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Composition of San Marzano tomato varieties

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Compositional characteristics of 11 lines of San Marzano tomatoes have been determined. The results come from a 3 year study (1989–1991), during which the following parameters were evaluated: total solids, soluble solids, organic acids (citric, malic, succinic and ascorbic), sugars (glucose, fructose and sucrose), cations (Na, K, Mg and Ca), anions (sulfate, phosphate and chloride), amino acids and formol value. The mean pH value of the San Marzano lines was 4·6, a value somewhat higher than that of the hybrid varieties usually employed in the food industry. Instead, the contents of Na^+, K^+, Ca^{2+} and Mg^{2+} ions were close to those of hybrid varieties. Three amino acids, i.e. glutamic acid, γ-aminobutyric acid and glutamine, represent about 65% of the total free amino acid content. Although, in the case of glutamic acid, the mean value was close to that of the hybrid varieties (240 mg/100 g), the variability of the content in the lines was high (between 110 and 360 mg/100 g). The elevated heterogeneity of the San Marzano populations strongly influenced the difference in parameters studied. From a compositional viewpoint it is very difficult to differentiate pure San Marzano lines from hybrids without a careful morphological examination of the product.

INTRODUCTION

The term 'San Marzano tomato' or even 'San Marzano tomato dell'Agro Sarnese-Nocerino' refers to a population with a wide range of different characteristics. These arise from different production areas, and differences are important to the companies that produce and market them. Natural selection has been manipulated in this vegetable by farmers who eliminated varieties not suited to the local environment and favoured those better for canning. Pressure in selection turned therefore toward the elongated and/or cylindrical fruit. The title 'San Marzano tomato dell'Agro Nocerino-Sarnese' belongs to tomatoes from the San Marzano plant, the characteristics of which are reported in Table 1. These ecotypes, as reported by Monti (1979), undergo undetermined growth and are cultivated by staking the plants. In contrast, the cultivars, disguised as San Marzano, are all (self-pruning) sp gene recessive, causing not only determined growth, but also plants that are fuller and more fruitful. In addition, the San Marzano plant often has a green shoulder around the stem when unripe. This is missing in the hybrid varieties due to the presence of the *u* gene that determines uniform colour. Because of its taste and smell, the San Marzano tomato is today the leader in the Italian canning industry. The production, however, is divided among small concerns over a widespread area from Naples to Salerno to Avellino (Southern Italy) and amounts to roughly 2·5 million quintals. Recently the canning industries in Campania (where San Marzano tomatoes are produced) associated in the ANICAV (Industrial National Vegetable Canning Association), in agreement with local government and with the largest producers of this tomato (CON. COO.SA), have set down rules for this product that respect the existing national law (law n.210 September 6th, 1985), but introduce substantial changes in the quality criteria for tomatoes which are set aside for 'whole peeled San Marzano tomato' production (Table 2).

The aim of this study is to identify the different varieties of San Marzano tomatoes in this circumscribed geographical area (Fig. 1), by their chemical composition. Despite the fame of this product there are but few references given in the literature (Frusciante *et al.*, 1980; Leone *et al.*, 1985). These include data for only a few components such as soluble solids, total solids, acidity and pH.

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Table 1. Morphological and growing characteristics of the San Marzano tomato

Plant characteristics

Undetermined growth to any height, with exclusion of the determinate growth types; fruit-covering foliage;

uneven ripening.

Morphological and physicochemical characteristics of the fresh product to be processed into whole peeled tomato

Mostly bi-lobed, paralleled, elongated fruit from 60 to 80 mm in length as determined from the stem attachment to the style scar (the following tolerances are allowed, lightly formed fruit kept to no more than 5% of the lot);

an axis ratio no less than 2·0;

typical red colour of the variety (the following tolerance is allowed, yellow area up to 2 cm^2 per fruit, no more than 5% of the overall lot);

soluble solids at 20°C, no less than 4·0%;

limited presence of uncoloured vessels in the stem end;

absence of stem (maximum tolerance 1% of fruit);

Growth characteristics

Exclusively vertical growth, with suitable stakes and horizontal wire. Cultivation without stakes or in protected environment is prohibited.

Table 2. Requirements for production of the San Marzano tomato from Agro Nocerino-Sarnese

The following minimal requirements are required for fruit to be processed:

red colour, reasonable uniformity with an *a/b* ratio (measured by tristimulus colorimeter with the following characteristics L = 25·9; a = 28·5 and b = 13·1) no less than 2·2;

absence of odour and foreign taste;

absence of parasite larva and change due to parasites seen as large rotten spots in the pulp. Absence of rot along the stem;

dry weight no less than 65% of net weight;

they must be whole or without blemishes that change the shape or volume of the fruit for no less than 70% of the dry product weight per packaged product not exceeding 400 g and not less than 80% in other cases;

no less than 5% refractometric solids at 20°C;

mean skin content from at least five containers not to exceed 2 cm^2 for every 100 g of content. In each container the skin content must remain within four-fold this limit;

levels of mould in the stored tomato (tomato and juice) must not exceed 30% of positive fields;

the D and L lactic acid content in the stored tomato (tomato and juice) must be below 0·3 g/kg;

mandatory pH value between 4·2 and 4·5;

up to 3% dry weight of table salt is allowed;

added basil leaves allowed;

tomato juice is allowed to be partially concentrated tomato juice, or semiconcentrated tomato from Agro Nocerino-Sarnese San Marzano.

MATERIALS AND METHODS

Plant materials

During the 1988 production campaign of the San Marzano tomato and thereafter, some true varieties were chosen from several different production establishments in the typical growing area (Fig. 1). Samples of these true varieties were planted in two experimental fields within the same growing area and grown following local guidelines (Castaldo *et al.*, 1991; Silvestri *et al.*, 1993).

During the entire production cycle, three harvestings were made (the San Marzano tomato is in fact a plant with undetermined growth, with multiple harvestings. At each harvest there were five 2 kg samples from the same line: these were carefully washed, chopped and strained by laboratory filter with 0·4 mm diameter holes. The juice was stored in 250 ml plastic containers and kept at –20°C.

