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Evaluation of fruit quality traits of traditional varieties of tomato (*Solanum lycopersicum*) grown in Tunisia

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Physicochemical, nutritional, agronomic and sensorial parameters, which define fruit quality of tomato (*Solanum lycopersicum*), were evaluated in 13 traditional varieties collected from several localities in Tunisia, using three commercial varieties as controls. Several varieties were identified as better score for total solid, soluble solid, sugars/acid ratio and vitamin C concentration than the commercial varieties. These varieties could be a resource of good quality in breeding programmes. The correlation between specific parameter seen in this study showed that the local varieties can be differentiated, not just as a function of their morphological attributes but also as a function of their organoleptic, nutritional and sensorial quality.

Key words: Tomato, quality, selection, breeding programme.

INTRODUCTION

Major fruit quality of interest to both fresh market and industrial tomato include a number of agronomic, organoleptic and nutritional qualities. Organoleptic quality is evidenced via physicochemical parameters that make product to be acceptance to consumers (Stevens, 1972; Kader et al., 1977). Total fruit solids content is particularly important to the processing industry and has probably received more attention than any other fruit trait. Total solids content of cultivated tomato amount to 4.5 to 8.5% of its fresh weight (André et al., 2005), though this percentage can be much higher in some wild species (Bertin et al., 2000).

Total solids comprise all fruit components such as aromas except water and volatiles. In cultivated tomato, the soluble (SS) and insoluble solids (ISS) account for about 75 and 25%, respectively, of total solids (Majid, 2007). Reducing sugars (glucose and fructose) are the major components of the SS; sucrose is also present but in very small quantities (Malundo et al., 1995). Remaining soluble solids consist of organic acids, lipids, minerals and pigments. ISS include proteins, cellulose, hemicellulose, pectins and polysaccharides, which determine fruit juice. Estimates of SS contents of the commercial cultivars of tomato range between 4.6 (mostly fresh tomato) and 6.3% (mostly for processing) of fresh weight. However, accessions have been identified within related wild species of tomato, including *Lycopersicon pimpinellifolium*, *Lycopersicon chmielewskii* and *Lycopersicon cheesmanii*, with much higher concentrations (9 to 15%) of SS (Chen and Foolad, 1999). Titratable acidity, pH, fruit firmness are important fruit quality characteristics of tomato. Organic acids give the fruits sourness, and affect flavour by acting on the perception of sweetness (Fisher et al., 1997). The major organic acids in tomato are citric and malic acid, with citric acid predominating (Davies and Hobson, 1981). Acidity influences storability of processed tomato. Lower pH reduces the risk of pathogen growth in tomato products, such as *Bacillus coagulans*, which is found to be completely inhibited by a pH below 4.1 (Majid, 2007). Titratable acidity has no significant effect on tomato flavour unless pH is low. For this reason, a pH below 4.5 and citric acid content of above 0.35 g/100 g of fruit fresh weight are desirable. Firmness is one of the major factors

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contributing to shelf quality of tomato fruit. Consumers judge the quality of fresh tomatoes by their firmness, colour and taste (Rosenfeld et al., 1994).

Organoleptic quality is correlated with sensorial parameters. Flavour is a function of both taste (e.g., sugars and acids), and aroma (e.g., volatile compounds) components. Sugars, acids and sugar/acid ratios have been defined as good indicators of tomato flavour (Stevens et al., 1977; Kader et al., 1978).

In addition, tomatoes may provide a convenient matrix by which nutrients and other health-related food components can be supplied to humans (Sanchez-Moreno et al., 2006). Thus, tomatoes contribute significantly to the dietary intake of vitamin C, lycopene, beta-carotene, folate, potassium, flavonoids and vitamin E (Willcox et al., 2003). Fresh and processed tomatoes are rich sources of a natural antioxidant which can replace synthetic antioxidants and thus protect cells from oxidants that have been linked to cancers of the stomach, oesophagus, lung, pharynx, endometrium, pancreas, and colon (Hounsome et al., 2008).

Tomatoes can provide a significant proportion of total antioxidants in the diet, in the form of carotenes and phenolic compounds. Lycopene predominates among carotenoids and is mainly responsible for the red colour of tomato fruits and their derived products (Valverde et al., 2002).

In recent years, with the arrival of new commercial varieties, fruit external attributes such as colour, size and shape have a priority in improvement programs, whereas organoleptic and nutritional attributes have been regarded to be of secondary importance in food production. However, these parameters alone do not guarantee correct flavour and texture quality of a product. The sum of sugars, organic acids and the amount of volatile compounds, as well as colour, shape and texture determine the sensory properties of tomatoes (Azodanlou et al., 2003). One possibility for improving the quality of numerous horticultural crops might be to obtain new cultivars from hybridisations between the present day improved varieties and traditional local lines.

