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Firmness and Colour of the Fruit of Some Tomato Cultivars from Various Sources During Storage

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The firmness of fruit of tomato cultivars Sonato, Grenadier, Adagio, Extase and Exquise obtained from growers was significantly different at time of harvest and after storage for 7 and 14 days at 19–23°C. However, all fruit had firmness values above 1000 *g* force on day 7 and above 700 *g* force on day 14, which are postulated minima for sale of fruit at retail level and use in the home respectively. There is no evidence to downgrade fruit of Sonato from a firmness point of view. Variation in fruit firmness within a sample was considerable for most cultivars on each testing date, and coefficients of variation were calculated to quantify this. Correlation coefficients between Hunter a/b ratio and firmness for the different cultivars ranged from −0.91 to −0.97. Regression lines relating a/b ratios to firmness fell into two groups. Firmness tests on samples of tomato fruit purchased from retailers suggested that all samples were adequately firm and had a firmness shelf-life of at least 7 days.

1. Introduction

Sensory quality can be divided into three aspects—appearance, sense of feel and flavour. For tomatoes, the appearance characteristics relate to colour, shape, size and defects, and sense of feel to firmness at time of purchase or afterwards when slicing and eating fruit. However, firmness may be the final index by which the consumer decides to purchase a given batch of tomatoes.

A number of workers have been involved in tomato fruit firmness measurements, and different cultivars and instruments for measuring firmness have been evaluated.[1–10] Short shelf-life and softness of the cultivar Sonato has been alleged in the trade press recently,[11,12] but it has also been stated that there is little objective evidence for this statement and that much of the so-called evidence is hearsay, which has come from markets and other sources.[12]

This paper reports studies on the changes in firmness and colour of the tomato fruit cultivars Sonato, Extase, Grenadier, Exquise and Adagio at the time of picking and again after storage for 7 and 14 days. Special attention was given to fruit of Sonato and it was tested from three sources. The relationship between firmness and fruit colour was established for each of the cultivars. Tomatoes purchased locally at retail level were also included in the study. These fruit were tested on the day of purchase and after storage for 7 days.

2. Experimental

2.1. Sources of fruit

Samples of fruit intended for export and for the home market were obtained from a number of sources. Sources 1, 2, and 4 were growers in the Dublin area, while source 3 was Kinsealy Research Centre. Fruit from sources 1, 2 and 3 was grown in peat modules, and that from source 4 in sandy loam. Fruit from sources 1, 2 and 4 was being exported while that from source 3 was being sold on the home market. The freshly picked fruit was tested for firmness and colour for 1, 7 and 14 days after storage at 19–23°C. These tests were repeated weekly for 15 weeks during the period

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mid-June to early October. The cultivars tested were Sonato (sources 1, 2, 3), Grenadier (sources 1, 3), Adagio (source 2), Extase (source 3) and Exquise (source 4).

Firmness tests were carried out on spot samples of tomatoes purchased from greengrocers and supermarkets on three separate occasions. Samples were tested on the day of purchase and again after storage at 19–23°C for 7 days. This latter measurement was used to test post-purchase shelf-life in the home.

2.2. Firmness and colour measurements

A modified shear press as described by Gormley and Keppel[9] was used to measure firmness and 15 fruits comprised a sample. The force required to compress each fruit by 5 mm was obtained. Colour was measured on a D25A Hunter Colour Difference Meter using 10 fruits per batch, and 'a' and 'b' values were recorded. In addition to quoting a mean firmness value for a sample of 15 fruits, it is also important to give the coefficient of variation as there are often large differences in firmness between individual fruits.

2.3. Relationship between fruit firmness and colour

Regression analyses (colour *vs* firmness) were carried out using firmness as the independent variable, nd the equations of the lines relating colour to firmness for each fruit cultivar or source were obtained. Correlation coefficients were also calculated in each case.

3. Results

3.1. Interpretation of firmness values

On the basis of panel tests[9] it was found that the minimum firmness value at which an individual tomato fruit could be acceptable for sale at retail level is about 680 *g* force, while the value for use in the home, i.e. capable of being sliced easily, is about 540 *g*. Results for 19 batches of tomatoes tested have shown that only 80% of fruit in a 12 lb box was within ±20% of the mean firmness value for the batch,[9] thus indicating large differences in the firmness of fruit within each batch. If, therefore, a lot of tomatoes has a mean firmness of 680 *g* force there would be individual fruit with values much lower than this. Therefore, it was decided to raise the 680 and 540 *g* force levels to take account of this. The values now become 850 and 675 *g* force respectively, i.e. 850—20% equals 680, 675—20% equals 540. It should be stressed that these are absolute minimum levels and most stores and consumers would opt for higher minimum levels, possibly around 1000 and 700 *g* force respectively.