Analytical determinations

Sugar and organic acids determinations. HPLC analysis
Quantitative liquid chromatographic determinations were conducted with a Waters 600E system controller/pump (Waters Assoc., Milford, MA). A Waters refractive index detector (mod 410) and Waters autoinjector (mod wisp 712) were used. Sugar determinations (glucose, fructose and sucrose) were carried out using a Merck Lichrosorb NH_2 cartridge. The eluent consisted of acetonitrile–water (80:20) which was degassed and filtered through a 0·22 μm Millipore filter. A sample of 20 μl was used for analysis after clarifying the sample

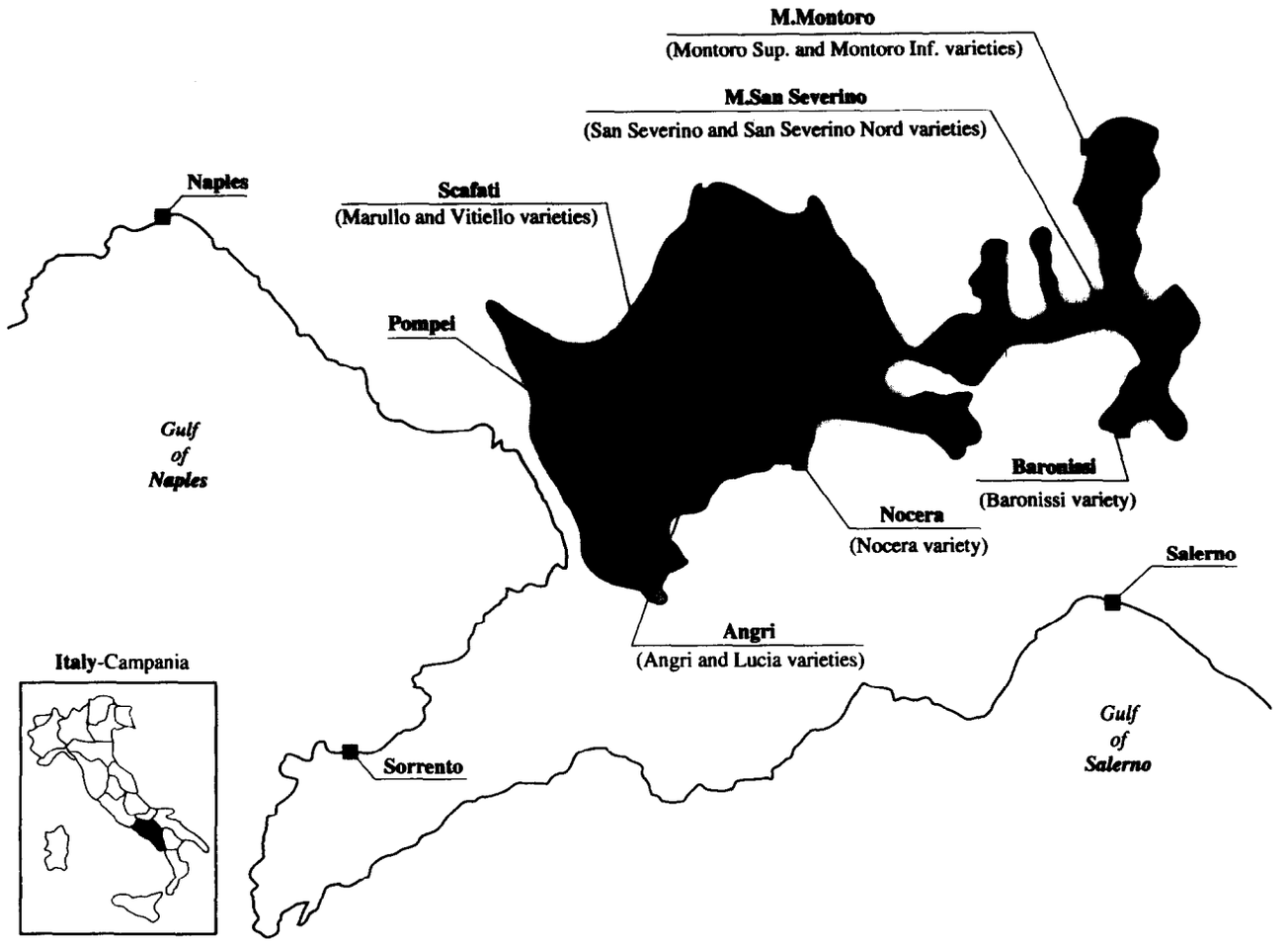

Fig. 1. Typical area of San Marzano tomato growing.

by 0·45 μm filter. Individual sugars were identified by comparison with reference compounds.

As for organic acids (citric, malic, succinic), the tomato juice (30 g) was clarified by centrifugation at 12 000 × *g* for 15 min. The clarified extract was filtered through a 0·45 μm Millipore filter; 10 ml was chromatographed through a cation-exchange column (AG-I-X8($HCOO^-$) poly-prep Bio-Rad) and washed with water to a total volume of 100 ml. The organic acids were eluted with 6 M formic acid (about 130 ml), collected and evaporated. The dry samples were recovered with water (10 ml) and filtered through a 0·45 μm Millipore filter before HPLC analysis. A Merck Lichrosorb RP-18 (10 μm) cartridge was used for HPLC analysis. The eluent consisted of water adjusted to pH 2·4 with H_3PO_4 at a flow rate of 2·0 ml/min as described by Bigliardi *et al.* (1986). The differential refractometer was used as detector.

Amino acid determination. HPLC analysis

Quantitative determination of amino acids was done according to Bidlingmeyer *et al.* (1987). Liquid chromatographic determinations were done using a Waters 510 double pump equipped with a UV/visible detector Waters (mod.484) and Waters autoinjector (mod wisp 712). Spectral acquisition was performed with a NEC power mate 433 equipped with a 2010 millenium software. Individual amino acids were identified by comparison with standard (Pierce).

Anions determination. HPLC analysis.

