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Composition and taste of tomatoes as affected by increased salinity and different salinity sources

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SUMMARY
Tomato plants were grown in rockwool slabs under glasshouse conditions at different salinities (3–9 mS cm^{-1}) to improve the taste of tomato fruit without reducing their quality in other respects. NaCl or different combinations of major nutrients (comprising Na, K, Ca, Mg, Cl, NO_3-N, P and SO_4-S) were applied as salinity sources. Increased salinity in the root zone increased the concentrations of dry matter, sugars, titratable acid, vitamin C and total carotene in the tomato fruit, and were in all cases but one independent of salinity source. On a per-fruit basis, no differences in glucose or fructose were found whereas the content of tritratable acid and dry matter decreased with increased salinity. The fruit composition was slightly affected by fruit position within the truss. A trained sensory panel found that NaCl improved the sweetness of tomato fruit more than the other salinity sources. The sensory panel was not able to separate samples from the different treatments by sourness. Fruit firmness increased with increasing salinity but only for measurements on fruit with intact skin.

Many investigations have shown that increased salinity of the nutrient solution supplied to greenhouse tomato plants in soilless culture produces fruit with a higher content of sugars and organic acids and a higher dry-matter percentage providing the basis for better tasting fruits (Adams, 1989; 1991). This is valid for both round and cherry tomato (Gough and Hobson, 1990). In general, increased salinity lowers the yield (kg $plant^{-1}$) because the fruit are smaller (Willumsen *et al.*, 1996) and fewer, the latter being less important than fruit size (Adams, 1991; Adams and Ho, 1989). The type of nutrient elements used to raise the salinity seems to have only little influence on the concentrations of most components in the tomato fruit and the lower water content of fruit appears mainly to be the result of a high osmotic concentration in the nutrient solution of the root zone (Ehret and Ho, 1986).

The aim of the present investigation was to compare yield, quality, composition and taste of tomatoes grown in rockwool slabs irrigated with nutrient solutions of increasing salinity established by adding either NaCl or different combinations of major nutrients. Also the influence of fruit position within the truss was investigated as fruit composition and dry-matter content of cherry tomato were shown to differ for distal and proximal fruit (Hobson *et al.*, 1986). In the present paper the effects on composition and taste are reported. The effects on yield and visible quality have been published previously by Willumsen *et al.* (1996).

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MATERIALS AND METHODS

Plots and treatments

Three experiments were carried out under glasshouse conditions. Experiment 1 was a whole-season crop (13 January–21 October 1988) using the two tomato (*Lycopersicon esculentum* Mill.) cvs Matador and Elin. Experiment 2 was a spring crop (16 January–7 June 1991) on the two cvs Matador and Sunsweet, and experiment 3 was an autumn crop (18 June-5 November 1991) with the one cv., Matador. The plants were grown on rockwool slabs. Different combinations of nutrient elements were added to the nutrient solutions to increase the salinity in the root zone to various levels (Table I). Table I shows the electrical conductivity (EC) determined in the root zone at two- or three-week intervals and averaged for the whole cultivation period for each experiment and cultivar. In all experiments, a complete nutrient solution was used as the control and as the "base level" in the other treatments. Each plot consisted of one double row of 12 plants. Each treatment was replicated three times in experiments 1 and 2 and four times in experiment 3 and arranged in blocks to minimize positional effects within the glasshouse. For each cultivar the treatments were completely randomized within a block. For the analysis of composition and taste all replicates were pooled in experiments 1 and 2 while the two southern blocks

TABLE I

Electrical conductivity (mS cm^{-1}) of solution samples withdrawn from the root zone of the respective cultivars and treatments in experiments 1 (13 January– 21 October 1988), 2 (16 January – 7 June 1991), and 3 (18 June – 1 November 1991). Mean of measurements at 2 or 3 week intervals during the cultivation period

	Experiment 1		Experiment 2		Experiment 3
Supplementary elements	'Matador'	'Elin'	'Matador'	'Sunsweet'	'Matador'
None	3.8	3.6	3.2	4.1	3.7
K,Ca,Mg,N,P,S	5.7	5.2	—	—	—
	8.1	7.2	—	—	—
Na,Cl	6.2	5.6	5.5	6.0	6.7
	7.4	7.5	6.1	—	7.7
	—	—	7.1	—	9.2
Na,N,S	7.5	6.9	—	—	—
K,Ca,Mg,Cl	—	7.6	5.1	5.7	5.5
	—	—	5.2	—	7.4
	—	—	6.5	—	8.7
K,Ca,Mg,Cl,S	—	—	4.6	6.4	5.9
	—	—	5.5	—	7.2
	—	—	7.4	—	8.7

and the two northern blocks, respectively, were pooled in experiment 3. Further details of plots, treatments and cultivation procedures are described in Willumsen *et al.* (1996).

Recording, sampling and analysis

Representative samples of pink and medium red grade 1 fruit (sorted in accordance with Danish and EU standards) were taken out for analyses every fourth week in experiment 1 and every third week in experiments 2 and 3. After further ripening for 5 d at room temperature (20°C) in experiment 1 and 3 d at 20°C in experiments 2 and 3, the fruit samples were analysed. In experiment 3, each fruit was divided into equal distal and proximal halves before chemical analysis.

Before destructive analyses of the fruit, the surface colour characters *L*, *a* and *b* were determined on a HunterLab colorimeter and the firmness (N) was measured by an Instron table model. For Instron measurements a 8 mm cylindrical puncture probe with convex end was used, with a loadcell from 5 to 50 kg and a crosshead speed and chart speed of 50 mm min^{-1}. In experiment 1, firmness was measured on tomatoes with intact skin and in experiment 2 on fruit where the skin was peeled off at the insertion point of the puncture probe. In experiment 3, firmness was measured both with and without peeling off the skin. Soluble solids were measured on filtrates of blended samples in a Bausch and Lomb refractometer and expressed as g sucrose per 100 g fresh weight. Titratable acids were determined on blended samples titrated to pH 8.1 with 0.1 N NaOH using a Mettler DL 4 automatic titrator and were expressed as g citric acid per 100 g fresh weight. Total ascorbic acid was determined by use of the dichlor-indophenol titration method (Pongraz, 1971).

