shininess (0-3)	Week 14 CS4	CS6	CS8	Mean	Week 22 CS4	CS6	CS8	Mean
5°C	1.70	1.65	2.05	1.80	1.50	1.50	1.75	1.58
10°C	1.60	1.55	1.40	1.52	1.40	1.70	1.60	1.57
20°C	1.15	1.35	1.75	1.42	1.05	1.40	1.40	1.28
SED (18 d.f.)				*0.111*				*0.083*
LSD (5%)				*0.23*				*0.17*
Significance				**				**

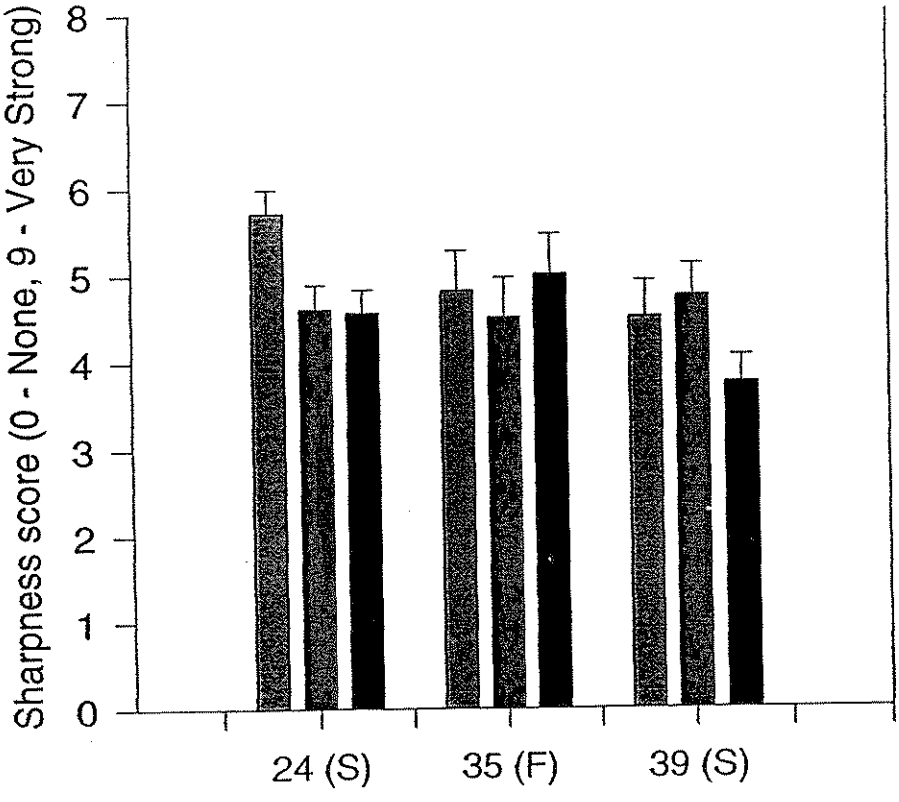
The taste panel assessment in week 17 compared CS4, CS6 and CS8 fruit after 48 h at 5°C followed by 3 days at 20°C. The results presented in a previous section (see Figs 5 to 9) show that the CS8 fruit were sweeter but less sharp, with less tomato flavour and more off flavour than CS4 and CS6 fruit. Fruit from this experiment were also sent to supermarkets for assessment (Appendix XI).

In order to assess the effects of temperature rather than colour stage at picking a series of three taste panels compared CS8 fruit that had been held for 48 h at 5°C, 10°C or 20°C and then allowed to equilibrate to room temperature before tasting. The results were not consistent across varieties. In weeks 24 and 39 low temperatures for 48 h seemed to have the effect of maintaining the sharpness of Solairo. However in week 35 the 20°C treatment provided the

sharpest fruit of Ferrari (Figure 11). In terms of tomato flavour there was even less consistency in the results. The 5˚C treatment produced the most tomato flavour in week 24 (Solairo) but the least in week 35 (Ferrari) (Figure 12). Differences between the other flavour and texture attributes were small and are listed in Appendix XII.

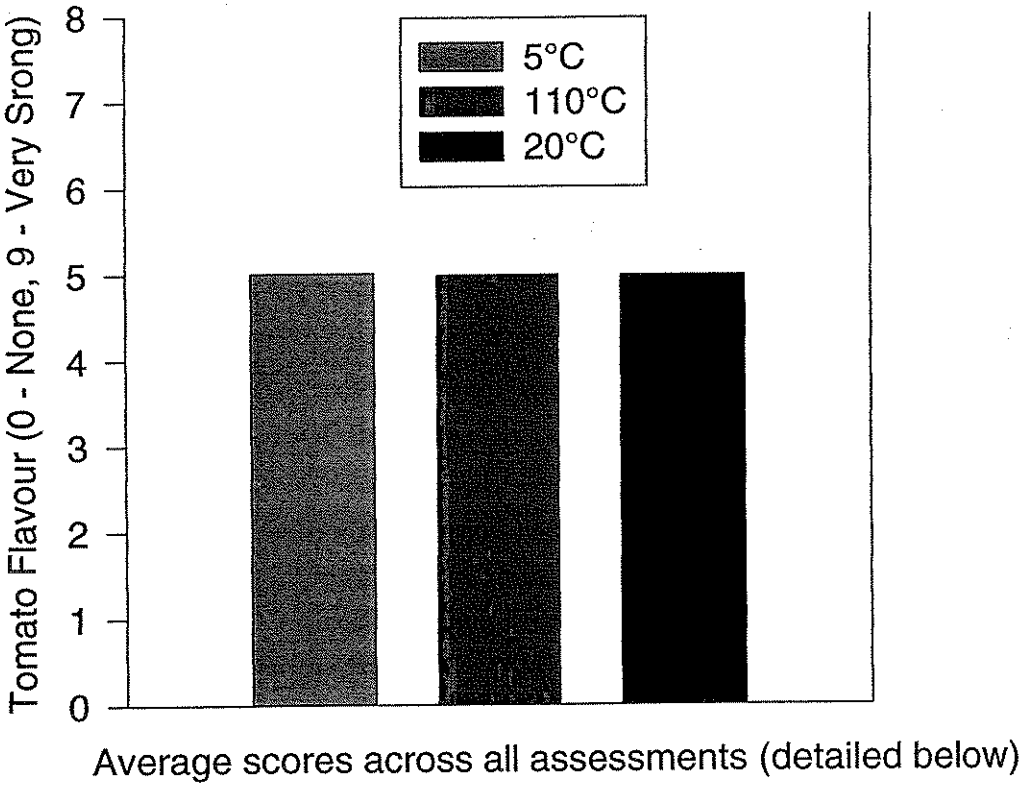
Figure 11. Effect 48h holding temperature on taste panel assessment of Sharpness after equilibration to room temperature

