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Preliminary communication

YIELD, QUALITY, ANTIOXIDANT, AND SENSORIAL PROPERTIES OF DICED TOMATO AS AFFECTED BY GENOTYPE AND INDUSTRIAL PROCESSING IN SOUTHERN ITALY

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Research was carried out on processing tomato in Southern Italy in order to compare four round-prismatic type hybrids oriented to diced produce (4420, Miceno, Nemabrix, Impact as a control). The hybrid Nemabrix attained the highest marketable yield (180.9 t ha^{-1}), due to both the highest number of fruit per plant and their mean weight (103.7 and 70 g, respectively), and it was not significantly different from the other genotypes in terms of processing efficiency both as a total and along dicing chain (67.8% and 65.6%, respectively). Lycopene attained the highest concentration in Nemabrix (155 mg kg^{-1}), and β–carotene was most concentrated in 4420 and Miceno (2.8 mg kg^{-1}). Significant differences arose between the genotypes with regard to the sensorial variables aspect, colour, taste, firmness, and fresh taste.

Keywords: *Solanum lycopersicum* L., round-prismatic type hybrids, fresh and processed production, lycopene, polyphenols, organoleptic features

Tomato is the most cultivated vegetable species worldwide with 5,023,810 ha (FAOStat, 2014); Italy is a major European producer and exporter of processing tomato with a surface area of 79,761 ha (I.Stat, 2017). In compliance with the interest of farmers, factories and seed companies to improve yield, processing efficiency, and quality of tomato diced-oriented type, new hybrids are to be evaluated. In order to carry out tomato genotype selection, some authors suggested performing a comprehensive evaluation using synthetic agronomic and quality indices (Arbex de Castro Vilas Boas et al., 2017), upon assessing an appreciable number of relevant variables such as dry matter, soluble solids, sugars, acidity, and antioxidants. Notably, high dry matter and soluble solids are desirable characteristics for the canned tomatoes industry since they improve the quality of the processed product (De Pascale et al., 2001). Indeed, soluble solid content and titratable acidity are the main components responsible for tomato flavour (Tieman et al., 2017), and they are most likely to match the consumer perception of the internal quality (Baldwin et al., 2015). In this respect,

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the balanced ratio between sugars and organic acids is important to sweetness, sourness, and overall flavour intensity in tomatoes (Baldwin et al., 2008). In fact, high acids and low sugars contents will produce a tart tomato, while high sugars and low acids contents will result in a tasteless tomato (Baldwin et al., 2008). Due to their antioxidant attributes in addition to sensory appeal, tomato-based products reduce risk of both cancer and incidence of coronary heart disease (Canene-Adams et al., 2005).

With the aim to identify promising genotypes, research has been carried out for evaluating yield, technological and quality characteristics of new hybrids oriented to diced tomato in Southern Italy.

1. Materials and methods

Research was carried out on processing tomato in Tavoliere delle Puglie (Foggia, southern Italy) in 2017, on silty-sandy soil, containing 2% organic matter, 1.3 g kg^{-1} N, 38 mg kg^{-1} P_2O_5, 95 mg kg^{-1} K_2O; the following values of mean temperature and rainfall were recorded during the crop cycles: 18.4 °C and 40 mm in May; 25 °C and 1 mm in June; 26.4 °C and 8.4 mm in July.

The experimental protocol was based on the comparison between 4 round-prismatic type hybrids oriented to diced produce: 4420 (HM Clause); Miceno (Syngenta); Nemabrix (United Genetics) and Impact (ISI Sementi) as a control. A randomized complete block design was used for the treatment distribution in the field, with three replicates, and the elementary plot had a 67 m^2 surface area.

Following wheat crops, tomato transplant was performed on 28 April by arranging a double-row layout and achieving a density of 3 plants per m^2. The following farming practices were carried out: fertilization with 230 kg ha^{-1} N, 250 P_2O_5, and 150 K_2O, of which 30% nitrogen and 50% phosphorus and potassium was applied at planting, and the remainder during crop by fertigation; 20 irrigations; plant protection against downy mildew, tomato leaf miner, aphids, whitefly, red spider, using Metalaxyl + copper, abamectin, imidacloprid; harvests were manually carried out between 3 and 7 August.

When the 90% of fruit were ripe, the following agronomic determinations were made in each plot: weight of marketable fruit (red + colour turning point) and waste berries (green + rotten); mean fruit weight on a random 100 fruit sample; middle length and width on a random 20 fruit sample.

Determinations of technological, quality, and sensory features of fruit collected in each plot and immediately transferred to SSICA laboratories in Angri (Salerno) were performed.

