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CHEMICAL COMPOSITION OF TOMATOES AS AFFECTED BY MATURITY AND FERTIGATION PRACTICES

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ABSTRACT

The objective of this study was to determine the effect of various fertigation practices and maturity stages on tomato fruit composition. Soluble solids, reducing sugar content, and sugar/acid ratio of tomatoes increased with maturity. Fertigation treatments had less of an effect on the chemical composition of the fruit than the stage of maturity. Mineral (P, K, Ca, Mg) levels of tomato fruits in fertigated treatments were higher than in the control plot treatments receiving no supplemental water during the production season. Ascorbic acid content in whole mature-red fresh tomatoes was 13.24% and 25.71% higher than that in mature-pink and mature-light pink tomatoes, respectively. The locule section contained more ascorbic acid than other parts of the fruit at maturity. Intensive mineral fertigation and harvesting at the ripe stage contributes toward higher nutritional quality in fresh tomatoes.

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INTRODUCTION

A substantial amount of the tomatoes for the fresh market and the processing industry are produced in Southern Ontario, Canada. In addition to yield and disease resistance, nutritional value of tomato fruits has been of increasing concern. Processing companies and growers are interested in maximizing processing tomato yields but, at the same time, there is sufficient justification to optimize nutritional value of the tomato fruits. There is an economic concern within the processing industry regarding the quality of the tomato fruit, especially when produced with irrigation or fertigation, to enhance yields. The concern is to avoid diluting the fruit dry matter with excessive water from irrigation or fertigation. Tomato fruit quality could be affected by rates of fertilization, irrigation, and soil composition (Mullins and Wolt 1983; Johnson *et al.* 1992; Hartz 1993). The effect of five mineral nutrients (P, K, Ca, Mg, N) on the yield of greenhouse tomatoes was reported by Winsor *et al.* (1967). Varis and George (1985) reported increased yields of field tomatoes with high N and P levels. Fruit quality and chemical composition differences among greenhouse tomato cultivars were affected by fertilizers (Gull *et al.* 1977).

Although the effects of mineral nutrients on tomato fruit production have been widely investigated (Cook 1972), there is little information on the effect of mineral levels in fertigation on the chemical composition of tomato fruits. The objective of the present study was to determine the effect of various fertigation treatments (various concentrations of soluble minerals in the irrigation water) and of maturity stages on the chemical composition of processing tomato fruits.

MATERIALS AND METHODS

Materials

Plum tomatoes, *Lycopersicum esculentum,* var. *Heinz* 9478, were grown at the Greenhouse and Processing Crop Research Centre, Agriculture and Agri-Food Canada, Harrow, Ontario. Tomato fruits produced with different mineral levels were harvested at different maturity stages. After harvest, the tomatoes were stored at 5C until use.

Fertigation Treatment

The tomato plants, were transplanted into Fox Sandy Loam soil in Harrow, Ontario, Canada, on May 23, 1996. The tomatoes were planted on 1m wide raised beds. Fertigation treatments were begun on June 6, 1996. All of the fertigation treatments received more than sufficient nitrogen (N), phosphorus (P) and potassium (K) for a potentially high yielding crop.

Different mineral levels of the fertigation treatments, including N, P, K, Ca and Mg, are summarized in Table 1.

TABLE 1.
FERTILIZER APPLICATION RATE THROUGH FERTIGATION (KG/HA)

Trt.	June 6-July 17		July 18-Aug. 21		Total		P	Ca	Mg
	N	K	N	K	N	K			
1	143	215	117	175	260	390	67	80	53
2	143	215	25	258	169	390	67	80	53
3	139	208	97	586	236	794	67	80	53
4	143	215	58	88	201	302	67	80	53
5	143	215	13	134	156	349	67	80	53
6	143	208	49	296	188	504	67	80	53
7	0	0	0	0	0	0	0	0	0

*Preplant soil incorporated, N for #7 (control) was 150 N and 225 K (kg/ha). The fertigated plots received 25 kg/ha N and 37 kg/ha K, applied preplant incorporated into the soil, in addition to that applied, as stated above, through fertigation. After July 18, Treatments #4, #5 and #6 received one half the volume of water that Treatments #1, #2 and #3 received.

Maturity Stage

Three maturity stages including mature-red (MR), mature-pink (MP) and mature-light pink (MLP) were assigned to tomato samples based on the overall color of the fruits.

