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Genotypic Differences Affecting Biometric, Processing and Functional Quality Attributes in Tomato Fruits[#]

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ABSTRACT

Processing tomato is an important agricultural crop worldwide suffering from genetic erosion due to a severe genetic diversity reduction and domestication hindrance. In Tunisia, some old underutilized tomato cultivars are increasingly being considered as genetic resources and are marginally used by small farmers constituting a real safety valve for the sustainability of the processing tomato value chain. Those tomato cultivars differ in their biometric, processing and functional quality attributes. Therefore, there is an increasing interest to examine their performances for processing and fresh market quality improvement. Recently, there was also a particular focus on improving the quality of fresh fruit via the introgression of high-pigment genes in processing tomato in order to obtain a high quality processed products. The results are important as large differences are highlighted and the main traits affecting tomato quality are also reported and clearly discussed. This suggest that maintaining of the existing genetic pools among cultivated tomato is as important as creating novel hybrids.

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Introduction

Tomatoes and tomato-based products are consumed around the world and consistently associated with a lower risk of several types of cancer and to a lesser extent, to a lower incidence of coronary heart disease (Ilahy et al., 2011; Pernice et al., 2010). All tomato-based products contain micronutrients, such as potassium, antioxidant vitamin C, vitamin E and folate (Pernice et al,. 2010). The Characteristics of the raw fruit are important considering the processing steps and final product (Siddiqui et al., 2011; Siddiqui, 2012). Size is less important for processing , but it is important for fresh consumption. The influence of fruit size has been often a consequence of the influence of fruit shape, and this can determine the consumer preference (Atta-Aly et al., 1995). Fruit weight also determines the shape of fruits; the varieties with the highest fruit weight is flattened in shape, while a rounded shape is predominant in small-fruited varieties (Rodríguez-Burruezo et al., 2005). Tomatoes with fewer locules (four or less than four) are desirable, particularly for fresh market. Tomato firmness is granted by the pericarp thickness. Thicker pulp generally enhances the firmness and ultimately the shelf life of the tomato (Batu, 2004). The moisture content affects the juice recovery, and the alcohol insoluble solids can affect the viscosity of the juice. According to Zegbe-Domínguez et al. (2006), lower water content in tomato fruit could be better for the processing industry. pH below 4.5 is a desirable trait, because it halts the proliferation of microorganisms in the final product during industrial processing (Giordano et al., 2000).

On the other hand, the bioactive content of tomato cultivars is having an impact on the processed destines. The bioactive constituents and their stability must be contemplated while selecting the processing steps of tomato fruits (Siddiqui, 2012). Among the most labile bioactive constituents, the ascorbic acid can be mentioned. Tomato contains moderate amounts of ascorbic acid (20 mg/100 g) (Abushita et al., 2000). Having performed various trials using open field tomato cultivars considered actually as landraces, a large variation in biometric, processing and functional quality attributes has been revealed among traditional cultivars and among high-pigment developed advanced lines in terms of most of the attributes. Therefore, this survey highlight the importance of all those attributes.

Biometric Attributes

Shape, Size, Weight and Colour

While phenotypic features are common and important selection tools for breeders, they can be influenced significantly by genetic and environmental factors. The shape (round and ovate), size (polar and equatorial diameter), and average weight of fruit are critical quality traits to preserve homogeneity in handling and final product for nutritional and processing purposes. The fruit size is less crucial for processing, but it is essential for fresh market tomato. The impact of fruit size is frequently a result of the impact of fruit form and the number of locules (Siddiqui et al., 2015; Ilahy et al., 2018). Regarding processing tomato cultivars in Tunisia, Ilahy et al. (2018) reported that average fruit weight ranged from 42-82 in Perfectpeel and Rio Grande respectively. Colour is also a critical traits strongly considered and evaluated for fresh market and processing purposes.