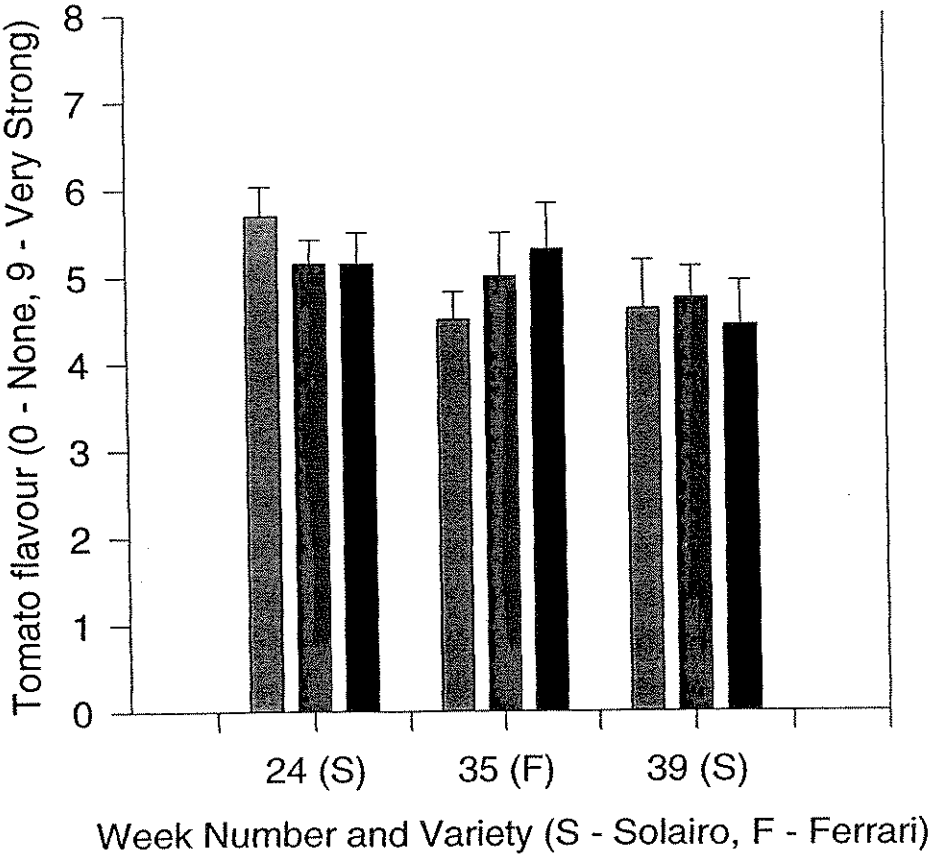




Error bars represent the Standard Error of the Mean

Figure 12. Effect 48h holding temperature on taste panel assessment of tomato flavour after equilibration to room temperature





Error bars represent the Standard Error of the Mean

DISCUSSION

The yields from the CS8 treatment were always behind the yields from the CS4 treatment partly at least as a result in the delay in harvesting fruit. However after the final harvest when all fruit were picked to the same colour there remained a small yield difference of less than 3% for total yield (not significant) and nearly 4% for marketable yield (significant at 5% probability level). The larger difference in marketable yield reflects the slightly higher percentage of Class I fruit in the CS4 treatment relative to CS8 due to some soft fruit at CS8. The small reduction in fruit size for CS8 relative to CS4 is further evidence to suggest that the delayed harvesting of CS8 fruit of just a few days acts as an extra drain on the plant's resources, using up assimilates which might otherwise have been directed to other fruits resulting in larger fruits and hence also higher yield.

The monetary cost of harvesting at CS8 rather than at CS4 has been calculated as £16,000/ha. In order to make up for this loss of yield a grower would need to achieve a premium for vine-ripened fruit over standard produce of 19 pence per 6 kg box. The difference in marketable yield as a result of picking colour stage is remarkably small in comparison with the difference between the two varieties, Ferrari and Solairo. In this trial the marketable yield for Ferrari was 13% lower than that for Solairo. In order to make up for this yield difference a premium of 52 pence per 6 kg box would be required and that is comparing the varieties across all picking colour stages. The comparison of Ferrari harvested at CS8 with Solairo harvested at CS4 results in a marketable yield difference of 16% requiring a premium of 76 pence per 6 kg box.

In order that a premium be obtained for a vine-ripe product it is quite important that the product is in fact superior to the standard product. There is obviously a difference in colour between vine-ripened and standard tomatoes but the question of whether or not there is an improvement in general appearance and flavour is less certain.

Fruit shininess was greater for freshly picked CS8 fruit than stored CS4 and CS6 fruit early in the season but not later in the season. It may be that the glasshouse environment was harsher for ripening fruit than the shelf-life room in the Summer period but not in the Spring.

There is some evidence from the experiments carried out in this trial that freshly harvested CS8 tomatoes tasted sweeter and had more tomato flavour than tomatoes harvested earlier at CS2, CS4 or CS6 and room ripened to colour stage 8. However the differences were small and not evident in every assessment. Although a difference in sweetness was detected by the taste panel, measurements of soluble solids content did not reveal any differences between treatments. It is likely that any small difference in sugar levels between treatments may have been confounded by differences in the levels of other soluble solids such as the organic acids. The work of Kader (1977) indicated a higher level of reducing sugars in fruit harvested table ripe compared to fruit harvested less ripe and stored until it reached the same colour.

Kader's work from field grown crops in California also showed that vine-ripe fruit have more tomato flavour and less off flavour than tomatoes harvested less ripe. However this was based on comparisons of 'immature green, partially mature green, typical mature green, breaker, light pink, dark pink and table ripe' fruits. Not surprisingly there were marked differences between fruit harvested green and those harvested red. However the differences between breaker, light pink, dark pink table ripe fruits (perhaps corresponding to CS2, CS4, CS6 and CS8 in this experiment) were less pronounced.

Picha (1986) suggests two reasons why fruit harvested under ripe may have lower sugar levels than fruit left to ripen on the plant. Firstly picking green fruit prevents any further sugar translocation from the leaves. It has been shown that glucose labelled with C14 applied to tomato leaves can be translocated to tomato fruits that were 10 days post breaker stage (McCollum & Skok 1960). Secondly there may be greater respiratory losses of sugar in the tomatoes during storage.

Another factor in determining tomato flavour but not assessed in this study is the effect of volatiles which are likely to be more pronounced in freshly picked fruit. Kader (1977) found freshly harvested table ripe fruit to have a significantly stronger fruity/floral aroma than both breaker and light pink harvested fruit.

The conclusion that a freshly harvested vine-ripened tomato tastes better than one picked less ripe and stored may be of use to people picking tomatoes from their back garden from where they are quickly consumed. However, for commercially grown tomatoes another factor must be considered. What happens in the time between picking and eating? Commercially produced tomatoes after being picked have to be graded, packed, distributed and perhaps stored before they arrive on the supermarket shelf. They then have to be bought and taken home where they may remain for a few days longer before being eaten. We estimate that the average time from picking to consumption for a UK produced tomato is 5 or 6 days and we need to know what happens to the flavour characteristics of tomatoes during that time.

In experiments where CS4, CS6 and CS8 fruit were harvested at the same time and put into shelf-life rooms at 20°C for 5 or 6 days CS8 fruit was softer, less shiny and less acidic than fruit harvested less ripe. Taste panels were still able to detect the increased sweetness of the CS8 fruit. However the taste panels also found CS8 fruit to be less sharp and to have less tomato flavour and more off flavours after the period of shelf-life.

Gaur & Bajpai (1982) found red ripe harvested tomatoes to have lower acidity and lower scores in organoleptic evaluations after 4, 8 and 12 days at room temperature than fruit harvested pink or 'turning'. The 'pink' harvested fruit were preferred in these tests as were the CS6 tomatoes in the taste tests at the Efford and Stockbridge House grower walks.

Janse (in press) found that freshly harvested 'far-red' round tomatoes *cv* Chaser were preferred to those harvested at breaker stage and found a small increase in sweetness as perceived by the taste panel. However there was no significant difference in soluble solids content or levels of reducing sugars. As in the Efford experiment it was found that after 1 week in storage at 20°C the sensory evaluations revealed reduced sourness (sharpness) and reduced pleasantness. Janse also measured significantly lower levels of titratable acidity in 'far red' Chaser that had been stored for one week.

