

Yield, quality and antioxidants of peeled tomato as affected by genotype and industrial processing in Southern Italy

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Abstract: Research was carried out on processing tomato in San Severo (Tavoliere delle Puglie, Foggia, Italy) in order to compare four long-type fruit hybrids oriented to peeled produce (Abbundo, Umex, Superpeel, Taylor), using a randomized complete block design with three replicates. The hybrid Superpeel reached the highest marketable yield due to the highest fruit number and mean weight; along the peeling chain, Umex and Taylor showed the highest processing efficiency. Titratable acidity and sodium were highest in Taylor fruits, whereas the highest fiber content was detected in Abbundo fruits. Compared to pre-processing fruits, peeled tomatoes showed increased values of total and soluble solids as well as reducing sugars, but decreased sugar ratio and colour. The highest concentrations of antioxidants in processed fruits were recorded in Umex for lycopene and in Superpeel for β -carotene. Compared to pre-processing fruits, in peeled tomatoes lycopene and β -carotene concentrations remained stable and polyphenols increased referring to fresh weight. The hybrids examined did not show univocal trends in terms of sensorial features.

1. Introduction

Tomato is the most cultivated vegetable species worldwide with 5,023,810 ha (FAO, 2014); Italy is a major European producer of processing tomato with a surface area as much as 79,761 ha devoted to this crop (ISTAT, 2017 - dati.istat.it), of which 32% are located in Emilia-Romagna and 25% in Apulia. The Italian industry of tomato and its derivatives (peeled, diced and sauce) attained an export gross marketable yield as

much as about 1.5 billion of euros in 2017 (ISTAT, 2017). These products are traditionally addressed to United Kingdom, USA, France, Australia, Japan, Germany, Belgium, but also to growing demanding markets, i.e. eastern Europe, South America (Brazil and Argentina), South Africa, South Korea, United Arab Emirates.

The interest of processing factories in southern Italy to valorize peeled-oriented tomato type matches the seed company goal to provide farmers with hybrids showing high yield, improved taste and flavour features, and better industrial requirements compared to the current genotypes. With these prospects, the new hybrids are evaluated with regard to the main traits, such as: plant architecture and parasite resistance; morphology, number, weight, ripeness uniformity, technological and quality performances of fruits.

In order to carry out tomato genotype selection, some authors suggested to perform a comprehensive evaluation using synthetic agronomic and quality indexes (Carli *et al.*, 2011), upon assessing an appreciable number of related 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 flavor (Kader, 1986; Flores *et al.*, 2008) and they are most likely to match the consumer perception of the internal quality (Baldwin *et al.*, 1998; Arazuri *et al.*, 2007). In this respect, the balanced ratio between sugars and organic acids is important to sweetness, sourness and overall flavor intensity in tomatoes (De Bruyn *et al.*, 1971; Stevens *et al.*, 1977). In fact, high acids and low sugars will produce a tart tomato while high sugars and low acids will result in a tasteless tomato (Kader, 1986).

Due to their antioxidant attributes in addition to sensorial appealing (Raiola *et al.*, 2016), tomato-based products are associated with a low risk of both cancer and incidence of coronary heart disease (Pernice *et al.*, 2010; Ilahy *et al.*, 2011).

The present research was carried out since new hybrids for peeled tomato with improved features are needed for the cultivation in Southern Italy and, in this respect, they were compared with a widespread cultivar in southern Italy, in terms of yield, technological, quality and sensorial characteristics.

2. Materials and Methods

Field conditions

Research was carried out on processing tomato at De Maio farm, located in San Severo (Tavoliere delle Puglie, Foggia, southern Italy) in 2017 on silty-sandy soil.

The experimental protocol was based on the comparison between 4 long-type hybrids oriented to peeled produce: Abbundo (HM Clause Italia SpA., Italy); Umex (Syngenta Italia SpA., Italy); Superpeel (United Genetics Italia SpA., Italy); Taylor (Nunhems Italy Srl, Italy) 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 m² surface area.

