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<th>Tomato fruit quality - an interdisciplinary approach</th>
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In the last two decades, tomato fruit yields in Ireland have increased by 100% to about 375 tonnes per hectare for long-season crops. This represents a very considerable increase in the intensity of growing and may have implications for fruit quality. For this reason, the inter-relationship between crop production, yield, quality and composition of tomato fruit from high-yielding, intensive growing systems was evaluated by the authors (a food technologist and a crop production specialist, respectively) with the aid of research contracts awarded under the 1979-1983 and 1984-1988 Agro-Food Programmes (Directorate General VI) of the Commission of the European Communities (Anon, 1978, 1983). The research embraced a number of elements, including baseline studies on the quality of commercially grown tomatoes. The effects of growing media, fertilizer levels, nutrient solutions, plant spacing, interplanting and energy-saving techniques on tomato fruit quality were assessed, as was the quality of different cultivars. Procedures for testing and evaluating tomato fruit quality (including sensory aspects) were assessed via interlaboratory studies with European colleagues. This paper highlights some of the findings of this research and cites the published results.

Commercially grown tomatoes
Tomatoes from 180 boxes (5·5 kg each) obtained from the Dublin market in each of the years 1981-1983 were tested for soluble solids (SS) content (largely sugar), titratable acidity (TA), electrical conductivity (EC) value, colour and firmness (Gormley & Egan, 1984). The EC value of the juice expressed from tomato fruit is a good indicator of flavour and correlates well with taste panel response (Gormley & Egan, 1982). The values for TA and EC declined during the season, while mid-season fruit was reddest and least firm. Interbox variation was greatest for fruit colour and firmness. Within-box variation for fruit firmness was greatest in 1981, with 46% of the boxes (samples) having coefficients of variation above 20%, compared with 13% and 16% of boxes in 1982 and 1983. It was concluded that, overall, the quality of Irish tomatoes in 1981-1983 was good. However, low end-of-season fruit composition values were a problem, as was colour and firmness grading.

Nutrient solutions and growing media
Tomatoes were grown as long-season crops in peat and rockwool media in two seasons and the fertilizers were applied as complete nutrient solutions with conductivities of 2, 3·5 and 5 mS cm⁻¹. The data showed that the fruit with the highest SS, TA and EC values generally came from treatments that gave the lowest yield. Increasing feed strengths gave yields of 23, 22 and 19 kg m⁻² and the corresponding fruit EC values were 515, 557 and 622 µS cm⁻¹. The results suggest that a feed conductivity of 3·5 mS cm⁻¹ is about optimum, but even the 5 mS cm⁻¹ feed failed to maintain EC values in the fruit in the late part of the season; it also depressed yield. Some data from this study have been published (Gormley & Maher, 1985) and the complete results are currently in preparation (Gormley & Maher, 1990).
Potassium and lime

Three concentrations of K in the liquid feed and two lime sources (in the base dressing) were compared in a long-season tomato crop grown in a peat substrate (Maher, Gormley & Monaghan, 1984). Increasing the K concentration from 180 to 280 mg l⁻¹ in the liquid feed raised total yield by 9% but a further lift to 380 mg l⁻¹ did not give a significant further rise. Increasing K levels reduced the non-uniformly coloured fruit from 40% to 21% to 12% and enhanced fruit composition. However, a seasonal decline in fruit EC was noted. The use of dolomitic limestone or a blend of dolomitic and ground limestones had no effect on fruit yield, visual quality or composition.

Interplanting

The decline in tomato fruit composition during the season, as noted above, was attributed to plant age, i.e. in older plants the roots became less efficient at nutrient absorption. Preliminary tests (Gormley & O'Sullivan, 1985b; Maher & Gormley, 1986) have shown that interplanting helps to reduce or overcome this problem and a comprehensive trial was set up where tomato plants (cv. Counter) were planted into rockwool slabs in mid-January. The plants were stopped and a second crop was interplanted on either 21 April, 19 May or 16 June. The fourth treatment was a single, long-season crop with no interplanting. This in effect gave four sets of plants of different ages. All plants were stopped on 9 September.

The results showed that interplanting increased yield in the second half of the season. It also raised fruit EC, TA and firmness values in comparison with values for monocrop fruit. However, the magnitude of the difference declined as the season progressed. Interplanting did not influence fruit flavour, as indicated by taste panels. This may be due in part to the fact that the boost given to fruit EC and TA values was not matched by a corresponding increase in SS levels. Tests in two seasons showed that tomatoes from earlier trusses had lower vitamin C contents (15 mg per 100g) than those from later trusses (20 mg per 100g). As a consequence, interplanting resulted in a temporary lowering in vitamin C values. The complete results of this large study are now in preparation (Maher & Gormley, 1990).