The following anions, Cl-, SO_4^{2-} and PO_4^{3-} were determined using the same tools used to measure sugars and organic acids except for the detector which was a Waters mod 431. The analyses were carried out on a IC-PAE Tm column (Waters) and samples eluted with an 8·5 pH borate/gluconate buffer following a procedure described by Schumuckler *et al.* (1986).

Chemical and physical determinations

Finally, the following parameters were determined on all samples: *pH, refractive index at 20°C* (Soluble solids), *total solids, total acidity* (expressed as monohydrated citric acid), *total sugars, ascorbic acid* and the *Mineral elements* (Na, K, Ca, Mg), determined by atomic absorption after sample mineralization performed with sulfo-nitric mixture using, as standard reference materials, sodium, potassium, calcium and magnesium nitrate (BDH Chemical Ltd., Poole, England), according to the Official Italian Methods, Ministero dell'Agricoltura e delle Foreste, 1989); *formol value* was determined in accordance with the method reported by the International Federation of Fruit Juice Producers (IFFJP, 1984); the *colour parameters* a, b, a/b and L

were determined for the various samples of tomato puree immediately after harvesting; the puree obtained was degassed and colour was measured with a tristimulus colorimeter mod XL-805 from Gardner. Reference tile (L = 25·9, a = 28·5, b = 13·1).

RESULTS AND DISCUSSION

The main carbohydrates in the San Marzano varieties were the sugars fructose and glucose (Table 3). Sucrose was present at very low concentrations and absent in some samples analysed. This is in agreement with Goose and Binsted (1964) who saw that this sugar content could be ignored for all practical purposes. Fructose was shown to be the most abundant sugar in all samples. As seen in Table 1, during the entire study period (1989–1991), all the different lines of San Marzano tomatoes always had more fructose than glucose. The mean fructose content in the San Marzano tomatoes was 1·4 g/100 g, whereas, for glucose, it was 1·2 g/100 g. These data are not substantially different from those of hybrids used for peeled tomato production. However, when comparing data for fructose and glucose from Silvestri *et al.* (1992*b*) who studied and characterized five hybrid varieties (Lero 165 Hy(ISI sementi), Italpeel (Peto Italiana), 829 (Verano Slu Gro), Concord 81 Hy (ISI sementi) and Mark 3 Don, often marketed as San Marzano tomatoes, it can be seen that the tomatoes in this study had fructose and glucose levels that tended to be lower than the hybrids.

In fact, the mean values from Silvestri *et al.* (1992*b*),

Table 3. Free sugars, soluble solids and total solids in San Marzano tomato varieties

Varieties	Sample numbers	Year	Soluble solids (°Brix)	Total solids (g%)	Glucose (g%)	Fructose (g%)	Total sugars (g%)
Angri	18	1989	5·8 ± 0·24	6·2 ± 0·33	1·5 ± 0·22	1·7 ± 0·19	2·8 ± 0·17
	16	1990	5·3 ± 0·29	5·6 ± 0·38	1·1 ± 0·21	1·2 ± 0·18	2·5 ± 0·27
	22	1991	5·3 ± 0·33	5·6 ± 0·39	1·2 ± 0·20	1·2 ± 0·18	2·4 ± 0·36
Baronissi	8	1990	5·2 ± 0·17	5·6 ± 0·32	1·2 ± 0·15	1·4 ± 0·13	2·5 ± 0·27
	12	1991	5·2 ± 0·18	5·5 ± 0·13	1·2 ± 0·15	1·3 ± 0·14	2·6 ± 0·32
Irno (valley)	12	1990	5·3 ± 0·37	5·8 ± 0·28	1·2 ± 0·17	1·5 ± 0·30	2·8 ± 0·41
	10	1991	5·3 ± 0·37	5·8 ± 0·43	1·1 ± 0·21	1·3 ± 0·33	2·4 ± 0·49
Lucia	8	1989	5·5 ± 0·34	5·8 ± 0·40	1·4 ± 0·10	1·6 ± 0·10	3·0 ± 0·13
	8	1990	5·0 ± 0·33	5·4 ± 0·54	1·1 ± 0·18	1·2 ± 0·21	2·4 ± 0·32
	8	1991	5·1 ± 0·26	5·6 ± 0·22	1·1 ± 0·19	1·2 ± 0·21	2·4 ± 0·40
Marullo	6	1989	5·7 ± 0·66	6·1 ± 0·66	1·5 ± 0·19	1·7 ± 0·10	3·2 ± 0·23
	10	1990	5·7 ± 0·51	6·1 ± 0·62	1·2 ± 0·03	1·3 ± 0·06	2·9 ± 0·45
	12	1991	5·7 ± 0·59	6·1 ± 0·43	1·2 ± 0·07	1·4 ± 0·10	2·7 ± 0·08
Montoro-sup	10	1990	5·2 ± 0·36	5·6 ± 0·23	1·2 ± 0·07	1·3 ± 0·07	2·2 ± 0·12
	12	1991	5·2 ± 0·36	5·5 ± 0·29	1·2 ± 0·06	1·3 ± 0·08	2·2 ± 0·16
Montoro-inf	12	1990	4·9 ± 0·27	5·2 ± 0·38	1·0 ± 0·14	1·2 ± 0·16	2·2 ± 0·29
	12	1991	4·9 ± 0·28	5·2 ± 0·32	1·1 ± 0·18	1·3 ± 0·17	2·5 ± 0·31
Nocera	10	1989	5·4 ± 0·46	5·8 ± 0·43	1·5 ± 0·09	1·7 ± 0·16	3·1 ± 0·13
	4	1990	5·3 ± 0·24	5·7 ± 0·34	1·1 ± 0·11	1·5 ± 0·20	2·6 ± 0·23
	6	1991	5·2 ± 0·22	5·7 ± 0·21	1·1 ± 0·11	1·4 ± 0·20	2·6 ± 0·26
S. Severino-sud	4	1990	5·1 ± 0·30	5·5 ± 0·49	1·1 ± 0·26	1·2 ± 0·25	2·3 ± 0·50
	7	1991	5·0 ± 0·31	5·4 ± 0·26	1·1 ± 0·26	1·2 ± 0·28	2·4 ± 0·47
S. Severino-nord	11	1990	5·0 ± 0·49	5·5 ± 0·55	1·1 ± 0·24	1·2 ± 0·22	2·3 ± 0·46
	10	1991	5·0 ± 0·47	5·4 ± 0·36	1·1 ± 0·27	1·2 ± 0·24	2·3 ± 0·29
Vitiello	8	1989	6·0 ± 0·44	6·3 ± 0·51	1·5 ± 0·23	1·8 ± 0·20	3·2 ± 0·42
	12	1990	5·4 ± 0·45	5·9 ± 0·35	1·3 ± 0·13	1·5 ± 0·16	2·7 ± 0·34
	6	1991	5·4 ± 0·46	5·8 ± 0·41	1·3 ± 0·10	1·4 ± 0·05	2·8 ± 0·14
Statistical parameters							
min			4·2	4·6	0·9	0·9	1·8
mean			5·3	5·7	1·2	1·4	2·6
max			6·5	6·9	1·7	2·0	3·7
SD			0·44	0·46	0·21	0·24	0·39