The transplant was performed on 28 April, arranging a double-row layout, with 35 cm between the plants spacing along the rows, 40 cm between the two rows in each couple and 150 cm between the outer rows of two adjacent couples, thus achieving a density of 3 plants per m².

The ordinary farming technique related to processing tomato in Tavoliere delle Puglie was followed and harvests were practiced between 3 and 7 August.

Yield, quality and technological determinations

When the 90% fruits were ripe, the following agronomic determinations were made in each plot: weight of marketable fruits (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; percentage of fruit coverage exerted by plant canopy, referred to the ranges of 0-25%, 25-50%, 50-75%, 75-100%.

Quality analyses of pre-processing fruits sampled in each field plot, as well as technological and quality determinations of processed fruit samples of each hybrid were performed at the laboratories of Stazione Sperimentale per l'Industria delle Conserve Alimentari in Angri (Salerno).

As for technological determinations, the processing yield was assessed, representing the ratio between the canned tomato fruit amount, after selection and technological process, and the marketable yield obtained in the field. The fruit processing was performed using the pilot plant available at SSICA. In this respect, tomato peeled production was carried out on a semi-industrial scale, with juice addition, packaged in painted tins of 1 kg; notably, the juice obtained by the same cultivar was added

after partial concentration at 7.5°Brix. In order to assess the processing yield, weights were recorded at each different step, the product to be peeled underwent selections and weighing of each fruit fraction such as yellow and necrotized, rotten, broken, under-sized; moreover, skins were weighed after peeling. As concerns the product submitted to the juice chain, yellow, necrotized and rotten fruits, as well as skins and refining seeds were weighed. Next, the drained fruit percentage was assessed, calculated as a mean of five cans; all the determinations were performed in triplicate and averaged.

The fruit quality features assessed on both fresh and peeled fruits, referred to fresh weight, were: total solids (TS), soluble solids (SS), reducing sugars (glucose and fructose) and sucrose, colour (a/b ratio), antioxidants (lycopene, β -carotene, total polyphenols). In addition, the components included in the current European nutritional label, according to EU Regulation 1169/2011, were determined: proteins, titratable acidity, lipids, fatty acids, fiber, salt and sodium. The analytical procedures were performed according to Caruso *et al.* (2012) for total and soluble solids, sugars, proteins, fiber, ash and sodium; MiPAF (1973) for titratable acidity and fats; Golubkina *et al.* (2015) for fatty acids; Conti *et al.* (2015) for colour; De Sio *et al.* (2001) for carotenoids; Golubkina *et al.* (2017) for polyphenols. Briefly, total solids were assessed in oven at 70°C under vacuum until steady weight, whereas soluble solids by means of a digital refractometer. Sugars were determined by HPLC, using the 600E Waters chromatographic system and a column Sugar-pak Waters at 85°C, EDTA-Ca in water solution as eluent (50 mg L⁻¹). Proteins were assessed with the Kjeldahl method, by a Foss Tecator digester with a Kjeltec 2300 distiller. Fibre was determined after the samples were weighed, dried (105°C), gelatinized in the presence of heat-resistant α -amylase and enzymatically digested by proteases and amyloglucosidase, to remove proteins and starch, whereas soluble fibre was precipitated by ethanol; the residue was filtered, washed with ethanol and acetone, dried, weighed and split into two fractions to determine proteins and ash, and fibre content as the difference to the residue weight. Sodium was assessed by atomic adsorption spectrophotometry, after sulpho-nitric mineralization, with a model 1100 Perkin-Elmer spectrophotometer. Fatty acids were detected by gas chromatography via appropriate methyl ethers chromatography on capillary glass column, using an Agilent 6890 Gas Chromatograph, equipped with a flame ionization