3.2. Firmness of fruit cultivars

The results (Table 1) show that there were significant differences between the firmness values of the different fruit cultivars and sources after storage at 19–23°C for 1, 7 and 14 days. It can be seen that

Table 1. Mean firmness values (*g* force) for tomato fruit cultivars from different sources stored at 19–23°C over a 14 day period

	Day		
Cultivar/source	1	7	14
Sonato—source 1	2965	1417	1077
—source 2	2419	1205	875
—source 3	2359	1084	735
Grenadier—source 1	3223	1314	944
—source 3	2240	1111	827
Adagio—source 2	2374	1068	801
Extase—source 3	2122	1099	758
Exquise—source 4	2721	1205	878
Significance of *F*-test	$p<0.001$	$p<0.001$	$p<0.001$
S.e.	96	45	33

fruit from source 3 was generally picked at a later stage of ripeness than that from the other sources as it was being sold on the home market rather than being exported. Fruit of the cultivars Grenadier (source 1), Sonato (source 1) and Exquise (source 4) were firmest on day 1. This pattern was generally maintained throughout storage. Fruit of Extase (source 3), Sonato (source 3) and Adagio (source 2) were softest on day 7, and this pattern was also maintained after 14 days.

The results (Table 1) show that all samples were above the minimum firmness level of 1000 *g* force postulated for sale at retail level on day 7. On day 14, Sonato from source 1 was the only fruit with a firmness value above 1000 *g*. However, fruit of all cultivars were still above the minimum firmness value for consumer use of 700 *g* force on day 14. Coefficients of variation associated with the firmness values are presented in Table 2. Coefficients were generally highest on day 14. There was less variation in firmness between individual fruit of Sonato, source 2, than for other cultivars or sources. Fruit of Grenadier, source 1, had most variation in firmness.

Table 2. Mean coefficients of variation[a] for tomato fruit cultivars from different sources stored at 19–23°C over a 14 day period

	Day			
Cultivar/source	1	7	14	Mean
Sonato—source 1	15.8	14.8	21.0	17.2
—source 2	12.2	13.7	17.1	14.3
—source 3	18.7	15.0	20.1	17.9
Grenadier—source 1	16.5	20.3	21.3	19.4
—source 3	16.3	12.5	17.4	15.4
Adagio—source 2	16.5	17.5	19.9	18.0
Extase—source 3	17.9	17.3	16.2	17.1
Exquise—source 4	16.7	15.5	18.3	16.8
Mean	16.3	15.8	18.9	

[a] For firmness data in Table 1.

3.3. Fruit colour

Approximate red/yellow (a/b) colour ratios for tomato fruit at various stages of ripeness are shown in Table 3. However, these should only be used as broad guidelines as some cultivars may develop more red pigment than others at an equal stage of maturity.

Table 3. Approximate red/yellow ratios for tomato fruit at various stages of ripeness

Colour description	Red/yellow (a/b) ratio
Green/green yellow	0.01–0.20
Half red (50% yellow and red)	0.50
Fully red (fit for eating)	1.40
Dark red (overripe)	⩾1.90

The results (Table 4) show that fruit of the different cultivars and sources had significantly different a/b colour ratios at each testing date, i.e. on days 1, 7 and 14. It can be seen (Table 4) that fruit from source 3 was picked at a more mature stage than that from the other sources. On day 7, fruit

Table 4. Mean red/yellow (a/b) colour ratios for tomato fruit cultivars from different sources stored at 19–23°C over a 14 day period

	Day		
Cultivar/source	1	7	14
Sonato—source 1	0.49	1.50	1.71
—source 2	0.45	1.48	1.69
—source 3	0.73	1.48	1.75
Grenadier—source 1	0.29	1.58	1.86
—source 3	0.91	1.78	1.93
Adagio—source 2	0.39	1.51	1.78
Extase—source 3	0.79	1.51	1.67
Exquise—source 4	0.22	1.52	1.84
Significance of *F*-test	$p<0.001$	$p<0.001$	$p<0.001$
S.e.	0.063	0.043	0.036

of the cultivar Sonato tended to be less red than that of other cultivars, and this pattern was maintained on day 14, with the exception of fruit of the cultivar Extase (source 3) which had the lowest a/b ratio. Fruit of the cultivar Grenadier was reddest on days 7 and 14.