Analytical Procedure

The chemical composition of whole tomatoes as well as the mesocarp, locule, and core was determined. The effect of maturity stage on the chemical composition of tomatoes was also determined. Tomato samples were sliced and homogenized in an Ultra turrax homogenizer (8 mm T25 axis, 13500 rpm) prior to analyses. Triplicated samples were used in each test.

The total solids of each sample were determined by vacuum-drying at 55C for 8 h. Ash contents were measured by incinerating the samples in a muffle furnace at 550C for 12 h. The total titratable acidity was determined using 0.1 N NaOH solution (AOAC 1990). Acidity was expressed as g citric acid monohydrate per 100 g of fresh weight. Soluble solids was determined by a hand refractometer (ATAGO N1, Japan). Fehling's reagent method was used to determine the reducing sugar in the juice samples. Ascorbic acid content was determined by the 2, 6-dichlorophenol indophenol method. The pH value of pureed tomatoes was determined with a pH metre (Accumet 915, Fisher Scientific). The total nitrogen content was determined by the Kjeldahl method (AOAC 1990). The mineral (P, K, Ca, Mg) content of tomatoes was analyzed by a Varian Spectra 300 Automatic Absorption Spectrophotometer.

Statistical Analysis

Data were analyzed using analysis of variance in the General Linear Model of the Statistical Analysis System (SAS Institute, Inc. 1988) to identify treatment effects. The T test procedure was used to test for significant differences between means.

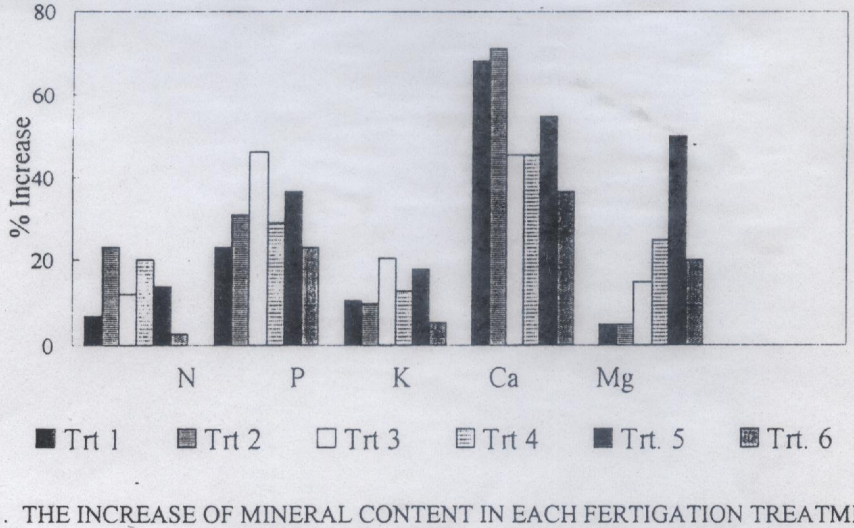

FIG. 1. THE INCREASE OF MINERAL CONTENT IN EACH FERTIGATION TREATMENT COMPARED WITH THE CONTROL

RESULTS AND DISCUSSION

Effect of Fertigation Treatments on Chemical Composition

Compared with the control plot, the mineral content in the fertigation treatments were higher than in the control tomatoes (Fig. 1). Fertigation especially enhanced the calcium content of the fruits. The chemical composition of the fresh tomato with different fertigation treatments is shown in Table 2. The ash content in each treatment was higher than in the control plot. All of the fertilized fruits were higher in soluble solids (SS) than the control.

TABLE 2.
CHEMICAL COMPOSITION OF TOMATOES IN DIFFERENT FERTIGATION TREATMENTS

T#1	T#2	T#3	T#4	T#5	T#6	T#7
Moisture Content (%)						
95.250^{a}	94.187^{ba}	94.177^{ba}	94.260^{ba}	93.190^{b}	94.370^{ba}	94.293^{ba}
Soluble Solids (Brix)						
4.133^{dc}	4.200^{bc}	4.267^{ba}	4.367^{a}	4.267^{ba}	4.100^{dc}	4.033^{d}
Reducing Sugar (%)						
2.057^{a}	2.063^{a}	1.937^{a}	1.950^{a}	1.950^{a}	2.200^{a}	2.137^{a}
Ash Content (%)						
0.520^{c}	0.557^{b}	0.622^{a}	0.507^{c}	0.622^{a}	0.519^{c}	0.482^{d}
Ascorbic Acid Content mg/100 g fresh material						
25.230^{a}	22.913^{a}	24.283^{a}	23.587^{a}	25.960^{a}	25.137^{a}	25.207^{a}
Titratable Acid Mg/citric acid / 100 mg						
0.414^{a}	0.359^{b}	0.362^{b}	0.357^{b}	0.429^{a}	0.423^{a}	0.275^{c}

* Data presented as means of triplicate determinations.
** Means in a row not sharing a common superscript ($^{a-d}$) are significantly different ($p<0.01$). Means in a column not sharing a common superscript ($^{a-d}$) are significantly different ($p<0.01$).