Interestingly Janse included the small round variety Aranca and the cherry Favorita in his trial and found that the improved flavour of freshly picked 'far-red' fruit was much greater in these cultivars than for Chaser and was indeed greatest for Favorita. The sweetness and reducing sugar content of Favorita in particular was much greater for the 'far-red' fruit and it was observed that Favorita continued to increase in weight by 25% from breaker to far-red colour suggesting a continual accumulation of dry matter during ripening that was not evident in Chaser or Aranca. However Favorita showed the same decline in acidity and pleasantness after one week in store. Unfortunately there was no yield data available from this trial so it is not clear whether a greater yield penalty resulted when harvesting cherry types vine-ripe compared to round types although from the evidence available this might be expected.

The rapid decline in quality of vine-ripened tomatoes once they have been harvested could be slowed down by storing fruit at an appropriate temperature. Temperatures of 9°C or less have been shown to cause physical damage to tomatoes harvested at an early stage of ripening (Hobson, 1987). However there is evidence that vine-ripened fruit are less susceptible to chilling injury (Whitaker, 1994). Long periods of exposure to 5°C failed to produce any obvious symptoms of chilling injury in this experiment where fruit were harvested at CS4, CS6 and CS8.

Holding fruit for shorter periods (48 h) at 5 and 10°C did have the effect of maintaining fruit shininess, firmness and acidity. Interestingly, the acidity and firmness was generally greater for fruit held at 10°C rather than 5°C. This suggests that temperatures as low as 5°C are unnecessary even if they do not cause direct physical damage. Taste panel assessments of CS8 fruit that had been held at 5°, 10° or 20°C for 48 h provided some further evidence that low temperatures maintained sharpness but were not conclusive.

CONCLUSIONS

1. Harvesting at ATB Colour Stage 8 rather than at Colour Stage 4 resulted in an ongoing yield reduction due to the delay of a few days in harvesting ripe fruit.

2. A small (4%) reduction in marketable yield remained at the end of the season when all plots had been harvested to the same colour

3. The effect of variety on yield was much greater than the effect of colour stage at picking.

4. Harvesting vine-ripe resulted in a small reduction in the percentage of Class I fruit due to an increased level of fruit softness.

5. Freshly harvested vine-ripe tomatoes were slightly sweeter and had more tomato flavour than fruit ripened in store.

6. After 6 days shelf-life at 20°C, vine-ripened tomatoes, while remaining sweeter than ones harvested less ripe, were of poorer quality due to being less shiny, less firm, less acidic, possessing less tomato flavour and more off flavour.

7. Long periods of exposure to 5° and 10°C failed to produce symptoms of chilling injury in fruit regardless of colour at harvest.

8. Holding fruit for 48 h at 10°C resulted in improved shininess, firmness and fruit acidity relative to 20°C.

9. Holding fruit at 5°C for 48 h was no more effective than 10°C in maintaining fruit quality.

10. The trial indicates that the improved tomato flavours achieved by harvesting fruits vine-ripe can only be maintained through to the customer by careful attention to storage temperatures. Further trials might be able to determine the optimum temperature for short-term storage.

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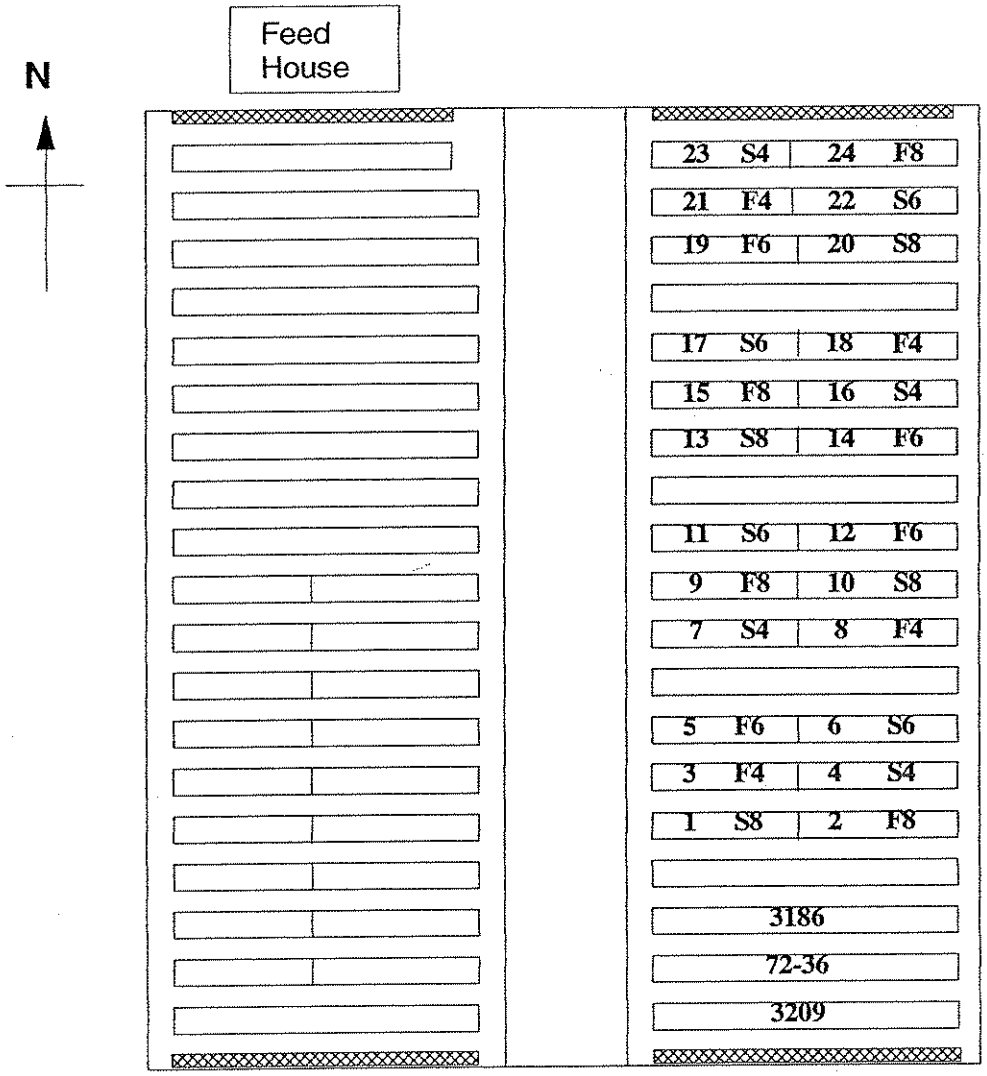
APPENDICES

Appendix I. Planting plan B- Block 1994/1995



Vine-ripening trial
Main treatments
Pick at colour stage 4 (4)
Pick at colour stage 6 (6)
Pick at colour stage 8 (8)

Sub-treatments-Varieties
Ferrari (F)
Solairo (S)

All unlabelled plots will be Pronto
North and South single row guards will be Pronto

APPENDIX II Standard procedure for tomato shelf-life and internal composition assessments

Introduction

The purpose of the shelf-life assessments is to assess the keeping quality of fruit. Internal composition gives an indication of the taste characteristics of tomatoes.

The shelf-life room is maintained at 20°C and 50-60% Relative Humidity.

Procedure for shelf-life:

1.1 For each plot/batch, sample Class 1 Grade D fruit from the picking buckets prior to grading. All of the fruit should be free from cracks, splits or bruises and should not be 'squat' or show any 'nippling'.

1.2 Weigh the sample of fruit (excluding the weight of the tray) in grammes to one decimal place.

1.3 Pass the sample of fruit through the handling simulator (500mm drop) and place the fruit on a plastic bag (labelled with plot number) in a plastic tray in the shelf-life room.

1.4 After 6 days reweigh each sample. Remove the calyx and place each fruit blossom-end up on the stage of the firmness meter. Press the start button to operate the machine which applies a 1 kg load to the fruit. Note the compression in mm on a record sheet or enter direct onto a spreadsheet.