Before analysis of total carotene ($\alpha + \beta$), samples were blended in darkness under argon. Carotenoids were extracted from frozen samples by acetone and ultrasonic disintegration and total carotene was determined on a Shimadzu HPLC. Samples were run on a Supelcosil LC-18-DB column, at a 1 ml min^{-1} flow rate, and the mobile phase was 30% acetonitrile, 60% tetrahydrofurane and 10% water. The chromatogram was monitored at 450 nm.

In experiments 2 and 3, the contents of glucose and fructose were determined on a Shimadzu HPLC by an Aminex column from BIO-RAD. The column support material was sulfonated divinyl benzene-styrene copolymer in an ionic form with lead and particle size 9 μm. The mobile phase was water and the column temperature 85°C.

Dry-matter percentage after 16 h at 80°C in a ventilated oven was also determined as well as the pH and electrical conductivity of blended fruit.

Tomato taste and firmness were assessed organoleptically by a trained taste panel using an incomplete block design with 11 or 12 panelists each evaluating six samples. Tomatoes were divided into six pieces and each panelist was served samples comprising several pieces from different tomatoes within a treatment. Samples were served together with a glass of water and a cream cracker. The sensory technique used was a scoring method in which the intensities of sweetness, sourness, aroma and firmness by biting were assessed by use of a scale from 0 = none or very soft to 10 = very intensive. Analysis of variance by the general linear models (GLM) procedure of SAS (SAS Institute, 1988) was possible only for data from experiment 3 due to the lack of replicated fruit samples in experiments 1 and 2. In experiments 1 and 2 confidence intervals were calculated.

In experiment 2, the effect of fruit position within the truss on composition and mineral content of 'Matador' and 'Sunsweet' was investigated. Fruit from the control treatment were divided into three categories: 1. fruit number 1 and 2 (proximal fruit), 2. fruit number 3 and 4, and 3. fruit number 5 and 6 (distal fruit) from the main stem. Samples were taken twice during May and the firmness without skin, surface colour, titratable acid, soluble solids, pH and dry-matter content were determined as described above. Contents of K, Ca, Na and Mg

TABLE II
Correction equations ($y = a + bx + cx^2$) used in experiment 3. The measured variables were corrected to the same red colour a = 30. R^2 indicates the regression coefficient

Variable	a	b	c	R^2	P
L	54.55	−0.462	—	0.96	0.0001
b	26.91	−0.060	—	0.53	0.0001
Firmness (−skin)	2.54	−0.068	—	0.97	0.0001
Firmness (+skin)	3.90	−0.073	—	0.98	0.0001
Vitamin C	14.33	—	0.003	0.63	0.0001
Titratable acid	0.53	−0.003	—	0.92	0.0001
Fructose	1.36	0.006	—	0.32	0.0026
Soluble solids	3.33	0.018	—	0.46	0.0002

were determined by atomic absorption spectrophotometry.

Because variation in ripeness between fruit samples was observed in experiments 1 and 2, correction to the same stage of ripeness was made in experiment 3. At the end of October, samples at the mature green stage were picked from the guard rows (control treatment) on 13 successive days and kept at 20°C. All samples were analysed on the same day as described above for experiment 3 except that the sensory evaluation was excluded. In this way analyses of fruit at all stages of ripeness from the mature green stage to table ripe fruit were available. From these data, correction equations were calculated by the use of SAS, proc GLM (SAS Institute, 1988), but only if there was a linear or quadratic relationship (Table II). Correction was made to the same red colour (a = 30) assuming that '*a*' was not significantly influenced by increased salinity. The *a* value is the HunterLab co-ordinate for green when negative and red when positive.

RESULTS

Surface colour and firmness

In experiment 3, the yellow colour (*b*) and the lightness (*L*) of fruit decreased significantly with salinity (Figure 1) but were not affected by the source of salinity.

In experiment 1, firmness was measured on fruit with intact skin and it tended to increase with salinity (Figure 2a). No clear effect of salinity on firmness was found in experiment 2 (Figure 2b) where it was measured on fruit without skin. Firmness was measured twice on the same fruit in experiment 3: first on an area where the skin was peeled off, thereafter on an area with intact skin, both measurements between walls. When the fruit samples were corrected to the same stage of ripeness, a significant