Table 4. Organic acid composition and pH in San Marzano tomato varieties

Varieties	Sample numbers	Year	pH	Total acidity g/100 ml	L-malic acid g/100 ml	Citric acid g/100 ml	Succinic acid g/100 ml
Angri	18	1989	4·5 ± 0·02	0·4 ± 0·17	0·04 ± 0·005	0·38 ± 0·084	0·03 ± 0·005
	16	1990	4·7 ± 0·03	0·3 ± 0·02	0·03 ± 0·008	0·32 ± 0·053	0·02 ± 0·012
	22	1991	4·7 ± 0·06	0·3 ± 0·02	0·03 ± 0·008	0·28 ± 0·012	0·03 ± 0·014
Baronissi	8	1990	4·6 ± 0·01	0·3 ± 0·02	0·03 ± 0·007	0·31 ± 0·035	0·01 ± 0·009
	12	1991	4·6 ± 0·02	0·3 ± 0·02	0·03 ± 0·007	0·29 ± 0·016	0·01 ± 0·001
Irno (valley)	12	1990	4·6 ± 0·08	0·3 ± 0·04	0·04 ± 0·004	0·32 ± 0·039	0·02 ± 0·013
	10	1991	4·6 ± 0·08	0·3 ± 0·04	0·04 ± 0·004	0·30 ± 0·028	0·02 ± 0·015
Lucia	8	1989	4·5 ± 0·17	0·4 ± 0·17	0·05 ± 0·004	0·37 ± 0·124	0·03 ± 0·005
	8	1990	4·5 ± 0·06	0·3 ± 0·04	0·03 ± 0·005	0·33 ± 0·042	0·01 ± 0·005
	8	1991	4·5 ± 0·06	0·3 ± 0·04	0·03 ± 0·005	0·33 ± 0·029	0·01 ± 0·005
Marullo	6	1989	4·5 ± 0·22	0·5 ± 0·14	0·04 ± 0·006	0·39 ± 0·112	0·03 ± 0·003
	10	1990	4·8 ± 0·06	0·3 ± 0·03	0·03 ± 0·011	0·26 ± 0·058	0·02 ± 0·010
	12	1991	4·8 ± 0·06	0·3 ± 0·03	0·03 ± 0·011	0·23 ± 0·031	0·02 ± 0·009
Montoro-sup	10	1990	4·6 ± 0·02	0·4 ± 0·02	0·02 ± 0·004	0·34 ± 0·044	0·02 ± 0·005
	12	1991	4·6 ± 0·02	0·4 ± 0·02	0·02 ± 0·005	0·35 ± 0·043	0·02 ± 0·006
Montoro-inf	12	1990	4·6 ± 0·03	0·4 ± 0·03	0·03 ± 0·011	0·35 ± 0·040	0·02 ± 0·002
	12	1991	4·6 ± 0·03	0·3 ± 0·02	0·03 ± 0·006	0·31 ± 0·012	0·02 ± 0·003
Nocera	10	1989	4·5 ± 0·16	0·4 ± 0·10	0·04 ± 0·005	0·32 ± 0·091	0·03 ± 0·007
	4	1990	4·5 ± 0·04	0·4 ± 0·02	0·04 ± 0·007	0·34 ± 0·117	0·01 ± 0·008
	6	1991	4·5 ± 0·04	0·3 ± 0·02	0·04 ± 0·007	0·28 ± 0·022	0·01 ± 0·007
S. Severino-sud	4	1990	4·5 ± 0·05	0·4 ± 0·04	0·04 ± 0·004	0·36 ± 0·041	0·01 ± 0·005
	7	1991	4·5 ± 0·05	0·4 ± 0·04	0·03 ± 0·003	0·33 ± 0·025	0·01 ± 0·006
S. Severino-nord	11	1990	4·6 ± 0·07	0·4 ± 0·06	0·03 ± 0·007	0·37 ± 0·055	0·02 ± 0·005
	10	1991	4·6 ± 0·07	0·3 ± 0·06	0·03 ± 0·005	0·31 ± 0·015	0·01 ± 0·003
Vitiello	8	1989	4·7 ± 0·37	0·4 ± 0·22	0·04 ± 0·003	0·34 ± 0·109	0·04 ± 0·002
	12	1990	4·5 ± 0·04	0·4 ± 0·21	0·04 ± 0·001	0·39 ± 0·103	0·02 ± 0·011
	6	1991	4·5 ± 0·05	0·4 ± 0·21	0·04 ± 0·001	0·35 ± 0·099	0·02 ± 0·009
Statistical parameters							
min			4·2	0·2	0·01	0·20	0·01
mean			4·6	0·4	0·04	0·33	0·02
max			5·1	0·7	0·05	0·51	0·05
SD			0·13	0·10	0·008	0·066	0·010

had fructose at about 1·5 g/100 g, while mean glucose was about 1·4 g/100 g. With vertical growth, the San Marzano fruit are covered more by the leaves. This not only causes better colour but the greater degree of shade reduces the sugar content as reported by Hobson and Davies (1971). This would explain the low sugar content in this product. The ratio of glucose to fructose (not reported in Table) ranged from 0·8 to 1·0. As for total sugars, the mean values were around 2·6 g/100 g. The soluble solids and total solids (Table 1) were not unlike those reported in the literature. In regard to organic acids (Table 4), citric acid predominated with mean levels around 0·33 g/100 g. Malic and succinic acids levels were 0·035 g/100 g and 0·020 g/100 g, respectively (Table 4). These data were not noticeably different from those found for other cultivars.

