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Quality of Cherry and Large Tomato Fruits Influenced by Varieties and Rootstocks

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Abstract

Currently, the main challenge is to improve crops' performances under a wide array of suboptimal growth conditions. In tomato production, grafting is one of tools increasing fruit quality. It depends on variety and rootstock selection. In this aim different combinations of rootstock-variety of tomato were studied in order to determine the induced changes on tomato quality. Experimental design including six rootstocks-Variety combinations was conducted. Four tomato varieties (Sweetle, SanPaulo, Angel a cherry tomatoes and Pulia a large tomato) and two rootstocks (Maxifort and Integro) were combined. Physical characteristics (shape, weight) and chemical composition (Brix, pH, polyphenol, protein) characterization of different combinations were compared. Results showed that large fruits presented the lowest firmness, polyphenol, protein and Brix values. Variety influenced significantly all the studied parameters. However rootstocks influenced significantly firmness, shape index, width, CE and polyphenols at $P<0,05$. All tomatoes fruits have the same protein contents approximately 717 mg/100g FW revealing the high quality and important nutritional value of geothermal tomato of western south of Tunisia. Sweetel variety grafted on Maxifort presented the highest polyphenol content.

Keywords: polyphenol; protein; Brix.

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1. Introduction

Improving tomato quality has become over time the main challenge of producers. It depends on two key factors i) selection of the appropriate tomato variety to specific production area and ii) rootstock selection during the grafting procedure. Grafting is not only a valuable tool for managing problems of tomato soil-borne pathogens but often generates unpredictable effects on crop yield and product quality [1,2]

Tomato (*Solanum lycopersicum* L.) is a one of most important greenhouse crops in the Mediterranean Basin [3]. Availability, good taste, low price and obvious health benefits of tomatoes are all characteristics that make tomato a popular and sought-after vegetable [4]. Tomato quality is an all-encompassing concept that includes physical properties (size, shape, colour, firmness and absence of defects and decay), flavour (sugar, acids) and health-related compounds (proteins, polyphenol, vitamins) of tomato [5]. Thus, studying this important factor that determines the market value, transport, and storage requirements remain of interest of producers as a response to the consumer's demands [6].

Firmness, a physical property of the typical attribute used to describe the texture of fruits [5]. A decrease of tomato fruit firmness occurs as a result of the progression of fruit ripening. This process is accompanied by fruit softening as a consequence of the combined effect of hydrolytic enzymes and changes in the hydrostatic pressure within the fruit cells [7]. The firmness of the tomato fruit influences the purchasing decisions of consumers [8]. Organoleptic quality of tomato has been often correlated with physicochemical parameters [9]. Tomato polyphenols constitute the largest part of the antioxidant content of the soluble solids and play an important role in human nutrition as antioxidants [10]. In addition, tomato is the first source of lycopene (71.6%), second of vitamin C (12.0%), pro-vitamin A (14.6%) and other carotenoids (17.2%), and third of vitamin E (6.0%), also contains polyphenols such as flavonoids and hydroxycinnamic acids [11].

Tunisia as an agriculture country depends in a big part on greenhouse cultivations. This country is known for its wide variety of products for the local and international market. Tomato is one of the country's key products [12]. About 1.2 million tons the annual production of tomato was estimated in 2015/2016 [13].

Many are varieties of cultivated tomato. The cherry tomato, named *Solanum lycopersicum* var. *cerasiforme*, is very common crop in Tunisian greenhouses and intended entirely for export. Charges and fees of tomato production in soilless geothermal conventional multi-tunnel in southern Tunisia are important regarding the use of costly hybrid of tomato varieties required by the importers. These hybrids maximize tomato production and qualities, but remains not adapted to the local southern arid bioclimate of Tunisia. To overcome this, most commercial rootstocks are resistant to multiple soilborne pathogens, allowing grafted plants to maintain high quality and resistance [14] and help plant adaptation in order to improve tomato quality.