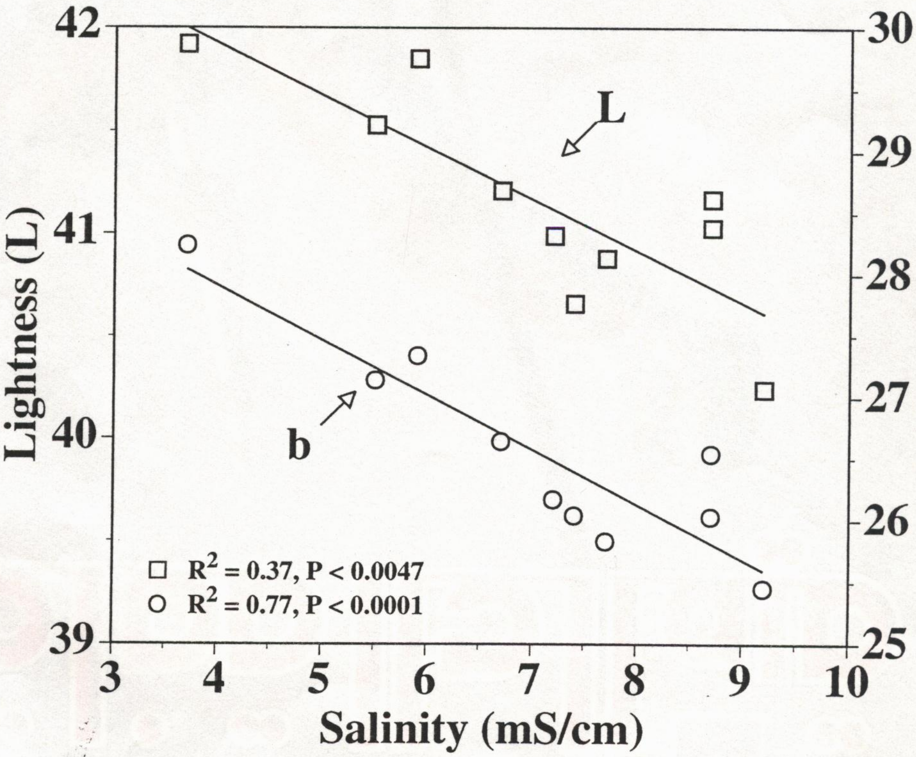

FIG. 1
The influence of increased salinity on yellow colour *b* and lightness *L* of tomato fruit. Mean of determinations at three-week intervals for cv. Matador in experiment 3.

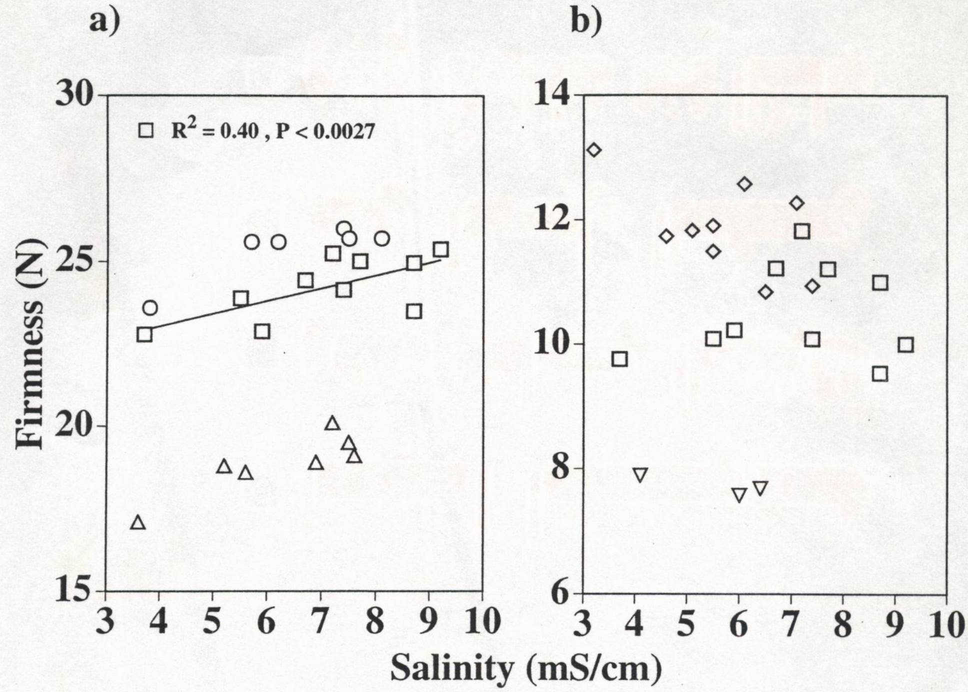

FIG. 2
Firmness measured on fruit with intact skin (a) or without skin (b) as affected by increased salinity. ○ = 'Matador' and △ = 'Elin' experiment 1, ◇ = 'Matador' and ▽ = 'Sunsweet' experiment 2 and □ = 'Matador' experiment 3. Mean of determinations at three- or four-week intervals.

increase in firmness with salinity was found only for measurements on fruit with intact skin (Figures 2a and b). Fruit firmness was unaffected by the source of salinity.

It was confirmed that the tomato cv. Matador is firmer than 'Sunsweet' and 'Elin' (Figure 2). The colour values (Figure 1) together with the firmness (Figure 2) indicate less ripe fruit samples of 'Matador' in experiment 2 and possibly in experiment 1 compared with those of experiment 3. The mean values for L, a and b were L = 40.7, a = 26.6 and b = 27.6 in experiment 2 and L = 41.2, a = 30 and b = 26.5 in experiment 3. They were not measured in experiment 1.

Composition

The dry-matter content (%) of fruit increased with salinity in experiment 3 (Figure 3a), but there was no effect of salinity source. The same trend was seen in experiment 2 (not shown). When the dry-matter

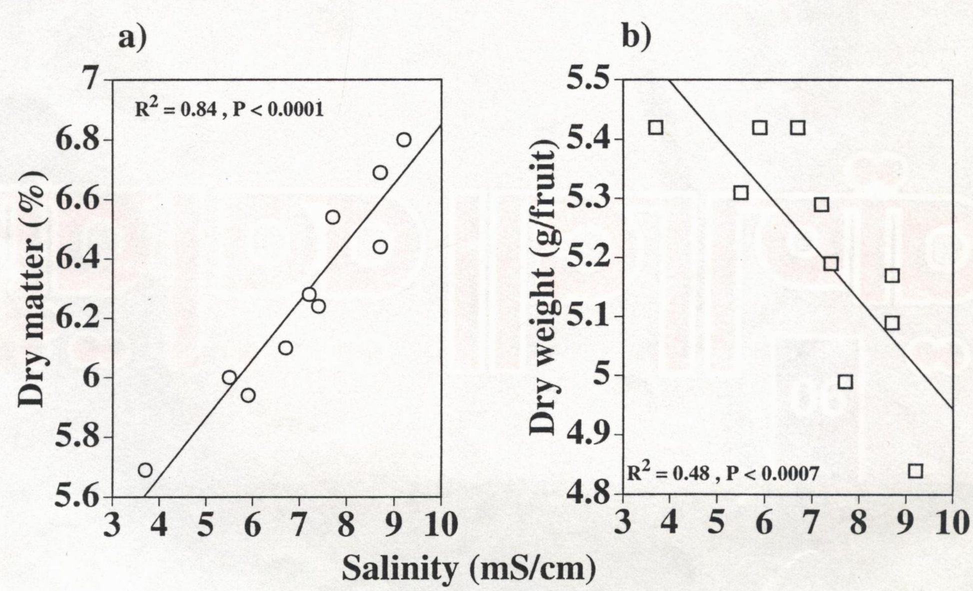

FIG. 3
The influence of increased salinity on (a) the percentage of fruit dry matter and (b) g dry matter per fruit. Mean of determinations at three-week intervals for cv. Matador in experiment 3.