Ascorbic acid content (not reported in the table), was about 20 mg/100 g, (as low as 6 mg/100 g and as high as about 30 mg/100 g).

The San Marzano lines had a mean pH value of about 4·6. This was much higher than the hybrids reported by Silvestri *et al.* (1992*b*). Total acidity was around 0·35 g/100 g for the San Marzano tomatoes vs 0·44 g/100 g in the hybrids seen by Silvestri *et al.* (1992*a,b*).

Na, K, Ca, Mg levels (Table 5) were in agreement with the literature. This emphasises once again that it is very difficult to discriminate between single analytic data regarding San Marzano tomatoes from the hybrids.

The same conclusions may be drawn for chloride, sulphate and phosphate. Levels for these are in perfect agreement with the literature (Souci *et al.*, 1986).

Colour results (Table 5), show that the San Marzano tomatoes have a mean *a/b* ratio of around 2·90 with a

Table 5. *a/b* parameter colour, minerals and anions content in San Marzano tomato varieties

Varieties	Sample numbers	Year	a/b	Na (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Cl- (mg/kg)	CO_4^{2-} (mg/kg)	PO_4^{3-} (mg/kg)
Angri	18	1989	2·9 ± 0·11	35 ± 8	2668 ± 302	44 ± 9	97 ± 18	493 ± 27	224 ± 17	551 ± 51
	16	1990	2·9 ± 0·03	45 ± 5	2719 ± 404	51 ± 5	97 ± 8	371 ± 42	277 ± 37	482 ± 102
	22	1991	3·0 ± 0·03	44 ± 4	2610 ± 467	47 ± 4	96 ± 8	345 ± 18	288 ± 21	482 ± 102
Baronissi	8	1990	2·8 ± 0·07	46 ± 5	2857 ± 91	52 ± 12	103 ± 5	428 ± 94	299 ± 22	482 ± 80
	12	1991	2·8 ± 0·07	45 ± 5	2822 ± 123	45 ± 2	105 ± 2	446 ± 86	291 ± 14	448 ± 75
Irno (valley)	12	1990	2·9 ± 0·04	52 ± 3	2887 ± 75	58 ± 11	106 ± 5	442 ± 90	311 ± 18	514 ± 87
	10	1991	2·9 ± 0·04	54 ± 2	2928 ± 75	59 ± 28	100 ± 4	430 ± 63	326 ± 16	481 ± 86
Lucia	8	1989	2·9 ± 0·11	32 ± 9	2508 ± 471	43 ± 3	102 ± 18	528 ± 61	242 ± 35	481 ± 68
	8	1990	2·9 ± 0·05	53 ± 10	2665 ± 339	57 ± 8	100 ± 15	392 ± 62	254 ± 18	503 ± 104
	8	1991	2·9 ± 0·05	57 ± 4	2584 ± 321	55 ± 7	97 ± 26	395 ± 68	263 ± 15	503 ± 102
Marullo	6	1989	2·9 ± 0·14	33 ± 10	2694 ± 187	43 ± 6	100 ± 15	499 ± 46	232 ± 38	562 ± 38
	10	1990	2·9 ± 0·08	50 ± 6	2946·6 ± 51	49 ± 4	114 ± 5	470 ± 16	294 ± 62	542 ± 72
	12	1991	2·9 ± 0·08	49 ± 6	2950 ± 51	49 ± 3	114 ± 4	470 ± 13	294 ± 50	541 ± 69
Montoro-sup	10	1990	2·9 ± 0·11	48 ± 3	2872 ± 114	55 ± 7	106 ± 8	433 ± 38	321 ± 17	522 ± 27
	12	1991	2·9 ± 0·12	47 ± 3	2870 ± 113	57 ± 8	108 ± 10	436 ± 38	321 ± 16	522 ± 26
Montoro-inf	12	1990	2·8 ± 0·08	49 ± 2	2828 ± 368	53 ± 1	101 ± 15	427 ± 58	297 ± 18	469 ± 134
	12	1991	2·8 ± 0·08	48 ± 1	2818 ± 350	52 ± 1	101 ± 14	427 ± 57	295 ± 17	469 ± 128
Nocera	10	1989	2·9 ± 0·08	32 ± 5	2211 ± 406	48 ± 4	97 ± 30	475 ± 46	224 ± 20	598 ± 36
	4	1990	2·9 ± 0·04	43 ± 3	2824 ± 207	56 ± 6	109 ± 13	455 ± 74	294 ± 9	448 ± 65
	6	1991	2·9 ± 0·04	46 ± 3	2926 ± 185	58 ± 8	118 ± 13	486 ± 43	298 ± 7	450 ± 64
S. Severino-sud	4	1990	2·9 ± 0·05	66 ± 5	2970 ± 68	54 ± 12	102 ± 3	465 ± 68	291 ± 43	504 ± 68
	7	1991	2·9 ± 0·05	66 ± 4	2971 ± 65	54 ± 12	101 ± 3	464 ± 68	291 ± 43	474 ± 37
S. Severino-nord	11	1990	2·8 ± 0·10	42 ± 4	2883 ± 87	49 ± 9	103 ± 4	520 ± 43	338 ± 25	452 ± 57
	10	1991	2·8 ± 0·10	42 ± 4	2880 ± 84	49 ± 10	102 ± 4	520 ± 41	338 ± 25	452 ± 57
Vitiello	8	1989	2·9 ± 0·09	32 ± 9	2688 ± 373	38 ± 3	96 ± 17	485 ± 77	267 ± 48	539 ± 24
	12	1990	3·1 ± 0·11	45 ± 3	2891 ± 311	52 ± 11	114 ± 7	431 ± 4	301 ± 62	499 ± 84
	6	1991	3·1 ± 0·11	46 ± 2	2624 ± 41	53 ± 8	110 ± 10	427 ± 5	265 ± 46	514 ± 69
Statistical parameters										
min			2·6	18	1680	33	67	326	187	316
mean			2·9	45	2781	51	104	448	290	496
max			3·2	72	3254	72	149	628	383	634
SD			0·09	10	273	9	13	65	41	76