SS is one of the fruit components considered important by commercial processing companies. In the present study, the SS of fruits in various fertigation treatments was higher than in the control plot. Normally, SS can be easily decreased with an over supply of water (Mohr 1987; Wright *et al.* 1962). The watering level in the fertigation treatments did not have that effect in this experiment, which is similar to the results of Mohr (1987).

The biggest difference between the fertigated treatments and the control was the increase in ash content of the fruits. All fertigated fruits had more minerals than the control. Even though the ash content was higher in the tomatoes from the fertigated plots, there was a decrease as the fruit matured. The highest ash levels were in treatment # 3, the high K (800 mg/L) nutrient feeding after July 18, and also at the higher volume of watering. The high K effect is similar to other work (Marschner 1986). Treatment #5, the low N feeding after July 18, at the reduced volume of fertigation also had a high ash content.

TABLE 3.

CHEMICAL COMPOSITION OF DIFFERENT PARTS OF THE TOMATO FRUIT

	Whole	Mesocarp	Locule	Core
		Moisture Content (%)		
MR	92.976^{a}	93.213^{a}	97.242^{a}	93.217^{a}
MP	92.618^{a}	92.935^{a}	93.898^{a}	92.553^{a}
MLP	92.472^{a}	92.731^{a}	91.621^{a}	91.522^{a}
		Soluble Solids (Brix)		
MR	5.567^{a}	5.667^{a}	5.600^{a}	5.667^{a}
MP	5.333^{b}	5.367^{b}	5.267^{b}	5.400^{b}
MLP	5.267^{b}	5.133^{ba}	5.100^{b}	5.233^{a}
		Reducing Sugar (%)		
MR	3.222^{a}	3.172^{a}	2.285^{a}	3.447^{a}
MP	2.626^{b}	3.070^{a}	2.077^{a}	2.103^{b}
MLP	2.293^{c}	2.760^{a}	1.920^{a}	2.413^{a}
		Ash (%)		
MR	0.5693^{a}	0.4740^{a}	0.6550^{a}	0.4807^{b}
MP	0.5337^{a}	0.4643^{a}	0.6253^{a}	0.4753^{a}
MLP	0.5260^{a}	0.4607^{a}	0.6007^{a}	0.4783^{a}

*Core refers to the central part of the fruit.

**Data presented as means of triplicate determinations. Means in a row not sharing a common superscript ($^{a-b}$) are significantly different ($p<0.01$). Means in a column not sharing a common superscript ($^{a-b}$) are significantly different ($p<0.01$).

Chemical Component

The chemical component of the whole and different part of tomatoes at different maturity stages are presented in Table 3. SS and reducing sugars of the whole tomatoes increased with maturity. At the mature-light pink stage, the locule section was composed of cellulose tissue and less juice, resulting in a low moisture content. At the full mature stage, most of the locule section was full of juice. SS and reducing sugar increased with maturity in the locule section. The ash content was higher in the locule section perhaps because the seeds increased in dry matter with maturity. In general, the moisture content, SS, reducing sugar, and ash content increased both in the whole tomato and in the mesocarp, locule, and core sections during ripening.

Titratable Acidity and pH

The titratable acidity (TA) and pH of fresh tomatoes are presented in Table 4. The TA decreased both in the whole fruit and in the mesocarp, locule, and core sections with maturity. The pH of the fruit remained fairly constant during maturation, while the TA decreased dramatically as the fruit matured from the MLP to the MR stage. At all maturity stages, the TA in the locule section was higher than in the mesocarp section. The TA in MR whole fruits was reduced by 59% compared with the MLP samples.