Procedure for internal composition

2.1 Pre-weigh foil trays to two decimal places.

2.2 After compression measurements have been made, take 5 fruit from the sample and cut 'latitudinal' slices from the middle of each fruit to ensure that all locules and locular walls are sampled. Place the slices in the foil trays and weigh, recording the weight in grammes to two decimal places (including the weight of the tray). Place the trays in an oven at 60°C. After 3 days reweigh the trays and their contents.

2.3 The remaining fruit not used for dry weights should be placed in labelled plastic bags and frozen to break down cell contents.

2.4 Thaw the fruit overnight by placing each plastic bag in a funnel over a beaker containing filter paper. In the morning, pulp the fruit (still in the bag) by hand, empty the contents into the funnel and allow to filter for 2 hours.

2.5 To measure the soluble solids content, place a few drops of filtered juice onto the prism of a hand refractometer (0-10% Brix), close the cover and record the % soluble solids indicated by the blue/clear border seen through the viewfinder. Also record the temperature of the juice in order that adjustment can be made as appropriate (see table in manufacturer's instruction leaflet).

2.6 To measure the acidity of the juice, add 0.38g of sodium orthophosphate ($Na_3PO_4.12H_2O$) to 20ml of juice. Shake to dissolve and then leave for 10 minutes. Measure the endpoint pH using a hand held pH probe.

2.7 Endpoint pH values can be converted to titratable acidity (ml 0.1N NaOH required to reach pH of 8.0) using the following conversion formula:

$$\text{ml 0.1N NaOH} = ((10\text{-pH})\text{x}1.1)+5$$

APPENDIX III Standard procedure for taste panel assessment of tomatoes

Introduction

The purpose of taste panel assessments is to obtain objective information about the taste characteristics of tomatoes

Procedure

A team of panellists who will meet regularly through the season initially sample a range of tomatoes with different taste characteristics and discuss attributes to be scored and how to score them.

The following attributes are suggested:

Sweetness
Sharpness
Tomato Flavour
Off Flavour (Metallic Taste)
Juiciness
Flesh Firmness
Skin Toughness

Using a scoring system from 0 - none to 9 - very strong

Once panellists are familiar with the attributes and scoring system regular assessments begin.

For each session a small number of samples is recommended (2 to 6).

Segments of fruit should be prepared by taking latitudinal slices through each tomato and cutting them in half so that locular contents and locular wall materials are sampled in the proportions that are representative of the whole fruit. Samples should be offered on a plate labelled with a code letter.

Before starting to record, panellists should taste a 'starter' segment. If this is not done the first sample is likely to receive higher scores for flavour attributes as a result of being first. Panellists can then taste fruit from the samples in any order they wish. They should taste more than one segment from each sample.

Scores should be entered onto previously prepared record sheets (one per panellist). Panellists must not discuss scores or preferences during the tasting session.

APPENDIX IV Effects of Colour Stage at Picking and Variety on total yield and gradeout

a) **Effects of Colour Stage at Picking and Variety on total yield to the end of October (including final harvest when all plots were picked to Colour Stage 4)**

ATB Colour Stage	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
4	0.90	2.79	4.89	8.64	8.25	8.54	8.18	6.80	5.30	54.28
6	0.80	2.64	4.68	8.40	8.22	8.30	8.33	6.34	5.55	53.25
8	0.82	2.61	4.57	8.64	7.71	7.98	8.36	6.33	5.79	52.80
SED (14 d.f.)	*0.030*	*0.051*	*0.117*	*0.143*	*0.131*	*0.144*	*0.134*	*0.066*	*0.144*	*0.603*
LSD (5%)	*0.06*	*0.11*	*0.25*	-	*0.28*	*0.31*	*0.29*	*0.14*	*0.31*	-
Significance	*	**	*	*N.S.*	**	**	*N.S.*	***	*	*N.S.*

Variety	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
Ferrari	0.72	2.71	4.45	8.03	7.66	7.69	7.52	5.87	5.01	49.65
Solairo	0.96	2.65	4.97	9.09	8.46	8.86	9.06	7.10	6.08	57.23
SED (14 d.f.)	*0.024*	*0.042*	*0.096*	*0.117*	*0.107*	*0.118*	*0.109*	*0.054*	*0.118*	*0.492*
LSD (5%)	*0.05*	-	*0.21*	*0.25*	*0.23*	*0.25*	*0.23*	*0.12*	*0.25*	*1.06*
Significance	***	*N.S.*	***	***	***	***	***	***	***	***

APPENDIX IV (b). Effects of Colour Stage at Picking and Variety on total marketable yield to the end of October (including final harvest when all plots were picked to Colour Stage 4)

ATB Colour Stage	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
4	0.89	2.75	4.83	8.55	8.11	8.31	7.94	6.51	5.03	52.9
6	0.80	2.61	4.62	8.27	8.07	8.07	8.03	6.06	5.27	51.8
8	0.82	2.58	4.50	8.47	7.55	7.69	7.90	6.01	5.39	50.9
SED (14 d.f.)	*0.029*	*0.046*	*0.123*	*0.141*	*0.127*	*0.152*	*0.132*	*0.064*	*0.146*	*0.584*
LSD (5%)	*0.06*	*0.10*	-	-	*0.27*	*0.33*	-	*0.14*	-	*1.3*
Significance	**	**	*N.S.*	*N.S.*	***	**	*N.S.*	***	*N.S.*	*

Variety	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
Ferrari	0.72	2.68	4.39	7.94	7.55	7.47	7.26	5.58	4.67	48.2
Solairo	0.96	2.62	4.90	8.92	8.27	8.58	8.65	6.81	5.80	55.5
SED (14 d.f.)	*0.024*	*0.038*	*0.100*	*0.141*	*0.104*	*0.124*	*0.108*	*0.052*	*0.119*	*0.477*
LSD (5%)	*0.05*	-	*0.21*	*0.30*	*0.22*	*0.27*	*0.23*	*0.11*	*0.26*	*1.0*
Significance	***	*N.S.*	***	***	***	***	***	***	***	***

APPENDIX IV (c). Effects of Colour Stage at Picking and Variety on % Class I fruit to the end of October (including final harvest when all plots were picked to Colour Stage 4)

ATB Colour Stage	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
4	99.0	96.1	92.3	95.5	93.6	92.6	90.3	86.0	80.5	91.2
6	98.9	96.1	91.4	94.8	93.5	92.1	89.5	85.9	81.2	90.7
8	98.7	95.9	90.2	93.7	92.7	90.8	87.2	87.0	76.5	89.3
SED (14 d.f.)	*0.50*	*0.71*	*0.67*	*0.40*	*0.41*	*0.37*	*0.74*	*0.91*	*2.01*	*0.38*
LSD (5%)	-	-	*1.4*	*0.9*	-	*0.8*	*1.6*	-	-	*0.8*
Significance	*N.S.*	*N.S.*	*	**	*N.S.*	***	**	*N.S.*	*N.S.*	***

Variety	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
Ferrari	99.0	96.7	93.1	96.1	94.7	92.6	90.3	84.9	74.8	90.8
Solairo	98.8	95.3	89.5	93.2	91.9	91.0	87.8	87.8	83.9	90.0
SED (14 d.f.)	*0.41*	*0.58*	*0.54*	*0.32*	*0.34*	*0.30*	*0.60*	*0.74*	*1.64*	*0.31*
LSD (5%)	-	*1.2*	*1.2*	*0.7*	*0.7*	*0.6*	*1.3*	*1.6*	*3.5*	*0.7*
Significance	*N.S.*	*	***	***	***	***	***	**	***	*

APPENDIX IV d). Effects of Colour Stage at Picking and Variety on percentage Class II fruit to the end of October (including final harvest when all plots were picked to Colour Stage 4)