standard deviation lower than that reported by Silvestri *et al.* (1992*b*; 1993) for some hybrid varieties. This result can be explained by the observation that the fruit colour depends on the ratio of fruit to leaves by which the fruits are protected from high temperature exposures. In fact, lycopene synthesis is inhibited above 32°C, while at this temperature carotenes are still formed (Hobson & Davies, 1971). The more intense and uniform red colour of the San Marzano tomato makes it of greater quality than other varieties for 'whole peeled tomato' production.

Finally, Table 6 lists the data for amino acids. The data reveal that the main amino acids are glutamate (mean value ≈240 mg/100 g), γ amino butyric acid with mean levels of about 156 mg/100 g and glutamine with mean values around 129 mg/100 g. These three amino acids represent about 65% of the entire amino acid content, followed by asparagine and aspartate with about 80 mg/100 g and 60 mg/100 g respectively, while all the other amino acids have lower levels (around 20 mg/100 g).

These data are close to those reported in a previous paper on some hybrid varieties (Silvestri *et al.*, 1992*b*) but the range of the variability is narrower for the hybrid varieties. This could depend on the much lower minimum value of amino acid content in the San Marzano varieties respect to the hybrids.

The most outstanding case is with glutamic acid, which in the San Marzano plant has a mean value of about 240 mg/100 g with a variability interval between 110 and 360 mg/100 g vs 320 mg/100 g in the hybrids, with a variability interval between 240 and 90 mg/100 g.

Table 6. Formol value, amino acids (mg/100 g) and total amino acids in San Marzano tomato varieties