The objective of this work was to select varieties with excellent fruits characteristic and that can easily compete with commercial varieties and thus could considerably ease future breeding programmes.

MATERIALS AND METHODS

Plant material and crop conditions

Thirteen traditional varieties of tomato, collected from the traditional agrosystem of Tunisia, were grown in winter cycle in covered greenhouse at the Institut des Régions Arides (Southern Tunisia, Latitude 33°35' N Longitude 10°48'3'' E Altitude 105 m). The climate in this region can be defined as arid inferior, with mild winter. Measured air temperature in the greenhouse corresponding to the harvest period is in average of 31.65°C.

The experimental design consisted of randomized blocks replicated four times. Each replicate contained five plants per variety. These varieties were called IRA, followed by a number to identify their origin. The commercial varieties “Marmande VF”, “Rio Grande” and “Ventura”, the three most cultivated varieties in Tunisia during the last decade, were used as controls. Tomatoes were harvested at the optimum ripeness stage between 9:00 and 11:00 am and immediately used for analysis.

Tomato samples were analysed for their agronomic traits (fruit weight, diameter), physicochemical traits (total solid percentage, citric acid concentration, pH and total soluble solid content), nutritional traits (vitamin C, potassium content) and sensorial traits (intensity of red colour, firm texture, elasticity, intensity of aroma and taste).

Physicochemical and nutritional analysis

Soluble solid content (°Brix) was determined using a hand refractometer (Reichert, Scientific Instruments), pH was measured with a pH-meter (pH-200L; Neo Met). For determination of total acidity, 10 g of tomato puree was titrated to 8.0 using 0.1 mol/L KOH. The titrated volume (mL) corresponds directly to total acidity expressed as g/L citric acid (Azodanlou et al., 2003). To determine potassium content, tomato homogenates were dried at 80°C for 48 h and were subsequently digested in a 60% nitric and 60% perchloric acid mixture (85:15, v/v) at 200°C for 6 h (Anza et al., 2006). Cationic mineral (K^+) was determined by flame atomic absorption spectrophotometry (Sherwood, Model 410).

Vitamin C (Ascorbic Acid) was determined as described by Serrano et al. (2007). A portion of 25 g of fruit was added to 25 ml of 4.5% ortho-phospohric solution. The mixture was homogenized and centrifuged at 9000 *g* for 25 mn at 4°C. The supernatant was filtered through Whatman No.1. Then 10 ml of the filtered sample were passed through a Millipore 0.45 micrometer membrane and were thus ready to be injected in the HPLC system (Knauer; UV and RI detecteur; Pump K501).

Sensory analysis

Sensory analyses were performed by a trained panel of 10 judges. For each variety, four different attributes were revealed: one related to appearance (red colour intensity), one to flavour (intensity of aroma), two to texture (firm texture, juiciness, and elasticity), and one to taste (tomato taste). Each panellist received 10 samples, then the panel rated the different parameters on 1-6 scale (e.g. 1 = very weak aroma intensity and 6 = very strong aroma intensity). The same liking scale was used for the overall appreciation.

Statistical evaluation

Statistical analysis was performed using SPSS program (version 15). Analysis of variance (ANOVA) and Duncan’s multiple range test ($P<0.05$) was used to establish possible significant variation among varieties of instrumental parameter (agronomic, organoleptic and nutritional parameters) analyzed. To assess key relationships which exist among characteristics involved in tomato fruit organoleptic quality, principal agronomic, nutritional and sensory parameters, Pearson’s correlations between all traits pairs were calculated and the significance of their associations was tested with t-test at a significance level of 0.05 and 0.01.

RESULTS AND DISCUSSION

Comparison between different tomatoes cultivar by average of all instrument traits calculated is presented in Table 1. Traditional tomato variety IRA17 had the highest

Table 1. Mean value of agronomic, physicochemical and nutritional parameters evaluated in tomato fruits of traditional varieties (IRA) and controls.