detector; the peaks of fatty acids methyl ethers were identified by comparison to the retention times of reference standards. Colour was assessed by a Hunter Associate Laboratories D25-A model colourmeter, using a suitable measurement cell with the standard BCR n. 1266 reference whose values are L= 25.7, a= 23.7, b= 14.8; chromatic parameter values are expressed in the Hunter scale as a/b. Carotenoids were assessed through HPLC, using a Waters Alliance chromatograph equipped with photodiode array detector mod. 996, performing the determinations at 450 nm on a reversed phase column YMC-Pack C30 (250 x 4.6 mm i.d.) filled with 5 μ m average particle size. Polyphenols were determined in water extract through a spectrophotometer (Unico 2804 UV, USA); the concentration was calculated according to the absorbance at 730 nm, using 0.02% gallic acid as an external standard.

Sensorial determinations

Sensorial or organoleptic determinations were performed on processed tomato samples of each hybrid, which were coded and anonymously analyzed by a panel test team composed of ten specialists in tomato derivatives and five fellows at the first panel experience. Each expert evaluated the samples under neutral light (4000 K) and his opinion was reported in a form including 11 sensorial variables. Among the latter, five were considered of primary importance and the remaining as their detailing. With regard to primary variables, the score ranged from zero (extremely unpleasant) to ten (extremely pleasant) and, in particular: colour score zero was matched to brick red and ten to bright red; firmness score zero was associated to chewiness resistance absence and ten to extremely tough product. As for secondary variables, the form delivered to the panel test team was elaborated in order to minimize the fluctuations caused by the first-experience fellows. Moreover, the following perceptions and the related scores in brackets were taking into account: absence (2), mild presence (4), medium presence (6), strong presence (8); the scores were used to calculate the average value per each sample.

Statistical processing

The data relevant to agronomic, technological, quality and sensorial determinations were statistically processed by analysis of variance, with the ensuing Duncan's multiple range test for mean separation at 0.05 probability level. The percentage values were subjected to angular transformation before processing.

no significant differences arose as concerns the juice yield (91.2% as an average).

In terms of waste along the peeling chain, Abbundo attained the highest occurrence of yellow and necrotized fruits, Umex the lowest and Taylor the lowest broken berry percentage. The undersized and rotten fruits were very few and Superpeel had the highest skin fraction.

As for waste along the juice chain, Abbundo showed the highest percentage of yellow and necrotized fruits, which was 79% higher than the lowest one corresponding to Umex; the latter hybrid also had the lowest value of rotten berries and the highest of skin and seeds.

The results relevant to the quality indicators of processed tomato (Tables 3 and 4) show that significant effects of the hybrid were recorded on the following parameters: titratable acidity and sodium attained the highest value in Taylor fruits (0.37% and 7.4 mg·100 g⁻¹ respectively) and lowest in Abbundo; the fiber content recorded in Abbundo fruits was 17% higher than Taylor one; ash and salt concentrations showed the highest levels in Umex (0.54% and 20.4 mg·100 g⁻¹ respectively) though the latter variable was not significantly different from Taylor.

No statistically significant differences were recorded between the hybrids referring to: total solids (7% on average), soluble solids (6.1%), reducing sugars (3.8%), sugars ratio (54.3%), proteins (1.6%), lipids (0.3%), energetic value (24.5 kcal·100 g⁻¹ or 104,5 kJ·100 g⁻¹), colour (1.82), glucose (1.5%), fructose (1.6%), sucrose (0.04%), fat acids expressed as saturated (0.07%), monounsaturated (0.06%) and polyunsaturated (0.14%).

Compared to pre-processing fruits, peeled tomatoes showed increased values of total and soluble solids as well as reducing sugars, but decreased levels of sugar ratio and colour; moreover, pH of fresh fruits was not significantly affected by the hybrid, ranging between 4.4 to 4.5. In previous research (Raiola *et al.*, 2018) the comparison between the values recorded before and after processing was genotype-dependent, except for titratable acidity and sugar ratio which always decreased and increased respectively, upon processing.