ATB Colour Stage	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
4	0.60	2.6	6.5	3.4	4.7	4.7	6.8	9.8	14.3	6.3
6	0.70	2.8	7.3	3.7	4.7	5.2	7.0	9.8	13.7	6.6
8	0.78	3.1	8.3	4.4	5.3	5.6	7.4	7.8	16.4	7.1
SED (14 d.f.)	*0.42*	*0.40*	*0.60*	*0.27*	*0.30*	*0.34*	*0.60*	*0.62*	*1.56*	*0.27*
LSD (5%)	-	-	*1.3*	*0.6*	-	-	-	*1.3*	-	*0.6*
Significance	*N.S.*	*N.S.*	*	*	*N.S.*	*N.S.*	*N.S.*	*	*N.S.*	*

Variety	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
Ferrari	0.56	2.0	5.6	2.8	3.9	4.5	6.3	10.1	18.3	6.4
Solairo	0.83	3.7	9.1	4.9	5.9	5.8	7.8	8.2	11.3	7.0
SED (14 d.f.)	*0.34*	*0.33*	*0.49*	*0.22*	*0.24*	*0.28*	*0.49*	*0.51*	*1.27*	*0.22*
LSD (5%)	-	*0.7*	*1.0*	*0.5*	*0.5*	*0.6*	*1.0*	*1.1*	*2.7*	*0.5*
Significance	*N.S.*	***	***	***	***	***	*	**	***	*

APPENDIX IV (e). Effects of Colour Stage at Picking and Variety on % waste to the end of October (including final harvest when all plots were picked to Colour Stage 4)

ATB Colour Stage	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
4	0.38	1.3	1.3	1.0	1.7	2.7	2.8	4.3	5.2	2.5
6	0.42	1.2	1.3	1.5	1.8	2.8	3.5	4.3	5.1	2.7
8	0.48	1.0	1.5	1.9	2.1	3.6	5.5	5.1	7.1	3.6
SED (14 d.f.)	*0.25*	*0.49*	*0.25*	*0.26*	*0.22*	*0.31*	*0.32*	*0.46*	*0.72*	*0.18*
LSD (5%)	-	-	-	*0.5*	-	*0.7*	*0.7*	-	*1.5*	*0.4*
Significance	*N.S.*	*N.S.*	*N.S.*	*	*N.S.*	*	***	*N.S.*	*	***

Variety	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
Ferrari	0.43	1.3	1.3	1.1	1.5	2.9	3.4	5.1	6.9	2.9
Solairo	0.42	1.0	1.4	1.9	2.2	3.2	4.5	4.1	4.7	3.0
SED (14 d.f.)	*0.21*	*0.40*	*0.21*	*0.21*	*0.18*	*0.25*	*0.26*	*0.37*	*0.58*	*0.15*
LSD (5%)	-	-	-	*0.4*	*0.4*	-	*0.6*	*0.8*	*1.3*	-
Significance	*N.S.*	*N.S.*	*N.S.*	**	**	*N.S.*	***	*	**	*N.S.*

APPENDIX IV (f). Effects of Colour Stage at Picking and Variety on % of Class I fruit in size grade C (>57mm) to the end of October (including final harvest when all plots were picked to Colour Stage 4)

ATB Colour Stage	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
4	8.7	7.8	9.1	11.9	18.8	18.5	19.9	24.5	39.0	18.5
6	8.3	5.3	7.7	11.1	17.8	15.7	18.5	19.8	34.0	16.5
8	9.0	7.4	8.6	9.2	15.2	13.1	16.3	17.7	30.8	14.7
SED (14 d.f.)	*1.90*	*1.23*	*1.24*	*0.86*	*1.65*	*1.59*	*1.48*	*2.15*	*2.68*	*1.08*
LSD (5%)	-	-	-	*1.8*	-	*3.4*	-	*4.6*	*5.7*	*2.3*
Significance	*N.S.*	*N.S.*	*N.S.*	*	*N.S.*	*	*N.S.*	*	*	*

Variety	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
Ferrari	12.1	6.1	6.2	8.8	15.3	11.9	17.4	18.3	32.3	14.3
Solairo	5.2	7.6	10.7	12.7	19.3	19.6	19.1	23.0	36.9	18.9
SED (14 d.f.)	*1.55*	*1.00*	*1.02*	*0.70*	*1.35*	*1.30*	*1.21*	*1.76*	*2.19*	*0.88*
LSD (5%)	*3.3*	-	*2.2*	*1.5*	*2.9*	*2.8*	-	*3.8*	-	*1.9*
Significance	***	*N.S.*	**	***	*	***	*N.S.*	*	*N.S.*	***

APPENDIX IV (g). Effects of Colour Stage at Picking and Variety on % of Class I fruit in size grade D (47-57mm) to the end of October (including final harvest when all plots were picked to Colour Stage 4)

ATB Colour Stage	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
4	80.3	85.3	85.3	80.5	75.8	78.5	78.1	73.2	58.2	77.0
6	80.0	86.8	85.5	80.7	76.4	81.2	79.2	77.0	62.8	78.5
8	81.4	84.8	85.1	82.4	79.0	83.3	81.6	79.2	66.5	80.3
SED (14 d.f.)	*2.20*	*1.04*	*1.18*	*0.68*	*1.01*	*1.40*	*1.30*	*2.31*	*2.52*	*0.92*
LSD (5%)	-	-	-	*1.5*	-	*3.0*	*2.8*	-	*5.4*	*2.0*
Significance	*N.S.*	*N.S.*	*N.S.*	*	*N.S.*	*	*	*N.S.*	*	*

Variety	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
Ferrari	79.7	87.6	86.0	80.9	77.5	84.5	80.7	79.0	65.1	80.2
Solairo	81.4	83.7	84.6	81.5	76.6	77.6	78.6	73.9	60.0	77.0
SED (14 d.f.)	*1.79*	*0.85*	*0.97*	*0.56*	*1.01*	*1.14*	*1.06*	*1.89*	*2.06*	*0.75*
LSD (5%)	-	*1.8*	-	-	-	*2.4*	-	*4.0*	*4.4*	*1.6*
Significance	*N.S.*	***	*N.S.*	*N.S.*	*N.S.*	***	*N.S.*	*	*	***

APPENDIX IV (h). Effects of Colour Stage at Picking and Variety on % of Class I fruit in size grade E (40-47mm) to the end of October (including final harvest when all plots were picked to Colour Stage 4)

ATB Colour Stage	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
4	9.9	6.3	5.5	7.0	4.9	2.9	2.0	2.0	1.5	4.1
6	10.7	7.4	6.6	7.8	5.5	3.0	2.2	3.0	2.3	4.7
8	8.4	7.4	6.0	7.8	5.4	3.3	2.0	2.8	1.9	4.6
SED (14 d.f.)	*1.37*	*0.70*	*0.67*	*0.43*	*0.51*	*0.48*	*0.30*	*0.33*	*0.44*	*0.31*
LSD (5%)	-	-	-	-	-	-	-	*0.7*	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*	*N.S.*	*N.S.*

Variety	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Total (inc final harvest)
Ferrari	7.0	5.9	7.5	9.7	6.8	3.5	1.9	2.4	1.8	5.1
Solairo	12.2	8.2	4.6	5.4	3.8	2.7	2.3	2.8	2.0	3.8
SED (14 d.f.)	*1.12*	*0.57*	*0.55*	*0.35*	*0.41*	*0.39*	*0.24*	*0.27*	*0.36*	*0.25*
LSD (5%)	*2.4*	*1.2*	*1.2*	*0.7*	*0.9*	-	-	-	-	*0.5*
Significance	***	**	***	***	***	*N.S.*	*N.S.*	*N.S.*	*N.S.*	***

APPENDIX V. Effects of Vine/Room ripening on % dry matter, soluble solids content, acidity, softness and colour