As for technological determinations, the processing yield was assessed, representing the ratio between the canned tomato fruit amount and the marketable yield obtained in the field. In this respect, tomato diced production was carried out on a semi-industrial scale, with the addition of 7.5° Brix juice of the same hybrid, packaged in painted tinplates of 1 kg. Each fruit fraction was weighed, such as yellow and necrotized, rotten, broken, undersized, and skins. The drained fruit liquid percentage was assessed, calculated as a mean of five cans; all determinations were performed in triplicate.

The fruit quality features and the related analytical procedures were as follows: total and soluble solids, sugars, titratable acidity, proteins, fats, fibre, ash, and sodium contents (Caruso et al., 2012); fatty acids content (Golubkina et al., 2015); colour (Conti et al., 2015); carotenoids content (De Sio et al., 2001); polyphenols content (Golubkina et al., 2017).

Briefly: sugars were assessed by HPLC, using the 600E Waters chromatographic system and a column Sugar-pak Waters at 85 °C; proteins with Kjeldahl method, by a Foss Tecator digestor with a Kjeltec 2300 distiller; fibre on dried and gelatinized samples enzymatically digested by proteases and amydoglucosydase, with soluble fibre precipitated by ethanol, calculated as the difference to the filtered dry residue weight upon protein and ash determination; sodium by atomic adsorption spectrophotometry using a model 1100 Perkin-Elmer spectrophotometer; fatty acids by gas chromatography on capillary glass column, using an Agilent 6890 gas chromatograph equipped with a flame ionization detector; colour by a Hunter Associate Laboratories D25-A model colorimeter; carotenoids through HPLC, using a Waters Alliance chromatograph equipped with photodiode array detector mod. 996, on a reversed phase column YMC-Pack C30 (250 mm × 4.6 mm i.d.); polyphenols in water extract through a spectrophotometer (Unico 2804 UV, USA), at 730 nm absorbance, using 0.02 % gallic acid as an external standard.

Sensory determinations were performed on diced tomato samples of each hybrid, which were coded and anonymously analyzed by a team (panel test) composed of fifteen specialists in tomato derivatives, five women and ten men, 40 to 60 year-old. Each expert evaluated the samples under neutral light (4000 K), and his opinion was reported in a form including 11 sensorial variables, five of primary importance and the remainder as their detailing. The score ranged from zero (extremely unpleasant) to ten (extremely pleasant).

All data were statistically processed by analysis of variance, and Duncan's test was used for mean separation; the percentage values were subjected to angular transformation before processing.

2. Result and discussion

The hybrids did not significantly differ in terms of crop duration, presumably due to the high temperatures during the crop cycles (reported in Materials and Methods), which led to fruit ripeness and harvest anticipation. From yield and biometrical data reported in Table 1, the hybrid Nemabrix attained the highest marketable yield (180.9 t ha^{-1}), as much as 96.7% of the total yield. The productive result positively correlated to the number of fruit per plant (R^2=0.90 at $P \leq 0.05$) and to their mean weight (R^2=0.92 at $P \leq 0.05$). Notably, Nemabrix produced the highest fruit number per plant (103.7), mean weight (70 g), and sizes (5.1 cm diameter and 6.0 cm length). No significant differences were recorded between the hybrids in terms of fruit covering by vegetation (> 75%). Yield levels obtained in our research are higher than those reported in previous investigation (Ercolano et al., 2015).

With regard to processing efficiency (Table 2), the control hybrid attained the highest values both as a total and along chain (80.0% and 67.8%, respectively), though not significantly different from Nemabrix (78.9% and 65.6%); as for waste, Miceno showed the highest drained liquid (27%).

Significant effects of the hybrid were recorded on the following quality indicators of diced tomato (Tables 3 and 4): the sugars ratio and colour attained the highest values in Nemabrix (54% and 2.00, respectively); the highest protein content was recorded in Miceno and the Control (1.92 g/100 g); the hybrid 4420 fruit showed the highest values of titratable acidity (0.5 g/100 g), fats (0.32 g/100 g), fibre (1.17 g/100 g), saturated fatty acids (0.1 g/100 g), ash (0.58 g/100 g), and sodium (6.5 mg/100 g), similarly to salt, which, however, was not significantly different from that detected in Miceno fruit (20 mg/100 g on average).