High total solids content in fruits is an industrial target, as it reduces the processing costs; this parameter in tomato varies around the 5-6% average and it is affected by some factors such as cultivar, soil type and climate conditions during the growing and

Table 3 - Quality features (referred to fresh weight) of peeled tomato fruits obtained from four hybrids

Hybrid	Total solids (g·100 g ⁻¹)	Soluble solids (°Brix)	Reducing sugars (g·100 g ⁻¹)	Titratable acidity (g anhydrous citric acid 100 g ⁻¹)	Sugar ratio (%)	Proteins (g·100 g ⁻¹)	Fats (g·100 g ⁻¹)	Fiber (g·100 g ⁻¹)	Energetic value (Kcal·100 g ⁻¹)	Colour (a/b)
Abbundo	7.0	6.1	4.0	0.27 c	56.7	1.56	0.27	1.32 a	24	1.82
Umex	7.0	6.1	3.8	0.29 c	53.5	1.52	0.31	1.23 b	25	1.81
Superpeel	7.0	6.1	3.7	0.33 b	53.5	1.59	0.26	1.19 bc	24	1.80
Control	7.1	6.2	3.8	0.37 a	53.6	1.64	0.32	1.13 c	25	1.85
	NS	NS	NS		NS	NS	NS		NS	NS
Average	7.0	6.1	3.8		54.3					1.82
Peeled/Fresh (%)	+ 24.7	+ 21.8	+ 18.2		- 5.2					- 30.6

NS= not significant; within each column, the values followed by different letters are statistically different according to Duncan's multiple range test at P≤0.05.

Table 4 - Sugars, fatty acids and mineral components (referred to fresh weight) in peeled tomato fruits produced by four hybrids

Hybrid	Sugars (g·100 g ⁻¹)			Fatty acids (g·100 g ⁻¹)			Ash (g·100 g ⁻¹)	Sodium (g·100 g ⁻¹)	Salt (g·100 g ⁻¹)
	glucose	fructose	sucrose	saturated	monounsaturated	polyunsaturated			
Abbundo	1.48	1.57	0.04	0.06	0.06	0.13	0.47 c	5.6 c	10.3 b
Umex	1.54	1.58	0.04	0.07	0.07	0.15	0.54 a	6.4 b	20.4 a
Superpeel	1.46	1.58	0.04	0.06	0.05	0.13	0.51 ab	5.9 c	9.8 b
Control	1.49	1.60	0.04	0.08	0.07	0.15	0.50 bc	7.4 a	19.5 a
	NS	NS	NS	NS	NS	NS			

NS= not significant; within each column, the values followed by different letters are statistically different according to Duncan's multiple range test at P≤0.05.

harvesting season (Siddiqui *et al.*, 2015). Other authors (Majkowska-Godomska *et al.*, 2008) recorded a total solids content of tomato fruits ranging from 3.83 to 7.00%.

Campos *et al.* (2006) and Kader *et al.* (1987) reported that values of soluble solids below 4.5% are considered low for industrial tomatoes; in this respect, Turhan and Seniz (2009) found this quality indicator ranging between 5.0 to 5.5 % in processing tomato fruits and in other studies (Cramer *et al.*, 2001; De Pascale *et al.*, 2001) soluble solids values of tomato fruits ranged from 4 to 6%.

Sugar content is positively and highly correlated with total soluble solids in tomato fruit and, notably, fructose has a large impact on the sweetness perception (Tieman *et al.*, 2012). In our research the sum of glucose and fructose accounted for the 80% of the total sugars, whereas it attained about 65% in previous investigations (Stevens *et al.*, 1977; Jones and Scott, 1984; Malundo *et al.*, 1995). Other authors found the total sugar content of ripe tomato ranging from 1.7 to 4.7% (Petro-Turza, 1987; Turhan and Seniz, 2009) or from 0.54 to 3.44% (Melkamu *et al.*, 2008) of fresh weight.