Tomatoes plants were cultivated under greenhouse in the geothermic area of western south of Tunisia, irrigated and heated with geothermal water. This option has been shown as an economic and effective practise to solve the problem of cold night temperatures [15]. To date, to observe the rootstocks-induced improvement in tomato fruit quality according to Mauro and his colleagues [16], the most popular approach has been based on examine

the effects of different rootstocks on one or few varieties. In the same approach, our study case, aim to evaluate the fruit quality of three hybrid cherry tomato in comparison with a large fruit tomato grafted on two rootstocks, according the main question on how grafting is advantageous on physical and biochemical quality characteristics of commercial hybrid tomato varieties. Sweetle, SanPaulo, Angel a cherry tomatoes and Pulia a large tomato were grafted on 'Maxifort' and 'Integro' (used as rootstocks). Tomatoes plants were cultivated in hydroponic system, heated and irrigated using geothermal water.

2. Materials and methods

2.1. Plant material and experimental design

Experiments were conducted in 2022 under Tunisian greenhouse, located in Chenchou (Southern-west of Gabes), heated and irrigated by geothermic water in the south of Tunisia. The greenhouse has a width of 12.8 m. and a maximum height of 9 m. Hybrid cherry tomatoes 'Angel', 'Sweetel', 'SanPaulo' and large tomato 'Pulia' were used as scions; while 'Maxifort' and 'Integro' were used as rootstocks. The experiment involved four replicates and six treatments (1) Control: Pulia/Maxifort (2) SanPaulo/Integro (3) Angel/Integro (4) Angel/Maxifort (5) Sweetel/Integro and (6) Sweetel/Maxifort. Transplant took place in August 2021; plants were grown under natural light conditions. They were grown with two stems. An open soilless cultivation system was adopted and coconut fiber was used as substrate.

2.2. Fruits Quality Analysis

2.2.1 Fruit physical properties

Samples for fruit quality assessment were collected on March 2022. Each replicate consisted of six tomato fruits selected from a pool of fruits collected from 10 plants per treatment. Within 2 h of harvest, the fruits were transported to the laboratory for further processing and determination of the main quality traits. To this end, the fruits were deprived from rachis then weighed to determine their mean weight, Fruit shape index was calculated as the ratio between longitudinal and transversal diameter, both determined through a digital caliper.

Firmness was measured using a penetrometer. The tomatoes were then cut into four parts. One quarter from each of six fruits was combined to make a replicate (a total of six quarters) and homogenized with a handheld blender. The resulting homogenate was used for determination of Brix, pH, EC on the same day as harvesting. The SSC (expressed as Brix) was measured with a manual refractometer set to zero with deionised water.

2.2.2 Polypenols and total soluble protein determination

Phenolic compounds were extracted according to the method of Farrés-Cebrián [17]; 0.5g of tomato juice was added to 3 ml ethanol 80%. The mixture was shaken vigorously for 2 min and then centrifuged (3500 rpm/5 min) and followed by 24 h in dark. Next, filtrated extract was adjusted to 15 ml with ethanol 80%. Then 0.2 ml of extract was added to 0.8 ml Na_2CO_3 and 0.1 ml Folins-Ciocalteau. The mixture was shaken vigorously for 2 min. After centrifugation (3500 rpm/5 min), the extracts were directly analyzed.

Spectrophotometer was set to zero with blank, optical density was taken (measure of absorbance) at 655 nm.

Folins-Lowry method was adopted for the estimation of protein concentration in each selected sample. Different dilutions were prepared by mixing tomato juice and distilled water (10 mg/10 ml) in the test tubes. The final volume in each test tube was adjusted to 50 ml. 0.1 ml supernatant of each sample was adjusted to 5 ml with distilled water. 1 ml copper sulphate reagent was added (Analytical reagent). These solutions were incubated at room temperature for 10 minutes. Then 0.1 ml of freshly prepared Folins-Ciocalteau reagent was added to each sample and incubated for 30-60 minutes in dark. After incubation, the spectrophotometer was set to zero with blank and the optical density (measure of absorbance) was taken at 695 nm.

2.3. Data analysis

Statistical analyses were performed using XLSTAT 2016. All data were compared using the parametric Tukey test. Differences between parameters were compared over the study for each treatment at $p \leq 0.05$. Factorial 'variety*rootstock' analysis of variance (ANOVA), were conducted according to the experimental layout adopted in the greenhouse.