3.4. Relationship between fruit firmness and fruit colour

Correlation coefficients between a/b colour ratio and fruit firmness ranged from −0.91 to 0.97. In the case of fruit of the cultivar Exquise (source 4) and Sonato (source 2) the correlation coefficients were both −0.97. The regression lines relating a/b ratios to firmness fell into two groups. Thus, the data for Sonato from sources 1, 2 and 3 and also for Grenadier and Extase from source 3 could be represented by the equation $y=3374-1381x$ (where x represents a/b ratio and y the firmness value). The corresponding equation for Grenadier (source 1), Adagio (source 2) and Exquise (source 4) is $y=2883-1138x$. If the two mean lines are plotted they correspond closely in the 700–1000 g force region; the force minima of 700 and 1000 g correspond to approximate a/b ratios of 1.90 and 1.65 respectively.

3.5. Firmness of fruit at retail level

Samples of fruit purchased from each of two supermarkets and each of two greengrocers on three separate occasions all had firmness values above 1000 *g* force on the day of purchase. Firmness figures varied from 2007 *g* to 1001 *g* with a mean value of 1422 *g*. Coefficients of variation were between 17.4 and 23.5.

After 7 days, only one sample had a firmness value below the minimum postulated level (700 *g*) for use in the home. Firmness values ranged from 1218 to 678 *g* with an average of 928 *g*. Coefficients of variation were between 17.1 and 23.3.

In this test no supermarkets or greengrocer could be singled out as selling the firmest or the softest tomato fruit.

4. Discussion

The results of these tests indicate that the source from which the fruits are obtained may be as important as the cultivar itself. Factors such as cultural practices, stacking of fruit in bulk bins after picking and the stage of ripeness at harvest all have an effect on the subsequent firmness of the fruit. Hobson[2] has shown that spherical fruit have a greater resistance to compression than fruit of a flatter shape and should be less susceptible to damage during storage. There is no evidence to downgrade Sonato fruit on the basis of softness. The results also indicate that fruit were still fit for sale 7 days after picking even though they were stored at a comparatively high temperature of 19–23°C.

Seven days should be more than adequate to move the fruit through to retailers and to sell it. This fact is borne out by the results for samples of fruit purchased locally, all of which had firmness levels above 1000 *g* when purchased.

Shafshak and Winsor[1] have shown that fruit of the cultivars Moneymaker, ES5 and Harbinger softened rapidly during storage over an 18-day period at 23–24°C. However, they did not state at what compression value (mm) the fruit became unacceptably soft. Hosbon[2] has shown a close relationship between firmness levels of fruit, as measured objectively, and the polygalacturonase activity in the fruit. Unfortunately, the polygalacturonase activity in the fruit was not measured in the present experiment. Stenvers and Stork[10] have defined shelf-life as the number of days in which all fruits remained edible after storage at 19°C; this concept is similar to the 700 *g*-firmness minimum postulated for fruit suitable for consumer use in this experiment. Fruit of a number of cultivars had a shelf-life of up to 18 days when harvested at the full orange-colour stage,[10] i.e. colour stage six on their scale.[8] This level of ripeness corresponds closely to an a/b ratio of about 0.50 in these tests. As can be seen from Table 4, fruit of some of the cultivars were picked with a/b ratios as low as 0.22 and as high as 0.91. Picking fruit at the green/yellow stage (a/b = 0.22) did not affect its subsequent firmness shelf-life. This contrasts with work by Stenvers and Stork,[10] who showed that picking fruit at the green/yellow stage (stage two on their scale) resulted in a shorter shelf life in the cultivars Moneymaker and Craigress.

The variation in firmness between the different lots of fruit purchased from retailers was large, even from the same supermarket. For example, the samples purchased from supermarket 1 on three different dates had firmness values of 2007, 1589 and 1011 *g*, indicating poor quality control by the supermarket personnel. In contrast, samples purchased from greengrocer 1 were of more uniform firmness with values of 1130, 1339 and 1212 *g*, but they were all rather soft. Variations in firmness within each sample as indicated by coefficients of variation were similar to those found for the test cultivars.

The coefficients of variation calculated from firmness data for fruit of the different cultivars and sources show that there is a large variation in firmness within a sample of 15 fruits, even when the fruit is size-graded and is at a uniform stage of ripeness. The relative order of coefficients of variation for the different cultivars and sources changed in some cases between days 1 and 7, showing that the samples behaved differently during storage.

The relationship of a/b ratio to firmness could not be represented by one single line for all cultivars and sources. It seems, therefore, that if predictions of fruit firmness are to be made from colour readings, the regression would need to be calculated for each individual cultivar or source, in every season, to ensure accurate predictions. Stenvers and Stork[8] have also related firmness of fruit to stage of colour. While a direct comparison cannot be made between their results and the results obtained in this experiment, the colour scales and firmness measuring instruments being different, inspection of the data suggests close agreement between the two experiments.

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