Week 17
Variety Ferrari

	Harvest date	% Dry Matter	% Soluble Solids	Endpoint pH	Compression (mm)	ATB Colour at assessment
CS2	-					
CS4	24.4	5.70	4.88	7.86	2.19	7.70
CS6	26.4	6.03	4.78	7.86	1.95	7.63
CS8	28.4	6.19	4.80	8.00	1.94	7.80
SED (8 d.f.)		*0.180*	*0.192*	*0.094*	*0.092*	*0.065*
LSD (5%)		-	-	-	*0.21*	-
Significance		*N.S.*	*N.S.*	*N.S.*	*	*N.S.*

Week 26
Variety Solairo

	Harvest date	% Dry Matter	% Soluble Solids	Endpoint pH	Compression (mm)	ATB Colour at assessment
CS2	28.6	6.03	5.00	7.80	2.11	7.85
CS4	30.6	6.00	4.95	8.32	2.25	8.00
CS6	3.7	6.29	5.08	7.92	2.14	7.90
CS8	5.7	6.45	5.05	8.14	1.98	7.73
SED (9 d.f.)		*0.094*	*0.058*	*0.259*	*0.043*	*0.063*
LSD (5%)		*0.21*	-	-	*0.10*	*0.15*
Significance		**	*N.S.*	*N.S.*	*	*

Week 33
Variety Ferrari

	Harvest date	% Dry Matter	% Soluble Solids	Endpoint pH	Compression (mm)	ATB Colour at assessment
CS2	15.8	5.98	5.63	8.07	1.78	
CS4	16.8	6.03	5.63	8.72	1.91	7.70
CS6	18.8	5.94	5.55	8.80	1.93	7.63
CS8	21.8	5.82	5.68	8.38	1.86	7.80
SED (8 d.f.)		*0.207*	*0.237*	*0.458*	*0.092*	*0.065*
LSD (5%)		-	-	-	-	-
Significance		*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 41
Variety Solairo

	Harvest date	% Dry Matter	% Soluble Solids	Endpoint pH	Compression (mm)	ATB Colour at assessment
CS2	9.10	5.73	5.00	9.77	2.31	7.53
CS4	11.10	5.95	5.15	9.71	2.37	7.93
CS6	13.10	5.76	5.03	9.71	2.10	7.80
CS8	16.10	6.20	5.23	9.84	1.67	7.85
SED (8 d.f.)		*0.222*	*0.129*	*0.186*	*0.101*	*0.136*
LSD (5%)		-	-	-	*0.23*	-
Significance		*N.S.*	*N.S.*	*N.S.*	*	*N.S.*

APPENDIX VI. **Effects of Vine/Room ripening on taste panel assessments of sweetness, sharpness, 'tomato flavour', 'off flavour', skin toughness, flesh firmness and juiciness.**

Week 19
Variety Solairo

	Harvest date	Sweetness	Sharpness	'Tomato Flavour'	'Off Flavour'	Skin Toughness	Flesh Firmness	Juiciness
CS2	-							
CS4	10.5	5.50	5.44	5.78	0.00	5.67	6.00	6.67
CS6	12.5	4.88	5.00	4.56	0.00	5.78	5.11	6.56
CS8	15.5	6.13	5.00	5.89	0.00	5.00	5.78	6.78

Week 30
Variety Solairo

	Harvest date	Sweetness	Sharpness	'Tomato Flavour'	'Off Flavour'	Skin Toughness	Flesh Firmness	Juiciness
CS2	17.7	5.13	4.50	3.44	1.75	5.13	5.00	5.63
CS4	19.7	5.13	5.00	4.63	1.75	5.50	5.13	5.75
CS6	21.7	4.88	5.81	4.88	1.50	5.50	5.38	6.50
CS8	24.7	5.81	5.25	5.19	1.38	5.25	5.63	6.81

Week 34
Variety Ferrari

	Harvest date	Sweetness	Sharpness	'Tomato Flavour'	'Off Flavour'	Skin Toughness	Flesh Firmness	Juiciness
CS2	14.8	5.00	5.75	5.38	1.00	5.75	5.63	6.19
CS4	16.8	5.25	5.50	5.38	1.00	5.63	6.06	5.69
CS6	18.8	5.94	5.66	6.13	0.63	5.38	6.00	6.19
CS8	21.8	5.88	5.50	5.50	0.88	6.13	6.13	5.75

Week 42
Variety Solairo

	Harvest date	Sweetness	Sharpness	'Tomato Flavour'	'Off Flavour'	Skin Toughness	Flesh Firmness	Juiciness
CS2	9.10	4.86	4.29	4.57	0.29	6.29	5.43	5.29
CS4	11.10	4.57	4.57	5.29	0.86	6.00	6.14	6.29
CS6	13.10	4.71	4.57	4.86	0.29	6.14	5.14	5.71
CS8	16.10	4.57	3.57	4.57	0.43	5.43	5.57	5.86

APPENDIX VII. Effects of Vine/Room ripening on taste panel assessments of fruit by supermarkets

Week 20
Variety Solairo **Supermarket A** **Assessment date 19.5.95**

	Harvest date	Appearance	External Texture	Sweetness	Acidity	Skin Toughness	Internal Texture	Overall Rating
CS4	10.5	4	3	2	4	3+	3	3
CS6	12.5	4	3+	4	3+	3+	4	4
CS8	15.5	4	3+	1+	3	3+	2	2+

Week 21
Variety Ferrari **Supermarket B** **Assessment date 26.5.95**

	Harvest date	Appearance	Texture	Flavour	Overall
CS4	19.5	6	Soft/Tough skin	Earthy/Some sweetness	Acceptable
CS6	22.5	6	Soft flesh	Bland, little acid/sweetness	Acceptable
CS8	24.5	6	Soft flesh	Acidic/Some sweetness	Acceptable

Week 21
Variety Ferrari **Supermarket C** **Assessment date 26.5.95**

	Harvest date	Aroma	Skin Texture	Sweetness	Acidity	Flavour	Overall Acceptability
CS4	19.5	4.4	4.6	4.1	3.1	4.4	4.3
CS6	22.5	4.1	4.6	4.5	3.1	4.7	4.7
CS8	24.5	4.6	4.6	4.8	3.6	4.9	5.3

Week 20
Variety Solairo **Supermarket D** **Assessment date 16.5.95**

	Harvest date	Sweetness	Sharpness	Tomato Flavour	Skin Toughness	Flesh Firmness	Juiciness
CS4	10.5	4	5	5	7	3	6
CS6	12.5	7	6	8	5	4	7
CS8	15.5	7	2	5	6	5	7

APPENDIX VIII. Effects of picking colour stage on % dry matter, soluble solids content, acidity, softness and colour after six days shelf-life

Week 19
Variety Ferrari

	% Weight Loss	% Dry Matter	% Soluble Solids	Endpoint pH	Compression (mm)	ATB Colour at assessment
CS4	2.14	6.25	5.13	7.78	2.37	8.75
CS6	2.28	6.26	5.15	8.54	2.73	9.00
CS8	2.62	6.26	5.23	8.69	2.95	9.00
SED (8 d.f.)	*0.358*	*0.151*	*0.170*	*0.295*	*0.104*	*0.094*
LSD (5%)	-	-	-	*0.68*	*0.21*	-
Significance	*N.S.*	*N.S.*	*N.S.*	*	**	*N.S.*

Week 31
Variety Solairo

	% Weight Loss	% Dry Matter	% Soluble Solids	Endpoint pH	Compression (mm)	ATB Colour at assessment
CS4	1.88	5.44	5.08	8.38	2.10	7.25
CS6	2.27	5.48	5.18	8.20	2.34	7.70
CS8	1.88	5.35	5.15	8.61	2.62	8.00
SED (8 d.f.)	*0.243*	*0.187*	*0.191*	*0.404*	*0.158*	*0.315*
LSD (5%)	-	-	-	-	*0.36*	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*	*N.S.*