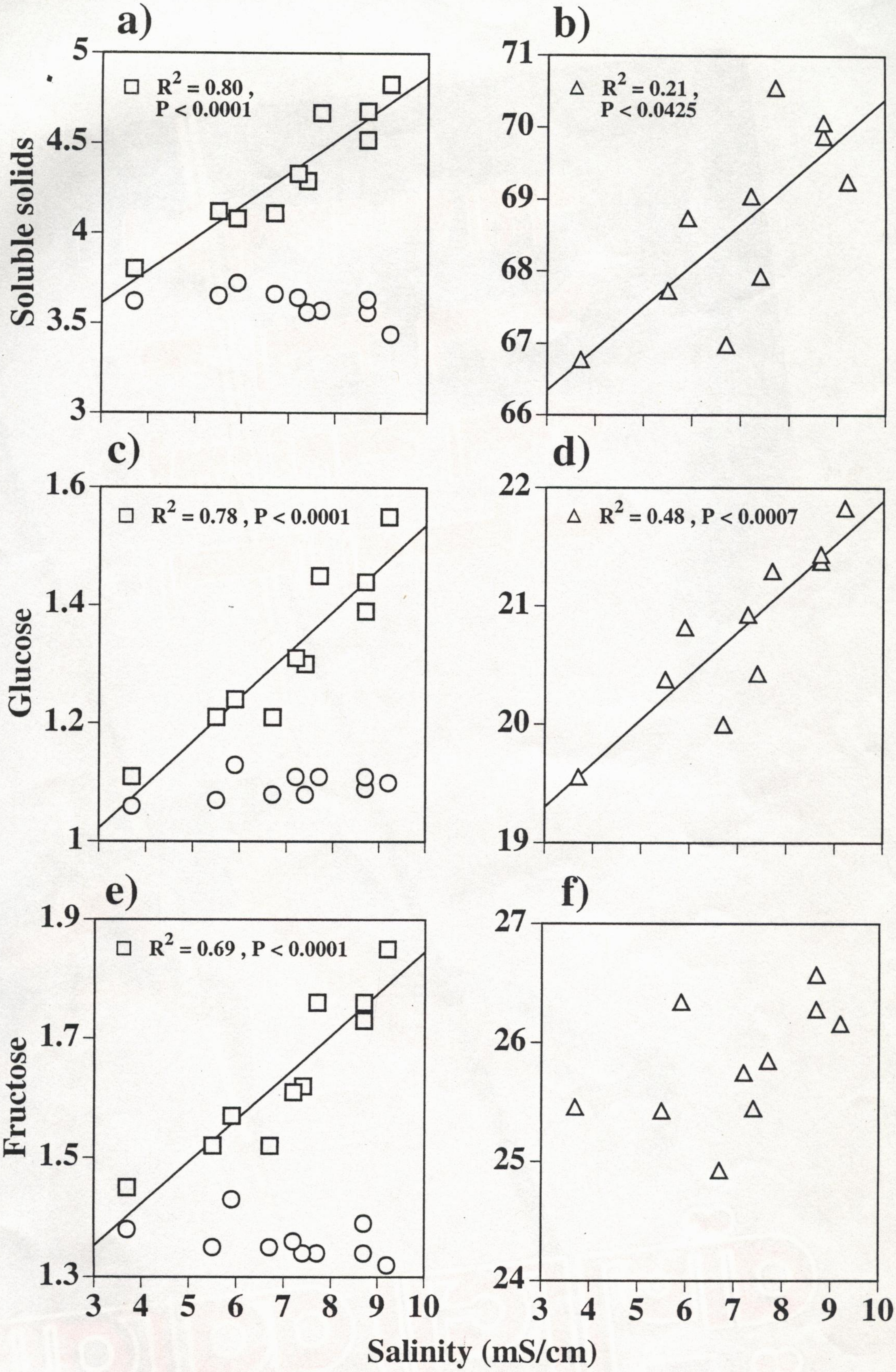

FIG. 4

The influence of increased salinity on the fruit content of soluble solids (a) and (b), glucose (c) and (d) and fructose (e) and (f) calculated as □ = g per 100 g fresh weight, ○ = g per fruit or △ = g per 100 g dry matter. Mean of determinations at three-week intervals for cv. Matador in experiment 3.