'Old' versus 'new' cultivars

The comment is often made that tomatoes do not have the flavour they had in the 'old days'. It was decided, therefore, to compare an 'old' cultivar of reputed good flavour, i.e. Ailsa Craig, with the modern hybrids Sonatine and Virosa (Maher et al., 1984). Ailsa Craig is not resistant to Tomato Mosaic Virus (TMV) and so the plants of this cultivar were inoculated with a mild strain of TMV as a precaution. The results showed that increased early yield and improvement of visual quality are clear advantages of the modern hybrids over Ailsa Craig. The fruit composition data
showed that this was achieved without loss of internal quality. These data, and also taste panel results, showed that Alisa Craig was no better than the modern hybrids, when grown intensively, and suggests that quality may be more influenced by production techniques than by cultivar.

Cultivars in NFT
The quality and yield of seven cultivars grown intensively by the nutrient film technique (NFT) (Gormley, Maher & Walsh, 1983) were compared. Yields for the cultivars Mondial, Ostona, Shirley, Sonatine and Virosa were fairly similar, while Bellina and Nemato gave lower yields. The cultivars were statistically different in terms of SS, TA, EC, mineral content and firmness but there were no differences in nitrate or β-carotene contents. Despite these differences, no cultivar stood apart from the others and from a practical point of view the differences were not large; SS values ranged from 4·7% to 5·1%, TA from 7·7 to 8·5 meq, EC from 545 to 591 µS cm⁻¹ and firmness from 29 to 32 N m⁻² for a 5 mm fruit compression. These EC values are very low, and seem to follow the general trend suggesting that the intensive growing of tomatoes gives lower EC values. The flavour of the cultivars was considered by taste panels to be similar.

Effects of energy saving
The effects of lining glasshouses with PVC panels ('Windocel') as an energy-saving technique were evaluated. The transmission of photosynthetically active radiation was 59·3% compared with 68·1% for an unlined house, i.e. a reduced light transmission (O'Flaherty & Grant, 1985). However, mean energy saving was 26%, which represents an annual cost saving of IR£2.50 m⁻². This is a favourable figure when set against the reduction in yield, which was estimated as IR£0.60 m⁻². In growing trials over 2 years, lining the inside of a glasshouse with 'Windocel' panels reduced the yield of tomatoes by 18% and 4%. Early yield was not reduced and even tended to be higher in the lined house. As a consequence the loss in crop value due to lining was less than the drop in yield, being 4% and 3% for the 2 years. In these trials, a very high proportion of the fruit was graded as Class One, i.e. round, uniformly coloured, and free from blemish. Lining the glasshouse did not affect the visual quality of the fruit (Maher & Mahon, 1985). The use of the panels had no affect on fruit flavour and mean composition values for fruit from lined versus unlined glasshouses were also similar, i.e. SS 4·8% and 4·8%; TA 8·2 and 8·0 meq; EC 597 µS cm⁻¹; fruit firmness 29 and 31 N m⁻² for a 5 mm fruit compression, respectively (Gormley & O'Sullivan, 1985a).

Effects of plant spacing
The effect of plant spacing (six levels) on yield, quality and composition was investigated using the cv. Marathion in an NFT system (Gormley & Maher, 1984). Plant densities ranged from 2·92 to 1·87 plants per m², with
Tomato handling simulator.

corresponding yields of 15·2 to 11·6 kg per m² to the end of June. High densities gave the most desirable tomato fruit size, but lowering plant density (less intensive) did not markedly affect fruit composition, colour, firmness, flavour or shelf-life. The SS values ranged from 4·4% to 4·7%, TA from 8·4 to 8·8 meq, and EC 667 to 725 µS cm⁻¹ for the six plant density treatments. The incentive to growers to use lower plant densities increases as labour costs rise, but any labour saving has to be balanced against a significant drop in yield. While these results were obtained for tomatoes grown in an NFT system, there is no reason to suspect that the findings would not apply to tomatoes from plants grown at different densities in peat, rockwool, soil or other media.