Week 36
Variety Ferrari

	% Weight Loss	% Dry Matter	% Soluble Solids	Endpoint pH	Compression (mm)	ATB Colour at assessment
CS4	2.50	6.32	5.48	8.66	1.87	7.95
CS6	2.39	6.39	5.50	8.87	2.07	8.05
CS8	2.52	6.27	5.48	9.29	2.20	8.65
SED (8 d.f.)	*0.130*	*0.088*	*0.110*	*0.454*	*0.084*	*0.292*
LSD (5%)	-	-	-	-	*0.19*	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*	*N.S.*

APPENDIX IX. Effects of picking colour stage on taste panel assessments of sweetness, sharpness, 'tomato flavour', 'off flavour', skin toughness, flesh firmness and juiciness after six days shelf-life

Week 23
Variety Ferrari

	Sweetness	Sharpness	'Tomato Flavour'	'Off Flavour'	Skin Toughness	Flesh Firmness	Juiciness
CS4	5.33	4.67	5.33	0.00	6.00	6.17	5.54
CS6	4.83	4.75	5.00	0.71	5.92	6.00	5.67
CS8	5.42	3.83	4.83	1.54	6.00	5.17	6.17

Week 32
Variety Ferrari

	Sweetness	Sharpness	'Tomato Flavour'	'Off Flavour'	Skin Toughness	Flesh Firmness	Juiciness
CS4	4.78	6.11	5.56	1.00	6.11	6.11	5.00
CS6	5.11	5.56	5.22	1.33	6.44	6.00	5.22
CS8	5.22	4.89	4.94	1.22	6.11	5.22	5.11

Week 33
Variety Solairo

	Sweetness	Sharpness	'Tomato Flavour'	'Off Flavour'	Skin Toughness	Flesh Firmness	Juiciness
CS4	5.00	4.86	5.29	0.00	5.36	5.29	5.57
CS6	4.86	3.71	4.00	0.71	5.71	5.43	5.86
CS8	5.79	4.71	4.43	0.71	5.71	5.21	5.86

Week 37
Variety Solairo

	Sweetness	Sharpness	'Tomato Flavour'	'Off Flavour'	Skin Toughness	Flesh Firmness	Juiciness
CS4	4.29	4.57	4.57	0.29	4.43	5.43	5.14
CS6	4.43	4.43	4.14	1.29	4.86	4.29	4.86
CS8	4.86	3.71	4.14	2.86	4.71	3.93	5.14

Week 38
Variety Ferrari

	Sweetness	Sharpness	'Tomato Flavour'	'Off Flavour'	Skin Toughness	Flesh Firmness	Juiciness
CS4	5.00	4.29	3.14	0.71	5.57	5.86	4.71
CS6	3.86	3.86	3.29	1.00	5.86	5.57	4.71
CS8	5.29	4.43	4.14	0.71	5.71	5.43	5.29

APPENDIX X. Effects of picking colour stage on taste panel assessments of fruit by supermarkets after shelf-life

Week 14
Variety Ferrari **Supermarket C** **Assessment date 3.4.95**

	Harvest date	Aroma	Skin Texture	Sweetness	Acidity	Flavour	Overall Acceptability
CS4	27.3	4.0	4.4	4.2	3.3	4.6	4.6
CS6	27.3	4.2	4.9	3.9	3.4	4.3	4.3
CS8	27.3	4.4	4.3	4.1	3.3	4.3	4.3

Week 26
Variety Solairo **Supermarket A** **Assessment date 28.6.95**

	Harvest date	Appearance	External Texture	Sweetness	Acidity	Skin Toughness	Internal Texture	Overall Rating
CS4	23.6	3.5	4	2+	3	4	4	3
CS6	23.6	3.5	3	4	3	4	3	4
CS8	23.6	4	4	3+	3	4	4	3+

Week 26
Variety Solairo **Supermarket B** **Assessment date 29.6.95**

	Harvest date	Appearance	Texture	Flavour	Overall
CS4	23.6	-	Soft	Sweet/Some acidity	Fail (Splits)
CS6	23.6	-	Soft	Sweetish	Acceptable
CS8	23.6	-	Soft	Bland/Slight acidity	Acceptable

Week 30
Variety Ferrari **Supermarket B** **Assessment date 26.7.95**

	Harvest date	Appearance	Texture	Flavour	Overall
CS4	21.7	6.5	Firm/Tough skin	Acidic	Acceptable
CS6	21.7	7.5	Soft/Juicy	Bland	Acceptable
CS8	21.7	7.5	Firm flesh	Sweet/Some acidity	Good

Week 33
Variety Solairo **Supermarket A** **Assessment date 18.8.95**

	Harvest date	Appearance	External Texture	Sweetness	Acidity	Skin Toughness	Internal Texture	Overall Rating
CS4	9.8	3	4	2	3	3	3.5	3
CS6	9.8	2	1.5	2	2	3	2.5	2
CS8	9.8	4	3	4	2	3	3.5	4

Week 35
Variety **Solairo** **Supermarket B** **Assessment date 30.8.95**

	Harvest date	Appearance	Texture	Flavour	Overall
CS4	25.8	4.5	Firm	Slight acidity/Sweet	O.K.
CS6	25.8	5	Slightly soft	Sweet	O.K.
CS8	25.8	6.5	Soft flesh	Sweet	Good

APPENDIX XI. Effects of picking colour stage on taste panel assessments of fruit by supermarkets after 48 h at 5°C followed by shelf-life at 20°C

Week 17
Variety Ferrari Supermarket A Assessment date 27.4.95

	Harvest date	Appearance	External Texture	Sweetness	Acidity	Skin Toughness	Internal Texture	Overall Rating
CS4	19.4	4	3	2+	2+	3	3	3
CS6	19.4	4	3	2+	4	4	4	3
CS8	19.4	4	4	3	3+	2	3	3+

Week 17
Variety Ferrari Supermarket B Assessment date 28.4.95

	Harvest date	Appearance	Texture	Flavour	Overall
CS4	21.4	5	Crisp flesh	Bland	Acceptable
CS6	21.4	6	Crisp/Tough skin	Earthy/Acidic	Fail (Splits)
CS8	21.4	6	Soft/Tough skin	Earthy/Acidic	Fail (Splits)

Week 17
Variety Ferrari Supermarket C Assessment date 28.4.95

	Harvest date	Aroma	Texture	Sweetness	Acidity	Flavour	Overall Acceptability
CS4	21.4	4.2	4.3	3.8	4.1	4.5	4.6
CS6	21.4	4.4	4.4	4.2	3.6	4.7	4.9
CS8	21.4	4.4	4.3	4.3	3.6	4.7	4.8

HDC PROJECT PROPOSAL

1. Title of Project

VINE-RIPE TOMATOES: OPTIMISING THE PICKING COLOUR STAGE AND STORAGE CONDITIONS OF TOMATOES TO MAXIMISE FLAVOUR AT THE POINT OF CONSUMPTION

2. Background and commercial objectives:

UK tomato growers face increasing competition from imports. One way in which UK growers can effectively compete is to produce better quality fruit. Already fewer pesticides are used to produce UK tomatoes and there is increasing demand from supermarkets for tomatoes 'grown for flavour'.

It is widely accepted that vine-ripened tomatoes have superior flavour in comparison with tomatoes picked under-ripe and then ripened in storage. Kader et al (1977) found field grown tomatoes picked at earlier ripening stages and then room ripened to be less sweet, more sour, less tomato-like and with more off-flavour than tomatoes picked at later colour stages. Currently most UK growers pick at ATB colour stage 4-5. New cultivars are now available which combine good taste characteristics with textural and spoilage resistance, such cultivars can be harvested at higher colour stages.