Table 1. Yield and biometrical parameters of round-prismatic tomato hybrids processing

Hybrid	Total fruit		Marketable fruit								Waste fruit
	Yield ($t \cdot ha^{-1}$)	Number per plant	Weight ($t\ ha^{-1}$)	Weight (%/total)	Number per plant	Mean weight (g)	Diameter (cm)	Length (cm)	Length/ width	Flesh thickness (cm)	Weight (%/total)
4420	169.9±7.1 b	87.6±4.8 b	159.8±7.4 b	94.0	78.6±3.1 b	67.6±3.1 ab	5.0	5.9	1.18 a	0.80±0.03 a	6.0 b
Miceno	150.4±5.6 c	80.1±5.2 b	139.7±6.9 c	92.9	73.5±3.9 b	63.1±2.6 b	4.9	5.5	1.13 b	0.72±0.02 b	7.1 a
Nemabrix	187.1±8.0 a	101.7±6.5 a	180.9±7.6 a	96.7	86.1±3.5 a	70.0±3.5 a	5.1	6.0	1.18 a	0.76±0.03 ab	3.3 c
Control	162.8±6.3 bc	90.8±5.7 ab	153.9±7.3 bc	94.6	80.3±3.0 ab	63.7±2.9 ab	4.8	5.7	1.19 a	0.72±0.02 b	5.4 b
				n.s.			n.s.	n.s.			

n.s.: not significant; within each column, values followed by different letters are statistically different according to Duncan test at $P \leq 0.05$.

Table 2. Processing efficiency of round-prismatic tomato hybrids along the diced chain

Hybrid	Processing efficiency			Waste along diced chain (%)				Waste along juice chain (%)		
	Total	Diced %	Juice	Yellow and necrotized	Rotten	Skins	Drained liquid	Yellow and necrotized	Rotten	Skins and seeds
4420	76.4±1.6 ab	63.3±1.2 bc	89.7	4.4 b	0.3 b	7.0 ab	24.9 a	4.7 a	2.3 a	3.3 b
Miceno	75.3±1.7 b	60.3±1.3 c	91.3	5.5 a	0.3 b	6.8 b	27.0 a	3.5 b	0.8 b	4.3 a
Nemabrix	78.9±2.0 ab	65.6±1.9 ab	92.1	4.3 b	0.3 b	7.6 a	22.1 b	4.5 a	0.8 b	2.6 c
Control	80.0±2.2 a	67.8±1.8 a	92.1	5.4 a	0.8 a	7.4 ab	18.6 c	3.5 b	2.0 a	2.4 c
			n.s.							

n.s.: not significant; within each column, values followed by different letters are statistically different according to Duncan test at $P \leq 0.05$.

Table 3. Quality features of diced tomato fruit hybrids

Hybrid	Total solids (g/100 g)	Soluble solids °Brix	Reducing sugars (g/100 g)	Titratable acidity (g anhydrous citric acid/100 g)	Sugar ratio (%)	Proteins (g/100 g)	Fats (g/100 g)	Fiber (g/100 g)	Energetic value (Kcal/100 g)	Colour a/b
4420	7.44	6.46	3.81	0.50±0.04 a	51.3±1.2 ac	1.70±0.06 b	0.32±0.02 a	1.17±0.05 a	26	1.79±0.02 c
Miceno	7.20	6.30	3.65	0.47±0.03 a	50.7±1.1 bc	1.92±0.08 a	0.27±0.01 b	1.02±0.03 b	26	1.90±0.03 bc
Nemabrix	7.14	6.16	3.86	0.35±0.02 b	54.0±1.6 a	1.85±0.07 a	0.26±0.01 b	0.94±0.03 c	26	2.00±0.04 a
Control	7.14	6.14	3.55	0.37±0.02 b	49.7±1.0 c	1.92±0.09 a	0.26±0.01 b	1.06±0.04 b	25	1.96±0.03 ab
	n.s.	n.s.	n.s.						n.s.	
Average	7.20	6.30	3.70		51.4					1.9
Relative variation of diced to fresh (%)	+22.7 *	+20.9 *	+24.6 *		+1.5 n.s.					–28.2 *

n.s.: not significant; *: significant at P≤0.05. Within column, values followed by different letters are different according to Duncan test at P≤0.05.

Table 4. Sugars, fatty acids, and mineral components in diced tomato fruit hybrids

Hybrid	Sugars			Fatty acids			Ash	Sodium	Salt
	Glucose	Fructose	Sucrose	Saturated	Monounsaturated	Polyunsaturated			
	(g/100 g)							(mg/100 g)	
4420	1.52	1.61	0.04	0.10±0.01 a	0.06	0.14	0.58±0.02 a	6.5±0.04 a	0.02 a
Miceno	1.44	1.55	0.04	0.07±0.00 c	0.06	0.13	0.49±0.01 c	6.2±0.03 a	0.02 a
Nemabrix	1.54	1.61	0.05	0.07±0.00 c	0.05	0.13	0.52±0.01 b	5.3±0.02 b	0.01 b
Control	1.44	1.52	0.04	0.08±0.01 b	0.05	0.13	0.53±0.02 b	5.3±0.02 b	0.01 b
	n.s.	n.s.	n.s.		n.s.	n.s.			

n.s.: not significant; within column, values followed by different letters are statistically different according to Duncan test at P≤0.05.