3. Results

In our study case, variety explained the highest variability of all measured parameters of tomato quality except for protein. Whereas the influence of rootstocks and combined effect of Rootstoks * Variety were significant at (P <0,05) or non significant. For shape index, firmness and CE with high significance variability of rootstocks.

It has been suggested that the improved plant growth in response to grafting flows from a greater root development, enabling plants for a better absorption of water and minerals from the growth substrate, thus maximizing the photosynthetic gain of the scion [16].

3.1. Tomatoes physical characteristics

Tomato quality and its physical components were all significantly affected by the main factors variety and rootstocks and their interaction, with rootstocks being by far the main source of experimental variation compared with highly significant effect of variety effect.

Tab. 1, showed that fruit length, width and shape index of large tomato is more than twice times the cherry tomato. In cherry tomato the largest fruit (31,5 cm) was Angel/Integro fruits and the widest fruit (25,3) was in SanPaulo/Integro. This last fruits had the highest shape index (1,57) and also was characterized by the higher weight of cherry tomato more than 11 g.

Firmness, a very important textural trait [5] and influences consumer preferences. Generally, tomato hardness of fully ripens fruits ranged from 15.01 N to 21.42 N. Fruit firmness was significantly the highest in Sweetel and SanPaulo grafted on Integro. The control Pulia grafted on Maxifort presented the lowest values of firmness (15,01). The comparison showed that all fruits of cherry tomato had higher firmness than control large fruits.

Firmness is highly significant affected by variety, rootstocks and their combination. These results corroborate researches confirming that rootstock and variety influenced the tomato firmness significantly. In this context, Intraspecific grafted tomato fruits on Armada rootstocks had the best quality characteristics in terms of firmness according to Walubengo and his colleagues [18]

Soluble solids content (Brix) is one of the most important quality parameters of processing tomatoes and fresh market production, due to important contribution of sugars to the organoleptic quality of tomatoes [20]. It represents the potential sweetness of the product. In this study, the variety with lowest content of Brix was the control Pulia grafted on Maxifort (5.25 °Brix) followed by SanPaulo grafted on Integro (6.5 °Brix). Sweetel and Angel varieties grafted on Integro and Maxifort presented the highest values of Brix (Tab. 1).

Statistics showed a high significant effect of variety on Brix content of tomato compared with rootstock effect. In this context, Nkansah and his colleagues [19] agree that Brix is not influenced by rootstock in his research on grafting onto African eggplant but others [21, 22] confirm that rootstock have a direct effects on tomato's Brix.

Table 1: Quality of cherry and large tomato fruits

	pH	CE ($mScm^{-1}$)	Length (mm)	Width (mm)	Shape Index	Fruit weight (g)	Firmness (N)	°Brix
SanPaulo/Integro	4,21 b	4,623 b	27c	25,3b	1,57 ab	11,4b	21,42a	6,5b
Angel/Integro	4,05 c	5,400 a	31,5b	20c	1,06 c	7,69c	17,7c	7,67a
Angel/Maxifort	4,03c	4,087 c	30,3b	20,67c	1,47 b	8,39c	20ab	7,75a
Sweetel/Integro	4,13 bc	4,300 c	30,83b	20,3c	1,52 b	8,36c	19,87ab	7,83a
Sweetel/Maxifort	4,05 c	4,213 c	30,83b	20,67c	1,49 b	8,58c	18,1bc	7,83a
Pulia/Maxifort	4,6 a	3,533 d	67,83a	40,5a	1,67 a	81,7a	15,01d	5,25c
Varieties	***	***	***	***	***	***	***	***
rootsocks	*	***	*	***	***	**	***	*
Varieties * rootsocks	**NS**	***	*	***	***	***	***	*

Different letters in each column represent significant difference by least significant difference after analysis of variance ($P < 0.05$ Tukey test).