The optimum colour stage for picking in order to maximise flavour for the consumer will depend upon the changes to the internal composition of fruit that occur during ripening both on the plant and also during storage and distribution. Gaur and Bajpai (1982) found that fruit picked 'pink' retained better flavour after 4-12 days at room temperature than either fruit picked 'turning' or 'red'.

Temperatures below 9°C during storage have been shown to cause physical injury to tomatoes by disrupting ripening processes (Hobson, 1987). Chilling injury leads to loss of firmness and reduced shelf-life.

Partial ripening of tomatoes has been shown to reduce chilling sensitivity (Whitaker, 1994). By harvesting at higher colour stages there may be more potential for prolonging shelf-life via cold storage.

Less is known about the effect of storage conditions on the flavour of tomatoes. Buescher (1975) found a reduction in levels of reducing sugars when tomatoes were held at 2°C.

In sweet peppers, harvesting red fruit rather than green incurs a significant reduction in yield. Tomatoes have ceased to grow once ripening has started but the respiration of ripening fruit may result in a reduction in the amount of assimilate available to other fruits. Growers considering harvesting fruit vine-ripe need to know the scale of any yield reductions.

3. Potential financial benefit to the industry

An improvement in product quality for the consumer, resulting from harvesting fruit at the optimal stage of ripening and storing fruit at appropriate temperatures is likely to result in increased demand for the product and an improvement in prices. Optimization

of the harvesting time would also reduce the amount of wastage. The benefits would extend to supermarkets and wholesalers as well as to growers.

Growers who opt to harvest at higher colour stages do so at present without knowing whether a yield reduction will result. By quantifying any loss of yield in this trial it will be possible for growers to make sound financial decisions about their harvesting operations.

4. Scientific/technical aspects of the work

To identify the best colour stage at which to pick tomatoes and the optimum conditions for storage in order to maximise flavour at the point of consumption without unacceptably reducing shelf-life. To investigate effects of vine-ripening on yield. Investigations will examine whether improved flavour characteristics resulting from vine-ripening are due to the ripening processes being inhibited in fruit harvested early and then stored or whether the freshness or shorter storage time of vine-ripened fruit is important.

5. Closely related work - completed or in progress

MAFF/DTI Agrofood Quality Link are funding a project with Nottingham University examining the biochemical factors that influence tomato flavour. The project aims to produce genetically altered tomatoes with key flavour pathways shut down or over-expressed to determine which compounds are important in the perception of flavour by humans.

6. Description of Work:

Summary of Experiments:

1. **Effects of Picking Stage on Yield and gradeout**
2. **Effects of Vine/Room ripening on quality**
3. **Effect of Picking Colour Stage on quality after storage (20 days @ 5°C, 12 @ 10°C or 6 @ 20°C)**
4. **Effects of short periods of low temperature on ripening processes**

Experiment 1: Effects of Picking Colour Stage on Yield and gradeout

A long season tomato crop will be grown in rockwool under standard conditions and subjected to three harvesting treatments:

1. Pick at ATB Colour Stage 4
2. Pick at ATB Colour Stage 6
3. Pick at ATB Colour Stage 8

Two varieties, Ferrari and Solairo, will be grown as sub-treatments.

Four replicates of each treatment, each consisting of 14.4m^2 will be grown. Total cropped area will equal 346m^2.

In addition plots of the varieties 3209, 3186 and 72-36 will be grown for observation.

Total and graded yield and percentage Class 1 fruit will be recorded to the end of the season.

Experiment 2: Effects of Vine/Room ripening on quality

This experiment is intended to confirm the observations of others, that tomatoes ripened on the plant have better taste characteristics than tomatoes ripened in store.

One sample of fruit of the variety Ferrari from each of the treatments in Experiment 1 will be tagged at colour stage 4. Fruit from the Pick at colour stage 4 treatment will be harvested and stored at 20°C. Thereafter fruit from the Pick at colour stage 6 and 8 treatments will be harvested and stored when the fruit already in store reaches colour stage 6 and 8 respectively.

The following assessments will be made on stored and harvested fruit at each harvest:

Colour stage
Shine
Calyx condition

At colour stage 10 the following assessments will be made:

Firmness (mm Compression)
Resistance to penetration
Soluble solids content (% Brix)
Acidity
Taste Panel Assessment

Experiment 3: Effect of Picking Colour Stage on quality after storage under different temperature regimes

If tomatoes ripened on the plant taste better than those ripened in store, there may be two explanations as to why this should be. Firstly, processes associated with ripening that are essential for the full development of flavour may be inhibited if the fruit is ripened in store. Secondly the fruit ripened on the plant will be fresher than the fruit that has been stored.

Tomatoes produced commercially have to undergo a period of storage during distribution, on the shelf in the shop and at home. Therefore it is important to determine to what extent the benefits of vine-ripening are in fact benefits of freshness. In this experiment comparisons will be made between tomatoes that have been picked at different colour stages but stored for the same time period and under the same storage conditions.

On three occasions fruit of Ferrari sampled from the replicated harvesting treatments in Experiment 1 and also fruit from other varieties (Solairo, 3209, 3186 and 72-36) picked at the same three colour stages will be assessed after storage for 6 days at 20°C, 12 days at 10°C and 20 days at 5°C for:

Colour stage
Shine
Calyx condition
Physical disorders
Firmness
Resistance to penetration
Weight loss during shelf-life
Soluble solids content
Acidity
Dry matter content

Taste panel assessments will be undertaken on fruit of Ferrari from Experiment 1 that have been stored at 20°C for 6 days on three occasions throughout the season.

Experiment 4: Effects of short periods of low temperature on ripening processes

On four occasions during the season fruit of variety Ferrari from the harvesting treatments in Experiment 1 will be stored for 48 hours at 5°C, 10°C or 20°C followed by 3 days at 20°C. Assessments will then be carried out for:

Colour stage
Shine
Calyx condition
Physical disorders
Firmness
Resistance to penetration
Weight loss during shelf-life
Soluble solids content
Acidity
Dry matter content

Taste panel assessments will be carried out on four occasions.

One taste panel will compare the effects of the three storage temperatures as soon as fruit have reached 20°C using fruit picked at Colour Stage 8.

Taste Panel Assessments

These will take place at Efford using staff who have been trained by Campden Food and Drink Research Association but will be supplemented by taste assessments carried out by the following supermarkets:-

Tesco
J. Sainsbury plc
Safeway
Marks and Spencer plc

7. **Availability of Results:** Interim results will be available to HDC and visiting groups throughout the season. A full report will be submitted within 3 months of the trial's completion.

8. **Commencement date and duration:** October 1994 for one year.

9. **Staff responsible:** Project Leader: Mr M Fussell
Location: HRI Efford

References:

Buescher, R.W. (1975). Organic acid and sugar levels in tomato pericarp as influenced by storage at low temperature. *Hortscience* **10** pp 158-159.

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Kader, A.A., Stevens, M.A., Albright-Holton, M., Morris, L.L. & Algazi, M (1977). Effect of fruit ripeness when picked on flavor and composition in fresh market tomatoes. *Journal of the American Society for Horticultural Science* **102(6)** pp 724-731.

Whitaker, B.D. (1994). A reassessment of heat treatment as a means of reducing chilling injury in tomato fruit. *Postharvest Biology and Technology* **4** pp 75-83.

Contract No: PC109

TERMS AND CONDITIONS

The Council's standard terms and conditions of contract shall apply.

Signed for the Contractor(s)

Signature.....

Position.....

Date.....

Signed for the Contractor(s)

Signature.....

Position.....

Date.....

Signed for the Council

Signature.....

Position.....

Date.....