TABLE 4.
pH AND TITRATABLE ACID OF DIFFERENT PARTS OF TOMATO FRUITS

	Whole	Mesocarp	Locule	Core
		pH		
MR	4.437^{a}	4.600^{a}	4.390^{a}	4.385^{a}
MP	4.373^{a}	4.403^{b}	4.350^{a}	4.367^{a}
MLP	4.320^{a}	4.367^{b}	4.220^{b}	4.293^{a}
	Titratable Acid mg citric acid / 100 g			
MR	0.201^{a}	0.191^{c}	0.286^{b}	0.208^{b}
MP	0.454^{a}	0.443^{a}	0.660^{a}	0.489^{a}
MLP	0.483^{a}	0.574^{b}	0.831^{a}	0.579^{a}

*Data presented as means of triplicate determinations.
**Means in a row not sharing a common superscript ($^{a-b}$) are significantly different ($p<0.01$). Means in a column not sharing a common superscript ($^{a-b}$) are significantly different ($p<0.01$).

Ascorbic Acid Content

The effects of maturity on ascorbic acid (AA) content are presented in Table 5. The AA content increased during ripening, both in the whole fruit and in the mesocarp, locule, and core sections. The AA content in MR fresh whole tomatoes was 22.9% and 46.8% higher than that in MP and MLP tomatoes, respectively. In the locule section, the AA content in the juice was 10.5% and 33.1% higher than in the mesocarp and pole sections at full maturity. This finding is similar to that reported earlier by Mathews (1974).

TABLE 5.
ASCORBIC ACID CONTENT OF DIFFERENT PARTS OF THE TOMATO FRUITS

	Whole	Mesocarp	Locule	Core
	Ascorbic Acid Content	mg/100g fresh material		
MR	25.633^a	30.483^a	33.677^a	25.320^a
MP	20.857^a	25.557^a	24.467^a	18.400^b
MLP	17.463^b	20.287^b	15.060^b	17.217^b

*Data presented as means of triplicate determinations.
**Means in a row not sharing a common superscript ($^{a-b}$) are significantly different (<0.01). Means in a column not sharing a common superscript ($^{a-b}$) are significantly different (p<0.01).

Ratio of Sugar to Acid

Tomato taste is largely a function of the sugar and acid content. However, differences can occur within cultivars as a result of harvest maturity, environment, or postharvest handling (Gull *et al.* 1984). The sugar to acid ratio of fresh tomatoes is closely related to its organoleptic properties, both for use in fresh and in the processed products. As a whole fruit, the reducing sugar content and sugar/acid ratio increased and TA decreased during ripening as shown in Fig. 2. In the mesocarp section, there was more reducing sugar and less TA, so the ratio of sugar/acid in the mesocarp section was higher than in other sections of whole tomatoes. There was more TA and less reducing sugar in the locule than other sections.

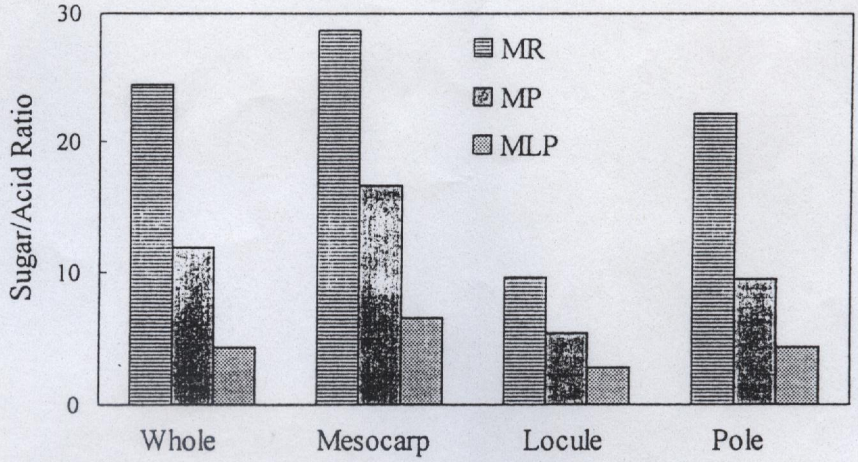

FIG. 2. SUGAR/ACID RATIOS IN THE TOMATO FRUIT

Fertigation treatments had effects on the changes of sugar/acid ratio. The sugar/acid ratio of fertigated fruits was 2-3 % higher than in the control plot. This ratio might be related to the increase of reducing sugar content and decrease of TA content.

CONCLUSION

Fertigation has the potential to improve tomato chemical composition. Maturity affected the contents of soluble solids, ascorbic acid, and the sugar/acid ratio. The soluble solids, reducing sugar content and the sugar/acid ratio in tomato fruits increased with maturity. The ash content of the tomato fruits was increased by the fertigation treatments used in this field experiment. The greatest increase was with the high K treatment. Intensive mineral fertigation, and full maturity result in high nutritional quality in tomatoes.

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