Varieties	Sample numbers	Year	Asp	Glu	Ser	Asn	Gly	Gln	His	Gaba	Thr	Ala	Arg
Angri	12	1989	47 ± 20·9	238 ± 41·4	21 ± 3·9	61 ± 21·0	4 ± 1·4	106 ± 13·6	7 ± 2·2	136 ± 88·2	12 ± 7·5	16 ± 12·8	4 ± 1·4
	16	1990	62 ± 6·8	192 ± 38·8	23 ± 2·4	80 ± 13·8	4 ± 0·5	134 ± 24·7	10 ± 1·0	187 ± 27·2	12 ± 2·0	20 ± 10·6	9 ± 2·2
	10	1991	73 ± 4·3	226 ± 7·2	23 ± 3·2	86 ± 12·3	4 ± 0·8	139 ± 33·4	10 ± 2·1	170 ± 15·2	13 ± 2·7	26 ± 113	8 ± 3·2
Baronissi	8	1990	58 ± 9·0	193 ± 56·5	18 ± 1·6	68 ± 16·0	3 ± 0·5	119 ± 19·8	9 ± 1·6	153 ± 22·8	10 ± 2·4	13 ± 6·0	7 ± 1·0
	12	1991	69 ± 14·1	286 ± 66·8	22 ± 5·1	91 ± 27·9	3 ± 0·7	148 ± 11·9	11 ± 3·6	150 ± 19·1	12 ± 1·6	12 ± 5·2	10 ± 2·2
Irno (valley)	12	1990	61 ± 2·4	221 ± 26·4	20 ± 1·8	78 ± 17·8	3 ± 0·2	133 ± 30·5	9 ± 2·4	160 ± 19·0	13 ± 2·7	16 ± 4·2	8 ± 1·9
	10	1991	63 ± 5·1	226 ± 43·9	21 ± 1·6	86 ± 20·2	3 ± 0·2	156 ± 27·4	9 ± 1·3	152 ± 25·7	13 ± 2·5	15 ± 4·0	9 ± 1·1
Lucia	8	1989	47 ± 16·0	258 ± 41·8	22 ± 3·9	81 ± 15·5	4 ± 0·9	119 ± 14·7	7 ± 2·2	148 ± 72·8	14 ± 4·4	20 ± 9·3	4 ± 1·2
	8	1990	59 ± 6·3	240 ± 66·0	20 ± 2·7	74 ± 11·8	3 ± 0·3	122 ± 12·0	10 ± 1·6	156 ± 26·9	14 ± 6·2	15 ± 6·1	8 ± 2·2
	4	1991	60 ± 6·4	242 ± 64·4	21 ± 2·3	76 ± 10·0	3 ± 0·3	121 ± 8·9	10 ± 1·7	157 ± 26·7	14 ± 6·1	16 ± 5·9	8 ± 2·1
Marullo	6	1989	60 ± 12·6	328 ± 20·0	23 ± 2·2	82 ± 27·4	5 ± 0·6	127 ± 25·3	9 ± 1·6	161 ± 40·5	22 ± 6·5	31 ± 8·8	5 ± 1·6
	10	1990	68 ± 11·9	222 ± 112·6	22 ± 2·2	74 ± 20·7	4 ± 0·3	109 ± 90·6	10 ± 2·4	201 ± 36·3	8 ± 2·4	21 ± 8·5	10 ± 1·5
	4	1991	57 ± 13·0	305 ± 76·4	22 ± 3·9	86 ± 28·8	4 ± 1·4	132 ± 26·1	9 ± 2·3	154 ± 11·3	19 ± 6·9	25 ± 16·7	7 ± 1·8
Montoro-sup	10	1990	68 ± 14·1	286 ± 66·8	22 ± 5·1	91 ± 28·0	3 ± 0·7	148 ± 12·0	11 ± 3·6	151 ± 19·0	13 ± 1·6	12 ± 5·2	10 ± 2·2
	4	1991	68 ± 14·2	288 ± 69·0	22 ± 5·4	92 ± 29·5	3 ± 0·6	148 ± 12·5	11 ± 3·6	147 ± 21·3	13 ± 1·0	12 ± 5·5	10 ± 2·2
Montoro-inf	12	1990	58 ± 9·0	234 ± 42·0	19 ± 2·2	73 ± 21·8	3 ± 0·3	123 ± 37·0	8 ± 1·9	134 ± 13·4	11 ± 1·2	12 ± 4·8	7 ± 1·4
	12	1991	64 ± 6·0	237 ± 40·3	20 ± 2·0	93 ± 15·4	3 ± 0·1	158 ± 37·0	8 ± 1·8	140 ± 9·2	11 ± 1·2	14 ± 2·8	7 ± 1·4
Nocera	10	1989	45 ± 12·6	217 ± 78·5	16 ± 7·8	69 ± 21·7	3 ± 1·5	89 ± 21·6	6 ± 2·4	126 ± 83·5	12 ± 6·1	17 ± 12·7	4 ± 1·8
	4	1990	48 ± 11·4	161 ± 72·9	17 ± 4·3	60 ± 27·0	3 ± 0·8	110 ± 100·7	6 ± 2·4	136 ± 15·5	9 ± 2·7	18 ± 8·4	6 ± 2·5
	3	1991	55 ± 9·7	228 ± 91·0	22 ± 3·8	79 ± 16·6	4 ± 1·1	112 ± 33·6	7 ± 2·6	166 ± 71·4	13 ± 5·5	25 ± 7·9	6 ± 2·6
S. Severino-sud	4	1990	55 ± 8·4	209 ± 53·0	19 ± 2·5	70 ± 17·0	3 ± 0·2	126 ± 26·5	8 ± 2·1	143 ± 11·7	12 ± 1·9	12 ± 3·9	7 ± 1·0
	3	1991	64 ± 6·4	253 ± 47·0	21 ± 2·2	94 ± 15·5	3 ± 0·2	151 ± 33·2	8 ± 1·9	132 ± 10·3	11 ± 1·5	15 ± 3·5	8 ± 1·5
S. Severino-nord	11	1990	55 ± 9·6	215 ± 43·6	20 ± 2·8	71 ± 17·2	3 ± 0·6	121 ± 34·1	9 ± 1·2	151 ± 20·6	14 ± 4·0	14 ± 8·3	8 ± 0·8
	10	1991	60 ± 4·1	232 ± 28·2	22 ± 1·7	86 ± 5·8	3 ± 0·3	110 ± 12·1	8 ± 1·3	157 ± 18·5	11 ± 0·8	16 ± 4·8	8 ± 0·8
Vitiello	8	1989	64 ± 17·1	302 ± 45·8	27 ± 1·4	86 ± 7·8	6 ± 0·9	118 ± 10·4	8 ± 2·3	201 ± 74·9	16 ± 6·7	29 ± 12·5	5 ± 1·2
	12	1990	66 ± 13·0	259 ± 60·8	25 ± 4·0	87 ± 14·6	4 ± 0·5	154 ± 40·7	11 ± 1·6	158 ± 18·9	15 ± 5·4	17 ± 6·9	9 ± 2·3
	2	1991	73 ± 6·0	251 ± 52·0	25 ± 4·1	79 ± 13·5	4 ± 1·7	153 ± 51·6	9 ± 2·3	183 ± 64·9	13 ± 2·1	23 ± 12·9	9 ± 4·1
Statistical parameters													
min			28	109	9	28	2	59	4	51	5	4	2
mean			60	240	22	80	4	129	9	156	13	18	7
max			80	360	30	120	7	200	17	305	32	42	14
SD			11·8	60·3	3·7	18·6	0·9	25·9	2·4	40·4	4·3	8·9	2·4

contd.

Table 6. Formol value, amino acids (mg/100 g) and total amino acids in San Marzano tomato varieties — *continued*