Variety	TS	TSS	pH	TA (g/l citric acid)	K+	Vitamin C (mg/100 g)	Weight (g)	Diameter	TSS/TA
Marmande VF	7.86^{bc}	4.5^{cd}	4.45^{c}	7.9^{c}	2.72^{b}	8.05^{abc}	150.25^{c}	90.96^{g}	0.56^{ab}
IRA 61	7.11^{ab}	3.3^{abcd}	4.31^{abc}	3.97^{ab}	2.1^{ab}	10.89^{cd}	108.25^{abc}	57.69^{cdef}	0.85^{abc}
IRA 622	7.11^{ab}	3.67^{abcd}	4.49^{c}	4.27^{ab}	1.86^{ab}	9.39^{abc}	116.25^{bc}	64.37^{def}	0.88^{bc}
IRA 103	7.30^{b}	2.35^{ab}	4.39^{bc}	2.52^{a}	1.81^{a}	9.45^{bc}	15.5^{a}	27.02^{a}	0.91^{bc}
IRA 17	10.32^{d}	2.67^{abcd}	4.46^{c}	3.25^{ab}	2.19^{ab}	10.55^{bcd}	25.25^{ab}	30.99^{ab}	0.83^{abc}
IRA 9	7.19^{ab}	4.22^{bcd}	4.41^{c}	9.05^{c}	2.43^{ab}	10.91^{cd}	324.25^{d}	91.03^{g}	0.47^{a}
IRA 162	8.82^{c}	3.95^{abcd}	4.35^{abc}	5.72^{b}	1.9^{ab}	10.53^{bcd}	126.25^{c}	92.57^{g}	0.69^{ab}
Rio Grande	6.82^{ab}	2.02^{a}	4.41^{c}	3.12^{ab}	2.72^{b}	6.01^{a}	97.25^{abc}	42.41^{abc}	0.65^{ab}
IRA 22	6.70^{ab}	3.85^{abcd}	4.36^{abc}	3.15^{ab}	2.14^{ab}	10.16^{bcd}	87^{abc}	46.02^{abcd}	1.13^{c}
IRA 23 A	7.58^{bc}	2.40^{abc}	4.41^{c}	4.85^{ab}	2.19^{ab}	8.57^{abc}	145.75^{c}	68.97^{ef}	0.45^{a}
IRA 23 B	7.57^{bc}	4.57^{d}	4.19^{a}	5.12^{ab}	2.38^{ab}	10.56^{bcd}	150.25^{c}	77.52^{fg}	0.95^{bc}
IRA 5	5.88^{a}	3.02^{abcd}	4.37^{abc}	3.45^{ab}	2^{ab}	9.15^{abc}	125^{c}	65.18^{def}	0.89^{bc}
IRA 21	7.02^{ab}	3.17^{abcd}	4.38^{abc}	3.47^{ab}	2.1^{ab}	8.80^{abc}	122^{c}	50.21^{bcde}	0.92^{bc}
IRA 2	7.83^{bc}	2.5^{abcd}	4.3^{abc}	4.57^{ab}	2.19^{ab}	9.59^{bcd}	120^{c}	63.51^{def}	0.58^{ab}
Ventura	6.74^{ab}	2.65^{abcd}	4.38^{abc}	2.9^{a}	2.29^{ab}	7.30^{ab}	80.25^{abc}	41.16^{abc}	0.92^{bc}
IRA 3	7.12^{ab}	2.47^{abcd}	4.21^{ab}	3.6^{ab}	2^{ab}	**12.94^{d}**	90.5^{abc}	60.44^{cdef}	0.73^{abc}

Means for groups in homogeneous subsets are displayed, alpha = 0.05, harmonic mean sample size used = 4,000.

total solid percentage. Both controls, Rio Grande and Ventura had significant lowest total solid content. In the industry, this parameter dictates the factory yield (Pedro et al., 2005), in which the highest tomato total solids content amount to less tomato to be used to produce processed tomato product. Higher value in TSS content (4.57° Brix) was found in traditional variety IRA23B. The lowest value was recorded in Rio Grande (2.02° Brix). Higher value in TA (9.05 g/L citric acid) was observed in IRA 9.

Traditional variety IRA 103 had the lowest value (2.52 g/L citric acid). It was reported that higher fruit acidity is an advantage, as it causes a lower incidence for fungal infection (Mohammed et al., 1999). The higher value in SS/TA ratio (1.13) was found in IRA 22. The lowest value (0.47) was recorded in IRA 9, which had the lowest titratable acidity. Some researchers have defined sugars, acids and sugars/acids ratio as good indicators of tomato flavour (Kader et al., 1978), and sugars/acids ratio as important parameter in differentiating tomato flavour among varieties (Stevens, 1972). All varieties had pH values equal or bellow 4.49, which is considered to be ideal for correct fruit sourness.

Higher vitamin C value was recorded in IRA3, whereas the three controls had significant lowest vitamin C concentrations. Potassium concentrations had the smallest range of variation in chemical parameters analysed in this study. Agronomic parameters, fruit diameter and weight, had larger range of variation in instrumental parameters.

Relationships among traits

Results of correlation analysis between instrumental traits are summarised in Table 2. Controls were not considered in correlation analysis because of their higher heterozygous characteristics (Gomez et al., 2001). Thus, only correlations between tomato traditional varieties traits were calculated. Fruit weight and diameter were positively correlated with TA on the one hand (0.689, P< 0.01; 0.662, P<0.01, respectively) and with TSS on the other hand (0.358, P<0.01; 0.387, P<0.01, respectively). Whereas, correlations between these agronomics parameters and SS/TA ratio were negatives.