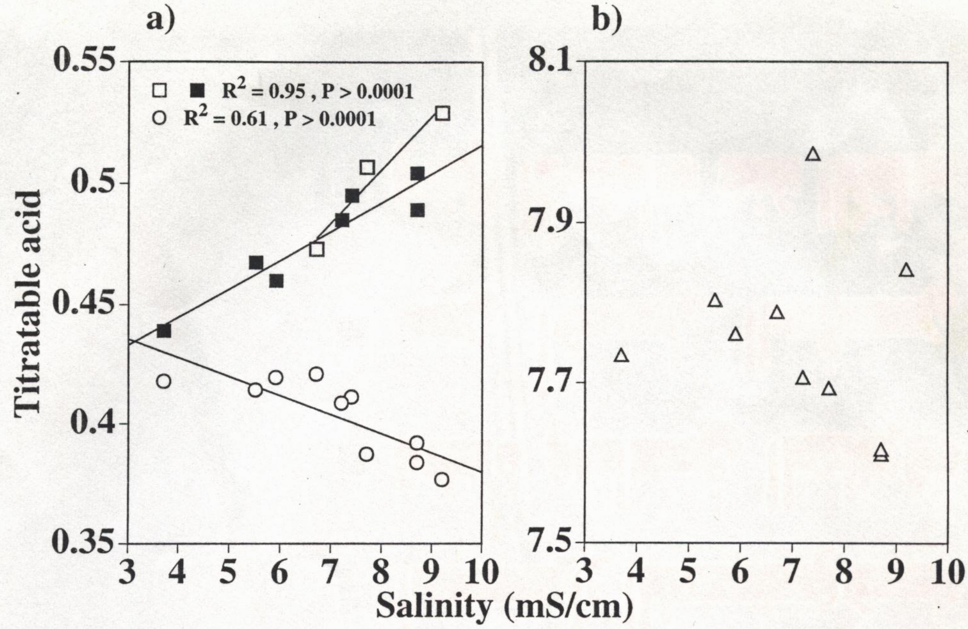

FIG. 5
The influence of increased salinity on the fruit content of titrable acid calculated as (a) □ (NaCl) or ■ (other supplementary salts) = g citric acid per 100 g fresh weight, ○ = g citric acid per fruit, or (b) △ = g citric acid per 100 g dry matter. Mean of determinations at three-week intervals for the cv. Matador in experiment 3.

content was calculated as g per fruit, it decreased with salinity (Figure 3b).

In experiment 3, there was little effect of the different combinations and concentrations of supplementary salts on the total concentration of minerals in fruit dry matter (Willumsen *et al.*, 1996). When NaCl was used to increase the salinity, the sodium and chloride concentrations of both the distal and proximal part of the fruit increased with increased salinity (P<0.001). In experiment 1, $NaNO_3$ + Na_2SO_4 also resulted in an increased level of Na per g dry matter. Generally, application of supplementary salts containing chlorides increased the concentration of Cl in fruit dry matter.

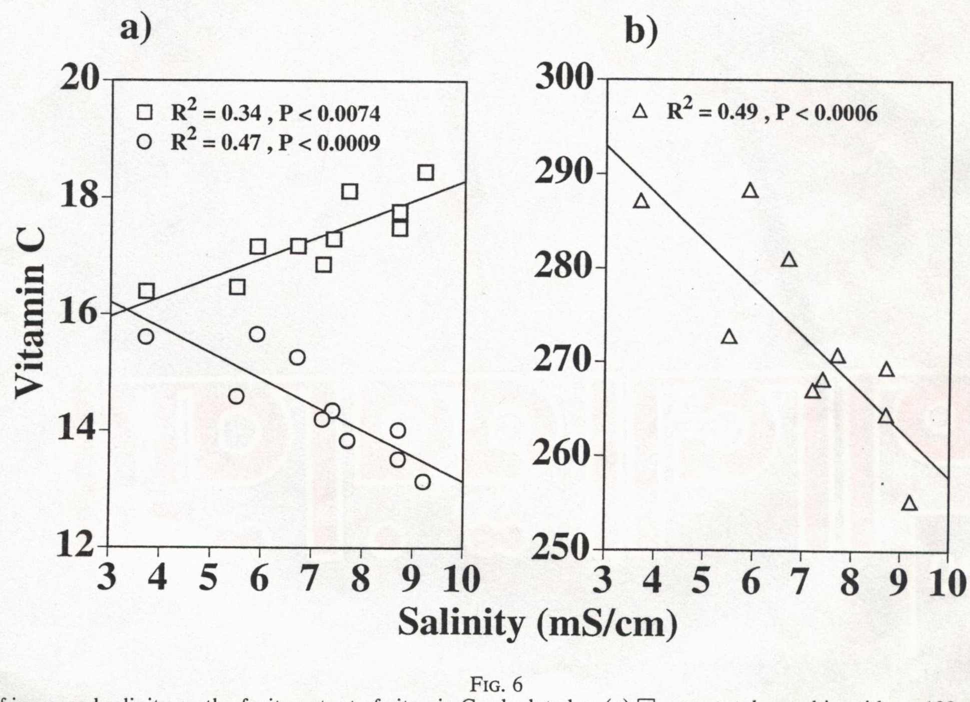

FIG. 6
The influence of increased salinity on the fruit content of vitamin C calculated as (a) □ = mg total ascorbic acid per 100 g fresh weight, ○ = mg total ascorbic acid per fruit, or (b) △ = mg total ascorbic acid per 100 g dry matter. Mean of determinations at three-week intervals for cv. Matador in experiment 3.