The end of the table represents the summary of the main results of the analysis of variance of the main variable and their interaction with the corresponding significance of the F-values. NS = not significant; *, **, *** significant at $p < 0.05$, 0.01 and 0.001, respectively

3.2. Tomatoes biochemical characteristics

Generally a pH value between 2.5 and 5.5 tends to prolong shelf life of fresh fruit and inhibit the multiplication of microorganism [20]. Tomato fruit is a low acid food with a pH levels depending on the cultivar. Generally, excessive increase in fruit pH affects negatively the sensory quality of the fruit and upsets its sugar to acid ratio

[23]. In our study case tomato pH varied from 4.03 to 4.6 among treatments. Comparison showed that large fruits of Pulia tomato grafted on Maxifort had the highest pH. Contrariwise the lowest pH values, respectively 4.03, 4.05 and 4.05 were observed in cherry tomato; Angel grafted on Integro and Maxifort and Sweetel grafted on Maxifort

Rootstocks didn't affect the pH of the tomato fruits. This result corroborates precedent researches reporting that rootstock did not affect the pH [19, 24].

Electric Conductivity (CE) of tomato fresh juice of Pulia tomato grafted on Maxifort was the lowest compared with different combinations of rootstocks-cherry tomato. Higher CE (5,4) was detected in cherry tomato Angel/Integro combination.

Tomatoes have been identified as the most important suppliers of phenols in the human diet, followed by corn and beans [25]. Figure 1 revealed significant differences ($P<0.05$) in polyphenols contents among the different varieties evaluated. The highest content was detected in Sweetel grafted on Maxifort (almost 146 mg/100gFW), followed by Sweetel grafted on Integro (almost 141 mg/100gFW). Varieties Angel and Sanpaulo grafted on Integro and control Pulia grafted on Maxifort presented the lowest values of polyphenol. Plyphenols content seems more influenced by variety (high significance ***) compared to rootstocks (*).

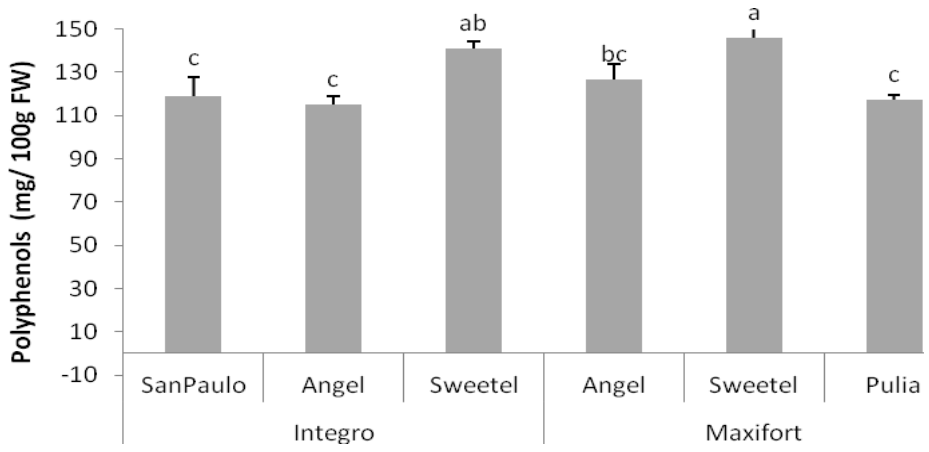

Figure 1: Total polyphenols content in cherry and large tomato fruits

Researches confirmed that in grafted plants, metabolic processes related to fruit quality are generally controlled by the scion or variety [21]. Our study case represented high amount of total polyphenol. Compared to George [26] results with concentrations were between 9-22 mg/100g FW according to Folin-Ciocalteu methods. According to Minutolo and his colleagues [27] genetic control is the main determining factor of phenolic compound content in fruits and vegetables. But, variations may be also caused by environmental factors, such as light and temperature [28]. So, high solar irradiance, typical of southern Tunisia, could cause the increase of phenols, because of their potential role in protection against ultraviolet radiation [29].