Varieties	Sample numbers	Year	Pro	Tyr	Val	Met	Cyst	Ile	Leu	Phe	Lys	Formol value (a)	Amino acids (tot)
Angri	12	1989	3 ± 2·5	13 ± 8·1	3 ± 1·0	5 ± 1·5	2 ± 1·0	1 ± 0·1	15 ± 3·6	7 ± 2·7	13 ± 3·0	4·3 ± 0·49	725 ± 168·4
	16	1990	3 ± 2·0	6 ± 1·4	6 ± 0·8	4 ± 1·9	16 ± 6·7	6 ± 3·4	9 ± 3·1	19 ± 4·6	9 ± 3·1	5·4 ± 0·80	776 ± 122·7
	10	1991	4 ± 2·8	6 ± 1·8	5 ± 0·7	5 ± 2·3	14 ± 8·8	4 ± 2·4	10 ± 4·3	17 ± 6·2	12 ± 4·2	5·4 ± 0·80	861 ± 23·2
Baronissi	8	1990	1 ± 0·4	4 ± 0·8	5 ± 0·3	2 ± 0·3	19 ± 4·5	4 ± 0·7	5 ± 1·3	16 ± 0·8	8 ± 1·6	5·8 ± 0·82	681 ± 131·7
	12	1991	1 ± 0·4	5 ± 0·9	5 ± 1·0	3 ± 0·6	18 ± 4·6	6 ± 1·6	7 ± 1·5	21 ± 4·8	9 ± 2·6	5·4 ± 0·74	894 ± 158·9
Irno (valley)	12	1990	1 ± 1·1	4 ± 1·1	5 ± 0·5	2 ± 0·3	18 ± 1·9	5 ± 0·5	6 ± 0·8	18 ± 5·1	7 ± 1·6	5·9 ± 0·23	772 ± 76·1
	10	1991	1 ± 0·5	5 ± 0·5	5 ± 0·4	2 ± 0·5	16 ± 1·7	5 ± 0·4	7 ± 0·7	20 ± 2·0	7 ± 1·3	5·9 ± 0·20	801 ± 91·9
Lucia	8	1989	2 ± 1·6	13 ± 4·4	4 ± 0·7	5 ± 0·9	2 ± 0·4	1 ± 0·1	15 ± 4·9	7 ± 2·2	14 ± 2·9	4·4 ± 0·44	798 ± 127·8
	8	1990	1 ± 1·1	9 ± 10·4	5 ± 0·6	3 ± 0·9	15 ± 6·2	4 ± 1·8	7 ± 1·5	18 ± 6·2	9 ± 4·7	5·3 ± 1·08	761 ± 139·9
	4	1991	1 ± 1·0	8 ± 7·5	5 ± 0·6	2 ± 0·9	16 ± 10·3	4 ± 1·8	7 ± 1·3	17 ± 6·0	10 ± 4·4	5·3 ± 1·08	788 ± 114·8
Marullo	6	1989	6 ± 2·1	11 ± 4·5	4 ± 0·1	6 ± 0·5	3 ± 0·1	1 ± 0·3	16 ± 5·2	8 ± 1·3	16 ± 2·6	4·4 ± 0·40	935 ± 47·1
	10	1990	2 ± 1·8	4 ± 1·4	6 ± 1·0	3 ± 0·7	19 ± 5·7	7 ± 2·1	8 ± 1·6	18 ± 5·1	8 ± 2·4	5·6 ± 1·00	760 ± 165·9
	4	1991	5 ± 4·0	7 ± 3·2	4 ± 0·5	5 ± 3·0	9 ± 7·9	3 ± 2·2	12 ± 8·2	11 ± 6·5	13 ± 6·7	5·5 ± 0·94	896 ± 150·1
Montoro-sup	10	1990	1 ± 0·4	5 ± 0·9	5 ± 1·9	3 ± 0·6	18 ± 4·6	6 ± 1·6	7 ± 1·5	21 ± 4·8	9 ± 2·6	6·1 ± 0·50	894 ± 158·9
	4	1991	1 ± 0·4	5 ± 1·0	5 ± 1·0	3 ± 0·6	17 ± 4·6	6 ± 1·6	7 ± 1·5	21 ± 4·8	9 ± 2·6	6·1 ± 0·46	896 ± 160·4
Montoro-inf	12	1990	1 ± 0·5	4 ± 0·8	5 ± 0·6	2 ± 0·8	16 ± 3·1	5 ± 0·6	6 ± 0·8	16 ± 3·4	7 ± 2·2	5·6 ± 0·40	731 ± 118·8
	12	1991	1 ± 0·4	4 ± 0·9	5 ± 0·5	3 ± 0·6	16 ± 2·8	5 ± 0·3	6 ± 0·9	17 ± 3·7	7 ± 0·6	5·6 ± 0·40	822 ± 77·8
Nocera	10	1989	3 ± 2·1	13 ± 3·4	3 ± 1·0	4 ± 1·6	2 ± 0·7	1 ± 0·1	12 ± 7·2	7 ± 2·7	13 ± 0·8	4·2 ± 0·23	672 ± 235·8
	4	1990	1 ± 1·5	3 ± 1·2	4 ± 1·6	2 ± 0·9	18 ± 4·6	4 ± 0·6	5 ± 1·5	9 ± 8·7	9 ± 8·5	5·0 ± 1·34	574 ± 219·7
	3	1191	3 ± 2·6	9 ± 7·0	4 ± 1·3	4 ± 2·2	11 ± 10·0	2 ± 1·8	12 ± 7·1	9 ± 3·5	15 ± 2·0	4·9 ± 1·33	774 ± 212·7
S. Severino-sud	4	1990	1 ± 1·0	4 ± 0·5	4 ± 0·4	2 ± 0·3	17 ± 2·8	4 ± 0·7	5 ± 0·7	16 ± 3·2	7 ± 0·9	5·2 ± 0·31	712 ± 123·7
	3	1991	1 ± 0·4	4 ± 0·9	5 ± 0·6	3 ± 0·6	16 ± 2·7	5 ± 0·3	7 ± 1·0	17 ± 3·7	7 ± 0·8	5·1 ± 0·22	830 ± 83·2
S. Severino-nord	11	1990	1 ± 1·0	4 ± 0·5	5 ± 0·5	2 ± 0·5	19 ± 2·4	5 ± 0·4	6 ± 1·3	17 ± 1·1	8 ± 0·6	5·0 ± 0·37	714 ± 154·5
	10	1991	1 ± 0·9	5 ± 0·7	5 ± 0·6	3 ± 0·5	18 ± 1·0	5 ± 0·8	7 ± 1·3	19 ± 0·9	7 ± 0·1	5·0 ± 0·87	790 ± 40·3
Vitiello	8	1989	5 ± 2·4	15 ± 3·2	4 ± 0·3	7 ± 1·0	3 ± 0·1	1 ± 0·1	19 ± 5·2	10 ± 1·5	15 ± 2·5	5·0 ± 0·32	956 ± 49·5
	12	1990	2 ± 0·6	6 ± 3·0	5 ± 0·9	3 ± 0·9	16 ± 6·9	6 ± 2·7	7 ± 2·1	19 ± 6·4	11 ± 3·7	5·7 ± 0·52	833 ± 139·1
	2	1991	3 ± 2·7	9 ± 6·6	5 ± 0·7	5 ± 2·8	14 ± 8·6	5 ± 3·3	11 ± 8·1	18 ± 6·7	12 ± 2·9	5·6 ± 0·47	886 ± 124·8
Statistical parameters													
min			0·3	1	2	0·9	1	0·6	3	4	1	3·9	378
mean			2	7	5	3	14	4	9	15	10	5·3	812
max			8	29	7	8	26	10	24	27	18	6·8	1040
SD			1·9	4·9	1·0	1·8	7·2	2·2	4·8	5·7	3·9	0·86	123·1

[a]ml of 0·1 M NaOH/100 g.

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