In previous research, titratable acidity (TA) in tomato fruits ranged from 0.22 to 0.40% (Turhan and Seniz, 2009) or even 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. Titratable acidity is mainly affected by citric and malic acids which reportedly attain about 15% of the dry content in ripe fresh tomatoes (Petro-Turza, 1987). Kamis *et al.* (2004) states that taste and flavour of tomato fruits are positively correlated to sugars and organic acids content. Moreover, in addition to flavour the organic acids influence pH, the latter being an important fac-

tor in canned tomato products to control the growth of thermophilic microorganisms (Yousef and Juvik, 2001). The influence of pH on the thermal conditions applied along the tomato processing chain is mainly associated to producing safe products and, in this respect, values below 4.5 prevent microorganism proliferation in the final product (Campos *et al.*, 2006; Garcia and Barrett, 2006). Notably, some authors did not detect varietal dependent pH differences in tomato berries (Kerkhofs *et al.*, 2005), whereas in other research pH showed differences among cultivars (Benal *et al.*, 2005; Frusciante *et al.*, 2007) even in the wide range of 3.78 to 5.25 (Turhan and Seniz, 2009).

Mineral element concentration in tomato fruits may reach 8% of dry matter and influences tomato fruit taste through the effect on pH and titratable acidity (Siddiqui *et al.*, 2015).

With regard to antioxidants (Table 5), lycopene attained a 16% higher concentration in Umex compared to Abbundo; Superpeel showed a 43% higher β -carotene content than Abbundo; polyphenols concentration was the lowest in the control fruits, but did not significantly differs between the three hybrids examined.

Compared to fresh fruits, in peeled tomatoes lycopene and β -carotene concentrations remained stable and polyphenols increased referring to fresh weight, whereas in relation to total solids lycopene had a 19.1% decrease whereas polyphenols just a slight reduction (5.2%).

In previous research (Binoy *et al.*, 2004) 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. Moreover, unlike our findings where lycopene remained stable and polyphenols increased upon industrial processing

Table 5 - Antioxidants concentration in peeled tomato fruits obtained from four hybrids

Hybrid	Lycopene		β -carotene mg·kg ⁻¹	Total polyphenols	
	mg·kg ⁻¹	mg·100 g ⁻¹ TS		mg eq. gallic acid 100 g ⁻¹	mg eq gallic acid g ⁻¹ total solids
Abbundo	127.0 c	181.9 c	2.1 c	36.7 a	5.3 a
Umex	146.6 a	208.3 a	2.3 bc	36.0 a	5.1 a
Superpeel	136.2 b	195.3 b	3.0 a	35.7 a	5.1 a
Control	131.0 bc	184.7 bc	2.4 b	31.7 b	4.5 b
Average	135.2	192.6	2.5	35.0	5.0
Peeled/fresh (%)	0.9	-19.1	-1.0	17.6	-5.2

Within each column, the values followed by different letters are statistically different according to Duncan's multiple range test at P≤0.05.

and referred to fresh weight, Dewanto *et al.* (2002) reported the increase of lycopene concentration with no changes in polyphenols content in processed tomato fruits compared to raw berries. However, in other research (Pavlović *et al.*, 2017) the antioxidants content in tomato fruits decreased upon processing thermal treatment, though the significance and amplitude of the differences are genotype dependent, and it is also affected by temperature settings (Jabbari *et al.*, 2018).

The scores resulted from the panel test performed by an expert team in tomato organoleptic evaluation and their subsequent statistical processing allowed to obtain the sensorial profiles which convey the immediate and clear quantitative and descriptive perception of the analyzed products.

The graphic representation of QDA (Quantitative Descriptive Analysis) obtained by processing the evaluation forms filled in by the experts is shown in figure 2 a.