No significant differences arose between the hybrids referring to contents of total solids (7.2% on average), soluble solids (6.3 °Brix), reducing sugars (3.7 g/100 g), glucose (1.5 g/100 g), fructose (1.6 g/100 g), sucrose (0.04 g/100 g), monounsaturated and polyunsaturated fatty acids (0.06 and 0.13 g/100 g, respectively), and energetic value (25.8 kcal/100 g or 108.3 kJ/100 g).

Compared to fresh fruit just after field harvesting (Table 3), diced tomatoes showed increased values of total and soluble solids (+22.7% and +20.9%, respectively) as well as reducing sugars (+24.6%), stability of reduced sugar ratio, and less intense colour (–28.2%). Moreover, pH of fresh fruit was not significantly affected by the hybrid, ranging between 4.2 to 4.4.

High total solids content in tomato fruit is an industrial aim, as it reduces processing costs, and it shows wide variation around the 5–6% average, also depending on cultivar (Siddiqui et al., 2015). As for soluble solids, Kader and co-workers (1987) reported that values under 4.5 °Brix are considered low for industrial tomatoes; in this respect, found this quality indicator varied between 4 to 6 °Brix in tomato fruit in previous research (De Pascale et al., 2001; Turhan & Seniz, 2009). Sugar content is positively and highly correlated with total soluble solids in tomato fruit, ranging from 0.54 to 4.7% of fresh weight (Melkamu et al., 2008; Turhan & Seniz, 2009). In our research, the sum of glucose and fructose accounted for 80% of sugars, whereas it attained about 65% in previous investigations (Jones & Scott, 1984).

Titratable acidity in tomato fruit reportedly ranged from 0.25 to 0.70% (George et al., 2004). According to Beckles (2012), values of total soluble solids and titratable acidity as much as 5.0 and 0.4%, respectively, are considered desirable to produce a good-tasting tomato. Moreover, in addition to flavour, organic acids influence pH, which should be lower than 4.5 in order to control proliferation of thermophilic microorganisms in canned tomato (Garcia & Barrett, 2006). Notably, some authors did not detect varietal dependent pH differences in tomato berries (Kerkhofs et al., 2005), conversely to other reports (Frusciante et al., 2007).

With regard to antioxidants (Table 5), lycopene attained the highest concentration in Nemabrix (155 mg kg^{-1} or 217.1 mg/100 g TS), whereas β-carotene was most concentrated in 4420 and Miceno (2.8 mg kg^{-1}). No significant differences were recorded between the hybrids examined concerning polyphenols content (on average 35.2 and 4.9 mg equivalent of gallic acid referred to 100 g of fruit or to 1 g of total solids, respectively).

Table 5. Concentration of antioxidants in diced tomato fruit hybrids

Hybrid	Lycopene				β-carotene		Total polyphenols	
	mg kg^{-1}		mg/100 g TS		mg kg^{-1}		mg GAE/100 g	mg GAE/g TS
4420	140.4±4.3	b	188.8±5.8	b	2.8±0.2	a	35.7	4.8
Miceno	153.1±5.6	a	212.6±7.8	a	2.8±0.2	a	35.7	5.0
Nemabrix	155.0±7.2	a	217.1 ±10.0	a	1.1±0.1	b	33.7	4.7
Control	150.1±4.9	a	210.2±6.9	a	1.1±0.1	b	35.7	5.0
							n.s.	n.s.
Average	149.7		207.2		2.0		35.2	4.9
Relative variation of diced to fresh (%)	–2.6	n.s.	–20.6	*	–6.1	n.s.	+12.5 *	–8.0 *

n.s.: not significant; * : significant at P≤0.05. Within column, values followed by different letters are statistically different according to Duncan test at P≤0.05.

In previous research (HELYES et al., 2008), significant differences were found in lycopene and phenolic contents between the different genotypes, with lycopene showing 1 to 4 fold and 1 to 2 fold variation on fresh and dry weight basis, respectively.