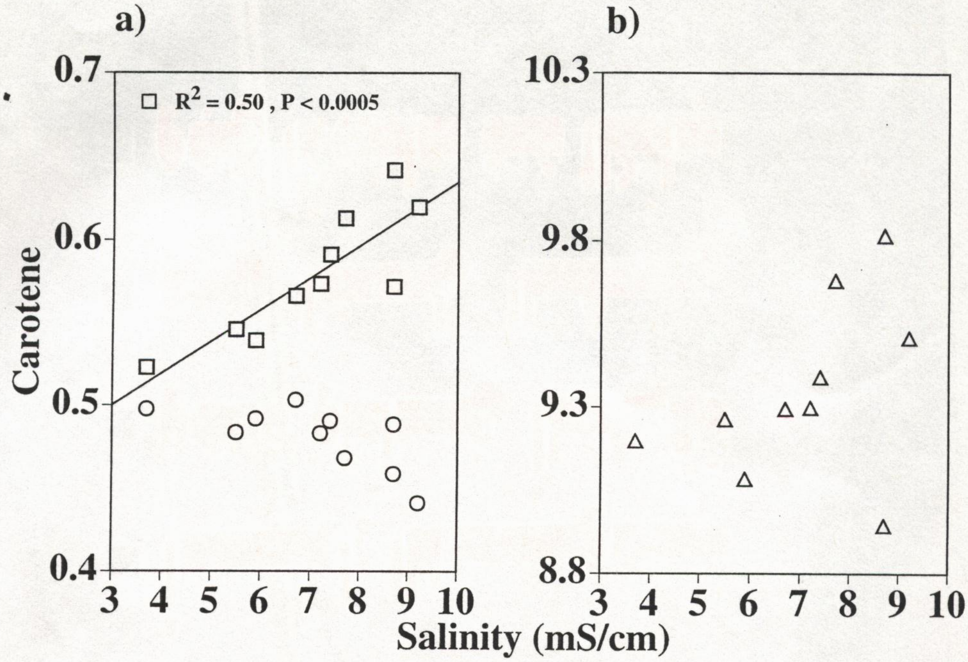

FIG. 7
The influence of increased salinity on the fruit content of total carotene calculated as (a) □ = mg per 100 g fresh weight, ○ = mg per fruit, or (b) △ = mg per 100 g dry matter. Mean of determinations at three-week intervals for cv. Matador in experiment 3.

The concentrations of glucose, fructose and soluble solids in g per 100 g fresh weight increased significantly with salinity in experiment 3 (Figures 4a, c, e). The same trend was found in experiments 1 and 2 (not shown). If calculated per 100 g dry matter, the concentrations of glucose and soluble solids also increased significantly with salinity (Figures 4b, d). The salinity did not affect the content of glucose, fructose or soluble solids when calculated as g per fruit (Figures 4a, c, e). The content of sugars was unaffected by the salinity source added to increase the salinity in the root zone. Only minor differences in the levels of fructose and glucose between experiments 2 and 3 were found, and there was little difference in fructose and glucose concentrations (g per 100 g fresh weight) between 'Matador' and 'Sunsweet'.

The concentration of titratable acid expressed in g citric acid per 100 g fresh weight increased with salinity in experiment 3 (Figure 5a). The same trend was found in experiments 1 and 2 (not shown). When the concentration was calculated as g per 100 g dry matter there was no difference in the concentration of titratable acid between treatments in experiment 3 (Figure 5b), but the content in g per fruit significantly decreased with increasing salinity (Figure 5a). An effect of salinity source was seen only when the concentration of titratable acid was calculated on a fresh-weight basis. In this case, sodium chloride increased the concentration of

TABLE III
Sensory evaluation of sweetness, sourness, aroma and firmness of ripe tomato fruit of experiment 1, rated from 1 to 10 where 10 = most intensive. Means of estimations at four-week intervals from 18 April to 17 October 1988. The EC was measured in the root zone. 95% confidence intervals of the means are given in parenthesis

a) *'Matador'*

Supplementary elements	EC mS/cm	Sweetness 1–10	Sourness 1–10	Aroma 1–10	Firmness 1–10
None	3.8	3.7(±0.3)	3.6(±0.5)	4.4(±0.3)	6.7(±0.3)
K,Ca,Mg,N,P,S	5.7	4.2(±0.3)	4.1(±0.4)	4.9(±0.3)	6.9(±0.3)
	8.1	4.9(±0.3)	4.6(±0.4)	5.5(±0.3)	7.0(±0.3)
Na,Cl	6.2	4.5(±0.3)	4.3(±0.4)	5.4(±0.3)	6.9(±0.3)
	7.4	4.6(±0.3)	4.3(±0.5)	5.4(±0.3)	6.9(±0.3)
Na,N,S	7.5	4.8(±0.3)	3.9(±0.4)	5.7(±0.3)	6.9(±0.3)
K,Ca,Mg,Cl	—	4.5(±0.3)	4.2(±0.4)	5.1(±0.3)	6.5(±0.3)

b) *'Elin'*

Supplementary elements	EC mS/cm	Sweetness 1–10	Sourness 1–10	Aroma 1–10	Firmness 1–10
None	3.6	4.4(±0.3)	3.6(±0.4)	5.1(±0.2)	4.5(±0.3)
K,Ca,Mg,N,P,S	5.2	4.3(±0.3)	3.9(±0.4)	5.0(±0.3)	5.1(±0.3)
	7.2	4.5(±0.3)	3.9(±0.4)	5.1(±0.3)	5.6(±0.3)
Na,Cl	5.6	4.7(±0.3)	4.0(±0.4)	5.3(±0.3)	5.4(±0.3)
	7.5	4.9(±0.3)	3.9(±0.4)	5.6(±0.3)	5.8(±0.3)
Na,N,S	6.9	4.6(±0.3)	4.0(±0.5)	5.5(±0.3)	5.6(±0.3)
K,Ca,Mg,Cl	7.6	4.7(±0.4)	4.1(±0.4)	5.5(±0.3)	5.5(±0.3)

TABLE IV

Sensory evaluation of sweetness, sourness, aroma and firmness of ripe tomato fruit in cv. Matador from experiment 3, rated from 1 to 10 where 10 = most intensive. Means of estimations at three-week intervals from 19 August to 5 November 1991. The EC was measured in the root zone. Within each column, values followed by the same letter do not differ significantly at P = 0.05

Supplementary elements	Ec mS/cm	Sweetness 1–10	Sourness 1–10	Aroma 1–10	Firmness 1–10
None	3.7	5.1 b	4.4 a	5.4 afg	5.8 a
	3.7	4.9 b	4.5 a	5.4 afg	6.0 ab
Na,Cl	6.7	5.0 b	4.5 a	5.8 cdgk	6.2 bc
	7.7	5.7 a	4.5 a	6.1 cdek	6.5 cd
	9.2	5.8 a	4.6 a	6.3 de	6.6 d
K,Ca,Mg,Cl	5.5	4.9 b	4.7 a	5.5 acfg	6.5 cd
	7.4	4.9 b	5.1 a	5.7 acfgk	6.4 cd
	8.7	5.1 b	5.0 a	6.0 cdek	6.6 cd
K,Ca,Mg,Cl,S	5.9	4.8 b	4.6 a	5.6 acfgk	6.4 cd
	7.2	5.1 b	4.8 a	5.8 cdfgk	6.6 d
	8.7	5.2 b	4.6 a	5.9 cdgk	6.3 bd

titratable acid more than the other salts at high salinities (Figure 5a). 'Sunsweet' contained more, and 'Elin' less, titratable acid than 'Matador'.