Taking into account the high number of data and in order to make it easier to interpret the profiles, the sensorial variable data considered negative for the relevant hybrids were extrapolated. In particular, the data related to strange taste and flavour and to acidity were clustered (Fig. 2 b): the profiles and the statistical processing performed show that there are no significant differences between the hybrids. The sensorial profiles of the positive variables are shown in Figure 2 c. Moreover, from data statistical processing reported in Table 6, it can be observed that the peeled product obtained from the hybrids Abbundo and Umex is statistically different in terms of colour, aspect and flavor; in addition, Abbundo is statistically different from Taylor for the colour and from Superpeel for the sensation of fresh flavor.

Table 6 - Organoleptic features of peeled tomato fruits produced by four hybrids: analysis of variance and F significance

Variable	Cultivar		Δ	σ
Aspect	Abbundo	Umex	-1.43	0.007
Colour	Abbundo	Umex	-1.30	0.013
Colour	Abbundo	Control	-1.10	0.035
Flavour	Abbundo	Umex	1.00	0.050
Flavour as fresh	Abbundo	Superpeel	1.20	0.023

Δ = differences between the means; σ = F significance.

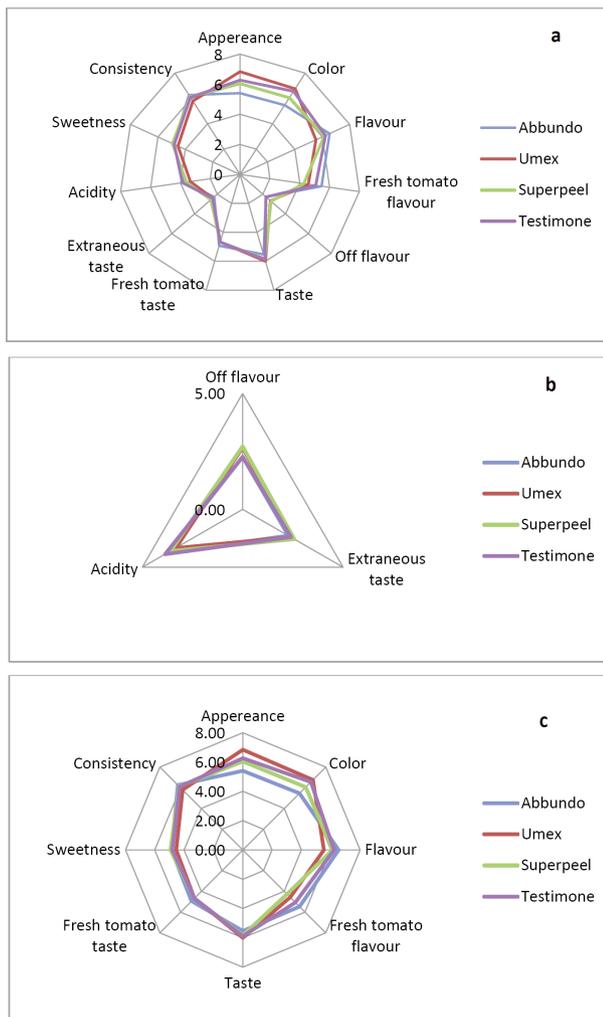


Fig. 2 - Organoleptic evaluations of peeled tomato fruits: comparison of the sensorial profiles of the four hybrids (a), sensorial profiles of the undesired features, named negative (b); sensorial profiles of the desired features, named positive (c).

4. Conclusions

From research carried out on the comparison between long-type hybrids oriented to peeled produce in Tavoliere delle Puglie (Foggia, southern Italy), Superpeel showed the best yield performances (175.2 t·ha⁻¹) with about 21% higher production than the average value attained by Abbundo, Umex and Taylor, as a consequence of the combined effects of fruit number and mean weight. However, the highest processing efficiency was recorded for the hybrid Umex and Taylor, whereas no hybrid displayed an overall superiority in terms of quality features and sensorial profile.

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