Number of Locules

The number of locules in the fruit is critical for selecting types for processing and determining its quality. (Chakraborty et al., 2007). Fruit hardness is inversely correlated to the number locule. As a result, the higher is the number of locules the lower is the fruit firmness index. Pear-shaped cultivars are reported to contain two locules, but round fruited cultivars have a greater number of locules (Chakraborty et al., 2007; Siddiqui et al., 2018). Tunisian consumer generally prefers Roma-type tomato fruits and generally the used cultivars are selected for double purposes, fresh market and processing (Ilahy et al., 2018).

Pericarp Thickness

Among the characteristics that influence fruit firmness, pericarp thickness is the most important. Thicker pulp typically improves tomato firmness and, as a result, tomato shelf life (Chakraborty et al., 2007). Tomato fruits with a thicker pericarp would be more stable to carry across vast distances and retain in good condition. Fruit firmness and the fruit wall-to-locular content ratio refers to the texture of the fruit and the rise in fruit pericarp. The skin, peripheral pericarp, radial arms, and pericarp are all parts of the pericarp as well as columella (Barrett et al., 1998). Fruit firmness is connected with a reduction in thickness. of the fruit's wall and inter-locular components (Bhutani and Kalloo, 1991). Varieties with an oval form have a thicker pericarp than others genotypes (Thakur and Kaushal, 1995; Chakraborty et al., 2007).

Fruit Firmness

Fruit morphology and tissues arrangement, have an important effect in determining tomato fruit texture (Ilahy et al., 2018; Siddiqui et al., 2015, 2018). Texture is an important factor perceived by customer to assess fruit quality (Siddiqui et al., 2015). Firmness is a critical component of interior fruit quality, both in terms of appearance and taste (Siddiqui et al. 2015, 2018). There are significant shifts in texture mostly related with softening during fruit ripening (Ilahy et al., 2011; Siddiqui et al., 2015). In Tunisia, consumers generally prefer fruits with high firmness such as cultivar Salba which is characterized by hard tomato fruits suitable for long storage and transport. This cultivar was accidentally found by the former head of the laboratory of horticultural crops, Naceur Hamza while he was assessing the behaviour of some tomato cultivars from USA.

Juice Recovery (%)

Variation in juice and pulp content among tomato cultivars has been observed in the literature (Mane et al., 2010; Gupta et al., 2011; Siddiqui et al., 2015). According to Gupta et al. (2011), the juice and pulp contents of two tomato varieties vary substantially. The juice recovery may differs between different tomato cultivars depending on pre- (ferti-irrigation, plant protection and good agricultural practices) and post-harvest (transport, storage and processing) agricultural practices (Siddiqui et al., 2015, 2018).

Juice Viscosity

The degradation on tomato juice viscosity is directly correlated with the breakdown of pectic components by endogenous enzymes such as pectin methylesterase and polygalacturonase. Thus, variation in the content of those enzymes can explain differences in viscosity among different tomato genotypes (Siddiqui et al., 2015, 2018). Jarret et al. (1995) found higher viscosity in high pigment tomato lines with respect to crimson or ordinary/traditional tomato cultivars suggesting their importance for processing purposes. Recently, Ilahy et al. (2018) reported detailed information from the seed to the consumer regarding the main high-pigment tomato cultivars as compared to the currently grown traditional cultivars.

Moisture Contents/Total Solids or Dry Matter

Tomato fruit is highly perishable due to the high moisture content > 90%. Therefore, genotypes with low water and high soluble solids content are more suitable for processing sector. For this reason, European processing plant severely control those attributes while receiving raw materials. The average dry matter or total solid content of tomato is 5.5% (Ilahy et al., 2018). Ilahy et al. (2018) reported acceptable soluble solid values ranging from 4.5 to 5.5° brix in high-pigment tomato genotypes grown under open field and greenhouse conditions around the world. Interestingly, the *IP* red-ripe fruits of the cultivar LA1563 showed a 35%-38% increase in total soluble solids compared to its near isogenic line LA0816, suggesting utility in breeding programs to develop high-soluble solid processing tomatoes (Lavi et al., 2009; Ilahy et al., 2018).