Testing methods
Three studies were carried out on procedures for analysing and testing tomato fruit quality. The first was an interlaboratory study on the effects of frozen storage on compositional values and came about because tomato cultural trials often result in the production of too many samples to analyse while fresh. The most common technique is to seal them in containers and preserve them by deep-freezing for subsequent analysis. An interlaboratory study was made of the effect of freezing for various lengths of time on a number of compositional factors. Tests for SS, dry matter content, EC, TA, K, pH, glucose, fructose, sucrose, total N and Vitamin C in frozen tomatoes indicated that the levels of most of these constituents remained relatively constant during frozen storage and were similar to values found in the fruit prior to freezing. When the tomatoes were frozen as a puree it was essential to thaw them in the stabilizing/extracting solution used in the Vitamin C analytical procedure, otherwise there was a large loss in ascorbic acid (Burel, Gormley & Roucoux, 1983).

The second study was on the development of a micro-cell for rapid EC measurements on tomato fruit (Gormley, Grant & O’Beirne, 1982). A small portable EC probe was assembled from two platinum wires (0·75 mm in diameter) held 5 mm apart with ‘Araldite’ in a plastic fitting. The wires were connected with leads to the terminals of an EC meter. Insertion of the probe into different parts of an individual tomato fruit gave EC values that varied by over 200%; similarly for measurements within a locule of an individual half-tomato fruit. This suggests that tomato fruit do not lend themselves to direct probe insertion EC measurements. However, the probe was very suitable for measuring the EC of a few drops of undiluted juice pressed by hand from half a tomato into a small plastic cylindrical container (8 mm in diameter) with a volume of 0·45 ml. This rapid technique was validated by testing the other half of each fruit (39 fruit tested) using the so-called ‘cell procedure’ with a ‘full scale’ conductivity meter. The correlation coefficient between EC values from the ‘cell’ and ‘probe’ procedures was + 0·92.

The third test investigated the effects of recompression on tomato fruit firmness.
This came about because, in shelf-life tests, when fruit firmness is measured by compressing the fruit, it may be desirable to recompress the same fruit a number of times to keep the size of the experiment to a practicable scale. Results of tests showed that tomatoes which were recompressed were softer than tomatoes tested only once. Therefore, it was concluded that when absolute data are required it may be necessary to test a replicate set of tomatoes at each time of testing (Gormley & Maher, 1987).

Taste panel tests

Two separate studies were carried out. The purpose of the first study (at four laboratories) (Gormley et al., 1986) was to see if tasters could distinguish between two tomato fruit samples, which had different composition values, when both were tasted as a pair or as single samples on separate days. These two procedures were compared in view of the findings of other workers; for example the single presentation design more closely simulates normal consumer assessment than does comparative evaluation. In addition, in paired comparison testing, a mediocre sample may be considered good when presented alongside a poor quality sample but may be considered unacceptable when presented alongside a good quality sample. The results showed that, in general, taste panelists were able to detect a significant flavour difference between two tomato fruit samples when presented as a paired comparison. However, each sample received a relatively similar score when tasted as a single sample using a seven point scoring system with moderate flavour as the mid-point (assigned a zero score) and very good flavour (+3) and very poor flavour (−3) as the end-points. Obviously, this finding has implications for the future flavour evaluation of tomatoes at laboratory, market and supermarket level.

The second taste panel study involved a comparison of laboratory (33 tasters) and consumer (480 tasters) taste panels. The reasons for carrying out the study were threefold. Firstly, supermarket panels gave unexpectedly high flavour scores (in relation to fruit composition values) to late season tomato fruit in preliminary tests carried out in the authors' laboratories. Secondly, there is little published information on the direct comparison of laboratory and consumer panels and, thirdly, this topic was pinpointed at EEC agro-food workshops as one worthy of investigation. Having said this, the study is only a modest start to a much wider range of tests on different food products that are needed to investigate more fully the relationship between laboratory and consumer taste panels. The results showed that mean flavour scores from taste panelists in a supermarket were higher than those from laboratory tasters on the same set of tomato fruit samples. This suggests that data from laboratory taste panels cannot be extrapolated directly to a market place situation, at least for tomatoes. There was also reasonable agreement between flavour scores of the supermarket panelists. Supermarket panelists in a high socio-economic class area gave less favourable flavour ratings to tomato fruit than those in a low socio-economic class area. Of the two people who presented the samples to the 480 supermarket panelists, one had a tendency to choose older tasters than the other. Full details of this study have been published elsewhere (Gormley, 1989).

Conclusions

The most consistent finding from these tests was the fall-off in tomato fruit quality and composition late in the season in long-season crops and the fact that no treatment or procedure was fully satisfactory for overcoming the problem. The overall results highlight the beneficial effects of an interdisciplinary approach, and also of EEC funding to study tomato fruit production, quality and composition.

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