The vitamin C concentration expressed as mg total ascorbic acid per 100 g fresh weight increased with salinity in experiment 3 (Figure 6a). However, the vitamin C content decreased with salinity when calculated either per fruit (Figure 6a) or per 100 g dry matter (Figure 6b). There was no effect of salinity source. Only minor differences were seen in the other two experiments and only small differences in vitamin C levels were found between cultivars. 'Matador' had a slightly higher content (26.7 mg/100 g fw) than 'Elin' (23 mg/100 g fw) in experiment 1 when means of all treatments and harvest days are compared. 'Sunsweet' did not differ from 'Matador' (experiment 2).

The concentration of total carotene in mg per g fresh weight increased significantly with salinity in experiment 3 (Figure 7a). There was no significant effect of salinity when the carotene content was calculated as mg per 100 g dry matter or as g per fruit and there was no effect of the source of salinity. The level of carotenes in 'Matador' was low compared with 'Elin' (0.44 mg per 100 g dry matter compared with 0.55) and 'Sunsweet' (0.42 mg per 100 g dry matter compared with 0.62).

Sensory evaluation

Irrespective of the source of salinity, increased salinity resulted in sweeter and more aromatic fruit of 'Matador' in experiment 1 (whole season crop; Table III). In experiment 3 (autumn crop), especially sodium chloride at the two highest salinity levels resulted in tomato fruit which were sweeter (Table IV), whereas no differences were achieved in experiment 2 (spring crop). Neither the sweetness nor the aroma of 'Elin' (Table III) and 'Sunsweet' were significantly influenced by increased salinity.

Sourness was generally difficult to assess, resulting in a high internal variation (Table III and IV). No consistent differences in sourness were found.

The score for organoleptically assessed firmness was in general increasing with salinity, although, only significantly for 'Elin' (experiment 1; Table III) and 'Matador' (experiment 3; Table V). Significant effect of harvest date was seen for all characters evaluated.

Position within the truss

No effect on surface colour, firmness and soluble solids was seen in relation to fruit position within the truss, in either 'Matador' or in 'Sunsweet'. In 'Sunsweet', the proximal fruit contained less titratable acid but more dry matter than the distal fruit (Table V). The same tendency was seen in 'Matador' although it was not statistically significant. The concentration of K in fruit (mg per kg fresh weight)

TABLE V

The influence of fruit position within a truss on the concentrations of minerals, titratable acid, soluble solids and dry matter in the control treatment of experiment 2. Positions 1, 2 and 3 indicate fruit number 1 + 2, 3 + 4 and 5+ 6 from the main stem, respectively

Position	K × 1000 mg/kg fw	Ca mg/kg fw	Na mg/kg fw	Mg mg/kg fw	Titratable acid g citric acid /100 g fw	Dry matter %
a) *'Matador'*						
1	2.957	82.4	51.7	81.2	0.482	6.17
2	3.082	71.3	62.4	90.2	0.509	6.12
3	3.147	68.5	61.3	93.5	0.521	6.04
$LSD_{0.05}$	0.128	n.s.	2.9	2.1	n.s.	n.s.
b) *'Sunsweet'*						
1	2.573	77.9	29.5	76.9	0.483	5.91
2	2.652	74.7	33.7	80.5	0.511	5.89
3	2.737	71.4	35.2	85.9	0.533	5.73
$LSD_{0.05}$	0.137	n.s.	n.s.	n.s.	0.019	0.09

increased significantly from the proximal to the distal fruit in both cultivars (Table V). The concentrations of Mg and Na also increased whereas the Ca concentration tended to decrease from the proximal to the distal fruits, both when calculated as mg per kg fresh weight (Table V) and as g per 100 g dry matter (not shown).

DISCUSSION

It is important but very difficult to achieve fruit samples at the same stage of ripeness. Both within and between samples variation of considerable magnitude can occur. We found it most difficult at the higher salinity levels to collect enough fruit for even samples due to the reduction in fruit yield. To overcome this problem a great surplus of fruit from all plots must be ensured, as stated by Winsor (1979), and the fruit used for compositional and sensory evaluation should be strictly selected for instance by the same *L*, *a* and *b* colour values. It would also be valuable for the estimation of firmness where relatively small differences between treatments can be obscured by differences in ripeness. The slightly firmer fruit (11.87 N) of 'Matador' in experiment 2, for instance, was related to a slightly higher *L* value and a lower *a* value, compared with experiment 3 where the firmness was 10.5 N. This is in agreement with Shewfelt *et al.* (1987).

In our experiments, a difference in firmness between high and low salinity could only be found if the skin was intact, indicating a tougher skin on fruit grown at high salinity. In a Dutch investigation (Verkerke and Gielesen, 1991), it was found that the pericarp of tomatoes grown at increased salinity (7.0 mS cm^{-1}) consisted of smaller cells with thicker walls which could explain why firmer fruit and a longer keeping quality were obtained. However, the better keeping quality in their investigation was more likely due to an increased concentration of potassium in the fruit rather than to the increased salinity. This is in accordance with Voogt (1988) who found that shelf life was improved by increased potassium levels in the fruit. In the present investigation, shelf life was not improved by increasing the salinity with combinations of salts which did not alter the fruit K content much (Willumsen *et al.*, 1996).

Firmness assessed by sensory evaluation was in our experiments only slightly correlated with firmness determined by Instron puncture test. The correlation coefficient was $R^2 = 0.23$ ($P<0.01$) for fruit with intact skin and $R^2 = 0.38$ ($P<0.0001$) when the skin was peeled off. There was no correlation between firmness assessed organoleptically and the difference between Instron measurements on the same fruit with and without the skin peeled off. This indicates that the taste panel did not only judge firmness from skin toughness.