Compared to fresh fruit (Table 5), diced tomatoes showed significantly reduced concentrations of lycopene and polyphenols in terms of total solids (–20.6% and –8%, respectively), but the latter antioxidants had an 8% increase referred to fresh weight; no significant differences between raw and diced fruit were recorded for lycopene and β-carotene on a fresh weight basis. Unlike our findings, DEWANTO and co-workers (2002) reported the increase of lycopene concentration and no changes in polyphenols content in processed tomato fruit compared to raw berries. However, in other research (PAVLOVIĆ et al., 2017), the antioxidants content in tomato fruit decreased upon thermal treatment, but the significance and amplitude of the differences were genotype dependent.

As for sensorial features, the graphic representation of QDA (Quantitative Descriptive Analysis) obtained by processing the evaluation forms filled in by the experts is shown in Fig. 1A. Taking into account the high number of data and in order to make it easier to interpret the profiles, the data of sensorial variables considered negative in relation to the processed products tested were extrapolated. In particular, the data associated with strange taste and flavour as well as with acidity were clustered (Fig. 1B); from the profiles obtained and from the statistical processing it arises that the hybrids 4420 and Miceno were significantly different with regard to the variable "strange flavour", and that 4420 was different from Miceno and Control concerning the variable "strange taste". The sensorial profiles of the positive variables (Fig. 1C) show that the hybrid 4420 is significantly different from the other genotypes with regard to the variables aspect, colour, taste, and firmness, and different from Miceno in terms of fresh taste.

3. Conclusions

From research carried out on the comparison of round-prismatic type hybrids oriented to diced produce in Southern Italy, Nemabrix showed the best yield performances, due to the highest fruit number and mean weight, and was not significantly lower than the top ranking Control in terms of processing efficiency. Each hybrid was best associated to a quality feature cluster and, in particular, Nemabrix fruit attained the highest content of lycopene, and 4420 and Miceno berries the highest β-carotene.

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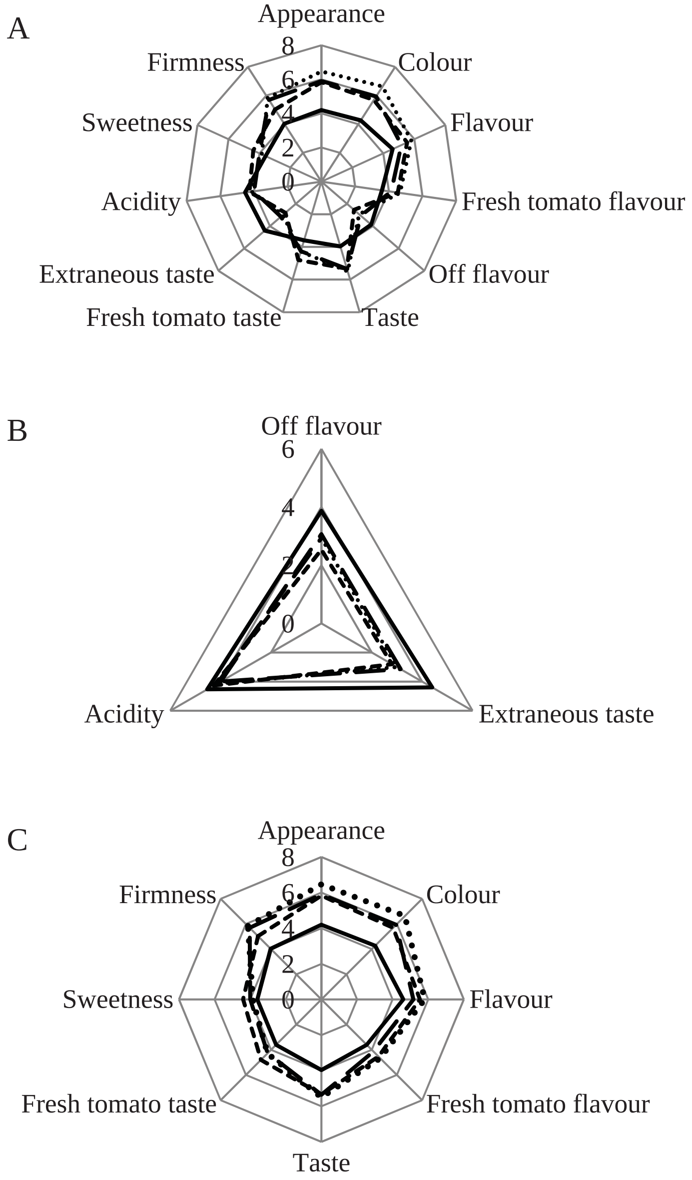

Fig. 1. Sensorial profiles related to hybrids (1A), sensorial profiles of the undesired features, named negative (1B); sensorial profiles of the desired features, named positive (1C).
—–: 4420; ----: Miceno; – –: Nemabrix; ······: Control

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