Processing Attributes

Total Soluble Solids

Total soluble solid is a refractometric index correlated to the level of dissolved solids in a solution. It is the sum of the sugars (sucrose and hexoses; 65%), acids (citrate and malate; 13%), and other minor components (phenols, amino acids, soluble pectins, ascorbic acid, and minerals) in tomato fruit pulp (Siddiqui et al., 2015). The tomato dominant INTENSE PIGMENT (IP) genotype is an additional tomato high pigment variety originated from a cross between the wild species [*Solanum chmielewskii* (C.M.Rick, Kesicki, Fobes & M.Holle) D.M.Spooner, G.J.A] and the cultivated tomato (*S. lycopersicum* L.).

Three genomic segments from the wild parent have been mapped to chromosomes 7 and 10 in the IP genotype and associated with increased soluble solids and pigments of both immature and mature berries (Ilahy et al., 2018).

Acidity

Organic acids, mainly malic and citric, comprise about 15% of the dry matter of fresh red-ripe tomato fruits and influence pH and Titratable acidity. TA values greater than 0.35% and low pH are desirable for processing purposes as acidity contributes to both taste and food safety through inhibition of microorganisms (Davies and Hobson, 1981; Garcia and Barrett, 2006; Ilahy et al., 2018). In high-pigment tomato cultivars, increased number and size of chloroplasts and the accumulation of chlorophyll in the unripe-green fruits of photomorphogenic tomato mutants (Kolotilin et al., 2007) may positively influence TSS via increased photosynthetic capacity and downstream accumulation of sugars, as proposed for other dark tomato genotypes (Powell et al., 2012; Ilahy et al., 2018). The levels of organic acids influence both fruit flavor and pH that are critical traits for canned tomato products to control the growth of thermophilic microorganisms (Yousef and Juvik, 2001). The average acidity (as citric acid) in ordinary tomato reported to be around 0.40% (Siddiqui et al., 2015).

Sugars

The typical tomato fruit contains approximately 5–7.5% total sugar, roughly 75% of which is reducing sugars (mainly glucose and fructose) with the remaining consisting of organic acids (citrate and malate) and minor amounts of minerals, lipids, pigments, vitamins, and volatiles (Davies and Hobson, 1981). The total sugar (TS) content and acidity are the most important characteristics of tomatoes taste (Siddiqui et al., 2015). High-pigment tomato cultivars accumulating higher number of chloroplast and chromoplast are supposed to accumulate higher levels of sugars with respect to ordinary cultivars (Ilahy et al., 2018).

Alcohol Insoluble Solids

The alcohol insoluble solid is an excellent indication of maturity and texture in some horticultural products. In tomatoes, alcohol-insoluble solids consists mainly of protein (8%), pectic substances (7%), hemicellulose (4%), and cellulose (6%) (Davies and Hobson, 1981). It determines the viscosity of fruit juice and thick consistency of processed products (Dhaliwal et al., 1999). Alcohol insoluble fraction contents of fruits varies among varieties and according to fruit shape; for example, oval fruits contained a higher percentage of alcohol insoluble solids than that of round fruited variety (Upasana and Bains, 1988).

Functional Quality Attributes

Ascorbic Acid

Ascorbic acid is an important quality indicator of fresh produce quality. Both ascorbic acid and its oxidized form, dehydroascorbic acid, contribute to total vitamin C. Traditional tomato cultivars contain generally moderate amounts of ascorbic acid (20 mg/100 g) (Gould, 1992), thus contributing to 40% of the recommended dietary allowance for ascorbic acid. The variation in ascorbic acid content in tomatoes depends mainly on pre- and post-harvest agricultural practices and genotypic differences (Singh et al., 2010; Chakraborty et al., 2007). Ilahy et al. (2018) reported that total vitamin C content reached 352.8 mg/kg fw in the hp-2dg/hp-2dg tomato cultivar HLY13. These data provide further evidence that hp mutations dramatically increase many important antioxidants including total vitamin C, as previously reported by Mochizuki and Kamimura (1984) and Mustilli et al. (1999). It has been reported that temperature and light intensity also have a profound influence on ascorbic acid content, the lower the temperature, the higher will be the Asa level (Chakraborty et al., 2007).