In the present experiments, raised salinity improved the fruit composition in terms of a better taste. In agreement with other investigations, the concentrations of dry matter, sugars, titratable acid and vitamin C increased with salinity when calculated on the basis of fresh weight (Adams and Ho, 1989; Adams, 1991). Per fruit, no differences in glucose, fructose or soluble solids content were found, whereas the content of titratable acid and dry matter decreased with increasing salinity. This was also found by Adams and Ho (1989). Recalculation of the data from experiment 3 on the basis of dry matter showed, unlike Adams and Ho (1989) and Ehret and Ho (1986), that raised salinity increased the concentrations of glucose and soluble solids.

The various supplementary salts tested did not generally differ in their ability to improve fruit composition, probably because the ion activity ratios $a_K/\sqrt{a_{Ca} + a_{Mg}}$ and a_{Mg}/a_{Ca} in the nutrient solutions supplied were kept almost the same for all treatments (Willumsen *et al.*, 1996). Contrary to our results, Adams (1991) found that addition of NaCl increased the concentration of reducing sugars more than addition of major nutrients, whereas the concentration of titratable acid increased more with major nutrients than with NaCl. The effect of salinity source on titratable acid content found in the experiment of Adams can be explained by a much higher ion activity ratio $a_K/\sqrt{a_{Ca} + a_{Mg}}$ in the root zone when major nutrients were applied to increase the salinity (Willumsen *et al.*, 1996). The higher ion activity ratio facilitated the potassium uptake and consequently a higher potassium level in the fruit, which is known to be followed by an increased concentration of titratable acid (Voogt, 1988; Adams and Ho, 1993).

A close correlation between the glucose and fructose concentrations was found, in agreement with Petersen and Willumsen (1992). The concentration of fructose was always higher than that of glucose.

In experiment 3, a taste panel scored the fruit from the two highest salinity levels of NaCl as significantly sweeter than fruit from all other treatments. These were also the two treatments out of three scoring highest values for aroma. Contrary to sweetness and aroma, the taste panel could not significantly separate fruit from the different salinity levels by their acidity, although there was a significant increase in the concentration of titratable acid per 100 g fresh weight with increased salinity. Others have also found that taste panels respond more to sweetness than to acidity (Gough and Hobson, 1990), perhaps because an increase in sugar concentration will overshadow a parallel increase in acid concentration. In agreement with Hobson *et al.* (1990) the tomato fruit from experiment 3 grown at increased salinity with NaCl obtained higher scores than fruits where major nutrients were added. The reason why fruit from the two highest levels of NaCl were judged sweeter and with more aroma could be the higher concentrations of Na and Cl in the fruit. NaCl is known to enhance the taste of food by enhancing the perception of sweetness and by improving the flavour balance and the overall flavour intensity (Gillette, 1985).

Sensory evaluation of fresh tomato fruit is very difficult, when the taste panel has to value one or more flavour or texture characters according to a scale. In two separate investigations (Müller-Haslach and Arold, 1986; Gormley and Maher, 1990) consumers or trained taste panels could discriminate between two tomato cultivars when a paired comparison test was used, but only occasionally when both samples were rated after a scale at the same time. When two samples were rated at different times, no differences were found.

To remember from one sensory evaluation to the next, with three-week intervals, is impossible for most panel members. At least an internal standard has to be included, but tomato taste changes during the harvest season and freezing down a standard is not possible when evaluating a fresh product. Therefore, an absolute standard is impossible. A better design might be a kind of ranking for each flavour and texture character at each time of evaluation, with a relative standard at a fixed position on a scale whose upper and lower limits are equal to the maximum and minimum scores of the sensory evaluation in question. In the present experiments, one of the samples from the control treatment might have been a possible standard.

The distal fruit within a truss had a slightly higher concentration of titratable acid in the fruit juice. This was also true when calculated as mg per g dry matter (not shown). The higher concentration of titratable acid in fruit farthest from the main stem was correlated with higher K concentrations, which is a well-known relationship (Voogt, 1988; Adams and Ho, 1993). Although only significant for Mg in 'Matador', there was a clear tendency in both cultivars that the Mg concentration increased, whereas the Ca concentration decreased the farther from the main stem the fruit was positioned. The same was found by Ho and Adams (1989) for both low and high salinity levels. This may indicate that the first developed fruit within a truss is less likely to develop blossom-end rot than the last developed. The dry-matter content slightly decreased in 'Sunsweet' from the proximal to the distal fruit, which agrees with Hobson *et al.* (1986) and Ho *et al.* (1982/83).

Conclusions

The experiments confirm that fruit firmness and the concentrations of dry matter, soluble solids, fructose, glucose, titratable acid, carotene and vitamin C in the fresh fruit are increased with increasing salinity thus improving the taste and quality of the fruit. The results indicate that the increases in fruit components are independent of the source of salinity if it is followed by only minor changes of the ion activity ratios $a_K/\sqrt{a_{Ca} + a_{Mg}}$ and and a_{Mg}/a_{Ca} in the root zone.

Increasing the salinity with sodium chloride improves the sensory evaluation of sweetness of tomato fruit more than other salinity sources, although no differences in dry matter, soluble solids, glucose, fructose or titratable acid are found. The reason could be the capability of sodium chloride to enhance the sensory perception of sweetness and to improve the flavour balance and the overall flavour intensity.

The fruit position within a truss slightly affects the chemical composition of the fruit. The concentration of calcium in the distal fruit tended to be lower than in the proximal ones indicating that blossom-end rot is more likely to develop in fruit at the end of the truss than in the fruit close to the main stem.

When firmness and fruit composition of different fruit samples are compared it is important that the samples are at the same stage of ripeness. Otherwise corrections of the results should be made, for instance to the same red colour as shown in the present study.

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