Among chemical traits, the strongest positive correlation was observed between sugars content and titratable acidity (0.602, P<0.01). Some recent studies, for example, Georgelis (2002), Colombani et al. (2001) and Getinet et al. (2008) had confirmed this correlation and had shown that positive correlation between sugars and titratable acidity means that, generally, plant with high sugars have more free organic acids than plants with low sugars.

Whereas many other studies support the hypothesis that organic acids are produced within the fruit from stored carbohydrate material although a proportion may also be translocated from leaves and roots to fruit (Sakiyama et al., 1976; Davies and Maw, 1972; Getinet et al., 2008).

Among the sensory traits (Table 3), red colour intensity was positively correlated with aroma intensity (0.619, P<0.01), taste (0.834, P<0.01) and juiciness (0.619, P<0.01).

Taste and aroma, which describe close flavour components of fruit, were strongly correlated (0.924, P<0.01), while, fruit elasticity was negatively correlated to most of sensory traits.

Table 2. Spearman's correlation coefficients and level of significance among instrumental traits analysed in fruits of traditional varieties.

	TA	TSS	TS	TSS/TA	K+	Vit C	pH	Weight	Diameter
TA	1.000								
TSS	**0.602****	1.000							
TS	0.088	0.020	1.000						
TSS/TA	**-0.342***	**0.452****	0.017	1.000					
K+	0.190	0.205	-0.020	0.074	1.000				
Vit C	0.088	0.027	0.201	-0.054	0.130	1.000			
pH	-0.133	-0.129	0.126	0.012	-0.021	-0.030	1.000		
Weight	**0.689****	**0.358****	-0.107	**-0.277***	0.142	0.041	0.016	1.000	
Diameter	**0.662****	**0.387****	-0.56	**-0.311***	0.207	0.188	-0.94	**0.698****	1.000

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed).

Table 3. Spearman's correlation coefficients and level of significance among sensorial traits analysed in traditional varieties fruits.

	Firm texture	Juiciness	Red colour intensity	Aroma intensity	Taste	Elasticity
Firm texture	1.000					
juiciness	0.040	1.000				
Red colour intensity	-0.028	0.619**	1.000			
Aroma intensity	0.008	0.491**	0.626**	1.000		
taste	-0.028	0.748**	0.834**	0.904**	1.000	
elasticity	0.162	-0.486**	-0.508**	-0.853**	-0.795**	1.000

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level.

Table 4. Spearman's correlation coefficients and level of significance between instrumental and sensorial traits analysed in fruits of traditional varieties of tomato.

	Firm texture	Juiciness	Red colour intensity	Aroma intensity	Taste	Elasticity
TA	**0.311***	**0.385****	Ns	ns	ns	ns
TSS	ns	ns	Ns	ns	ns	ns
TS	ns	ns	Ns	0.553**	0.357**	-0.425**
TSS/TA	ns	-0.417**	Ns	ns	-0.318*	ns
K	ns	ns	Ns	ns	ns	ns
Vit C	ns	ns	Ns	ns	ns	ns
pH	ns	-0.280*	-0.308*	ns	ns	ns
weight	0.426**	0.349*	Ns	ns	ns	ns
diameter	0.366**	0.492**	Ns	ns	ns	ns

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed), ns = correlation not significant.

Correlation between sensory and instrumental traits

Correlations between sensory and instrumental traits are shown in Table 4. Total acidity had a positive correlation with firm texture and juiciness. This is to be expected when we look at physiological process, which take place during fruit maturation, when a decrease in acidity and firmness is observed.

Positive correlation was recorded between firm texture and agronomic traits. This correlation can be investigated as association of selection traits, which can offer easy hybridisation possibilities. Red colour intensity was negatively correlated to pH. Total solid content had positive correlation with aroma intensity and taste on one hand and negative correlation with elasticity on other hand. These correlations confirm the importance of this parameter in tomato flavour.

Correlations analysis shows that there is no correlation between vitamin C and potassium contents and all parameters analysed in this study. They can be correlated to physiological parameter such as flowering time, growth and harvest date or environmental factors.

Conclusions

To assess traits that contribute to defining the target quality to design strategies to improve it is a long-term objective of tomato breeding programmes.

In general, results of this study show that traditional varieties had several specific parameters, with score better than the commercial varieties; these varieties could thus be used for improvement programs as a source material for optimal quality characteristics. Some local varieties, which had the same range of some quality characteristics as commercial varieties, have the advantage of being pure line and the transfer of such a character in a breeding programme may be less difficult.

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