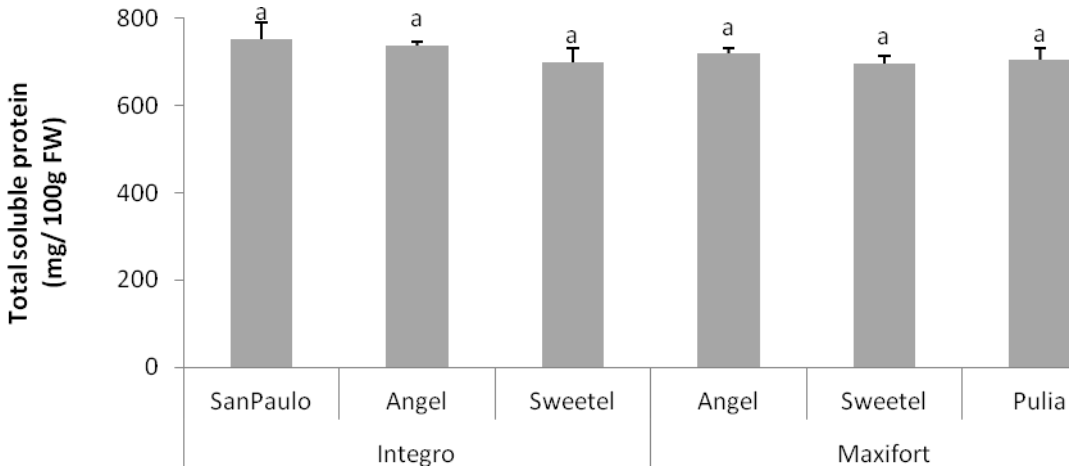

Figure 2: Total soluble protein content in cherry and large tomato fruits

There is no significant difference in total soluble protein among tomato varieties and rootstocks in our study case. A means of 717 mg $100g^{-1}$ FW of TSP was detected (Figure. 2). According to bibliography [30,31], tomato has a high level of proteins which improved the fruit quality and its nutritional value. These authors suggested that a difference in TSP content depending on varieties and fruit type witch disagree with our study. Tab. 2 showed a non significant statistics test of variation of fruits proteins concentrations among different variety and rootstocks.

Table2: Summary of the main results of the analysis of variance of the main factors and their interaction for total Polyphenol content and total soluble protein with the corresponding significance of the F-values

	Total soluble protein		**Total Polyphenol content**	
Source of variation	**F**	**P**	**F**	**P**
Variety	2,667	NS	23,620	***
rootstock	0,614	NS	5,848	*
Variety * rootstock	0,261	NS	1,012	NS

NS = not significant; *, **, *** significant at $p < 0.05$, 0.01 and 0.001, respectively.

3.3. Corroborating variety and rootstocks effect on physical and biochemical's tomato's characteristics

From this study, it is evident that the effect of grafting on tomato quality is dependent on hormonal and biochemical scion/rootstock interactions and or combination of both. Tomatoes from Angel and SanPaulo grafted in Integro rootstock had improved physical qualities (length, width, Shape Index and Fruit weight) as compared to other varieties and rootstocks combinations. Integro rootstock seems to be more preferment in tomato physical qualities improvement and firmness. Sweetel and Angel varieties grafted on Integro and Maxifort presented the highest values of Brix. Sweetel variety present the most important content of polyphenol

compared to other variety. Regardless rootstocks and varieties proteins content of tomatoes fruits are important. Grafting would play a significant role in boosting the quality of tomato.

Our study revealed that the scion cultivar was the top contributor to all studied tomatoes characteristics mostly related to the commercial identity of the fruit (with a high significance except for proteins). On the other hand, significance of the variety*rootstocks interaction for 7 out of 10 variables in our study case suggested that the bio-agronomical response of tomato to grafting was largely unpredictable, most of all in terms of plant growth and yield performances. A similar result was reported in Mauro and his colleagues [16] study dealing 63 graft combinations Influences on growth, yield and quality characteristics of cherry tomato.

4. Conclusion

The outcome of this experiment, conducted on different varieties of tomato and rootstocks graft combinations, highlighted variable responses in terms physicals and chemicals fruits quality traits. Higher reduction of the cherry tomato fruit shape index compared to the large tomato fruit was compensated by improved firmness and nutritional fruit value with higher content of soluble solids and polyphenols.

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5. Conflict of interest

The authors declares that they have no conflict of interest

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