Carotenoids, Lycopene and β-carotene

Carotenoids are the main bioactive metabolites in tomato berries and various studies reported significant variations in total carotenoids, lycopene, and β-carotene among traditional and high-pigment (Ilahy et al., 2018). Field experiments performed in the Mediterranean (Israel, Italy, Spain, and Tunisia) confirmed that hp genotypes accumulate increased levels of total carotenoids (at least twice) with respect to their near isogenic counterparts. Tomato lycopene, responsible for the red color of tomato fruits, varies considerably, reflecting the influence of varietal differences, maturity, agronomic and environmental conditions during growing (Ilahy et al., 2018). Variety is an important factor affecting both the composition and content of plant pigments (Ilahy et al., 2018; Siddiqui et al., 2015, 2018). Various research works conducted in Tunisia during the last decennie outlined that some selected high-pigment tomato lines such as HLT-F81 and HLT-F82 are characterized by exceptional lycopene content attaining 300 mg/kg fw under suitable growth and climatic conditions. Generally traditional processing tomato cultivars rarely exceed 90-120 mg/kg fw of lycopene content. This suggest feasibility of using such cultivars for fresh market and processing purposes. Various tomato cultivars considered as landraces in Tunisia were also tested during the last years for their horticultural performances and functional quality compared to the main grown tomato cultivars and showed that cvs Salba, Nemador, Justar, Rio Grande and Rimone exhibited exceptional traits willing to be used in future breeding programs.

Total Phenols and Total Flavonoids

Phenolic compounds are important secondary metabolites in plants characterized with exceptional antioxidant activity against a wide array of free radicals. The protective roles of total phenolics in reducing risk of various diseases has been the subject of various researchs (Liu et al., 2010). In ordinary tomato berries, chlorogenic acid and the flavonoid quercetin, followed by naringenin and rutin are the main representative phenolic compounds (Siddiqui et al. 2018). Ilahy et al. (2018) highlighted the significant variation in phenolic contents of tomato among ordinary and high-pigment varieties. Values attaining 1330 mg/kg fw was reported for the high-pigment cv HLY13.

Tomato fruits accumulate also flavonoids, a sub-class of phenolics, flavonoids are mainly concentrated in the peel of tomato fruits (Muir et al., 2001). Rutin (quercetin-3-rhamnosylglucoside) and naringenin chalcone are representative flavonoids of tomato, respectively conjugated and nonconjugated (Siddiqui et al., 2015) and flavonols such as myricetin are found in tomato and its products (Shen et al., 2007). Flavonoids are important metabolites for human health because of their capacity to activate endogenous antioxidant defense systems and various signalling pathways (Meiers et al., 2001; Williams et al., 2004). Ilahy et al. (2018) focused on various ordinary and high-pigment tomato cvs aiming to improve the fresh produce quality for both fresh market and processing. The authors revealed that high-pigment tomato cvs accumulate significantly higher total phenolics and flavonoids with respect to traditional cvs suggesting their promising use.

Total Antioxidant Activity

The evaluation of the radical scavenging capacity is becoming increasingly pertinent for fresh processed products as it provides useful information regarding health promoting properties without the analysis of each antioxidant compound (Ilahy et al., 2011; Ilahy et al., 2018). These traits express the synergistic and/or antagonistic interactions existing between antioxidant components of the hydrophilic and lipophilic fractions. Recently Ilahy et al. (2018) reported the selection of some high-pigment tomato lines with higher antioxidant potential in both hydrophilic and lipophilic fractions with respect to most of the tomato cvs grown in Tunisia (Ilahy et al., 2016, 2018; Siddiqui et al., 2018)

Conclusion

The variation in biometric, processing and functional quality attributes among tomatoes has been correlated to various causes mainly genotypic. The higher lycopene content and other bioactive contents in high-pigment tomato lines is also particularly important industrial processing traits to compensate for the loss of antioxidant activity due to chemical, physical as biological factors. A special attention to these constituents should be given considering future research on designing elite tomato cultivars with high nutritional quality while integrating most of the suitable biometric and processing attributes particularly under a continuously changing climate.

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