



Article

Analysis of Physico-Chemical and Organoleptic Fruit Parameters Relevant for Tomato Quality

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Abstract: Increased interest in tomato (*Solanum lycopersicum* L.) production requires breeding to create new cultivars with highly marketable values (e.g., regarding quality, nutrition, and health) and valuable sensorial parameters. The purpose of this research was to compare four tomato commercial hybrids—two newly created and two used as controls in the breeding process, cultivated in a high plastic tunnel, regarding a wide range of physico-chemical properties as well as nutritional and organoleptic components of the fruits, which are relevant for the quality of the tomatoes. The new AS 400 commercial hybrid registered the best results for carotenoids (16.64 mg 100 g^{−1} FW) and dry matter (6.88%). The highest total ascorbic acid value (28.03 mg 100 g^{−1} FW) was recorded in the other new hybrid, AS 300, while the highest values of total acidity were recorded on the Precos, used as the control (184.87 mg NaOH 100 g^{−1} FW). The correlations between the analyzed characteristics and the multivariate analysis provided insight into breeding tomatoes to meet the current fruit quality requirements. Based on the results, hypotheses have been formulated for the creation of new cultivars with anticipatory, prospective character, in order to ensure the future needs of the market and consumers.

Keywords: carotenoids; fruit quality; nutritional compounds; sensorial parameters; *Solanum lycopersicum* L.



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1. Introduction

The tomato (*Solanum lycopersicum* L.) is one of the most important vegetables in the world due to its nutritional, economic, and social values; it is particularly important in human nutrition due to its antioxidant properties [1,2]. Globally, more than 5 million ha of tomatoes have been cultivated [3], with an average yield of 35.9 t/ha and an annual production of more than 180 million tons, according to FAOSTAT [4]. Tomatoes, being a crop of paramount global interest, can be consumed in various forms, both fresh and processed [5,6]. *Solanum lycopersicum* belongs to the *Solanaceae* family, its closest wild relative being *S. pimpinellifolium*, with an estimated divergence of only 0.6% base nucleotide pairs. Tomatoes are also related to potatoes (*Solanum tuberosum*), presenting more than 8% of genome divergence [7].

Current conceptions surrounding rational nutrition make the consumption of tomatoes a priority, primarily because they provide the human body with a wide range of nutritious and healthy substances such as vitamins, minerals, and water, which are necessary for the normal physiological activity of the human body [8]. Among the many valuable substances in tomatoes, carotenoids are well-known natural substances that help prevent diseases such as diabetes, gastrointestinal, and cardiovascular diseases, by, among other effects, lowering the number of low-density oxidized lipoproteins in the blood [9].

In addition to nutrients, tomatoes contain large quantities of lycopene. Numerous medical studies show the direct action of this pigment on free radicals in the human body. Free radicals are considered powerful oxidative molecules that attack the cell membranes of cells in various human body tissues; they also induce defective replication processes in human DNA that lead to rapid aging of the body [10]. Lycopene accumulates mainly in the last ripening period, giving the fruit an attractive red color. Due to its biological and physico-chemical properties and numerous health benefits, this essential antioxidant is of excellent importance [11]. The main tomato micro-components responsible for antioxidant attributes are lycopene and β -Carotene. The chemical composition of the tomato fruit is highly dependent on environmental factors, cultivation technology, genetic differences, agricultural procedures, biotic and abiotic stresses, and post-harvest storage [12–18].

Of three different types of tomatoes (cherry, Roma, and vine tomatoes), cherry tomatoes ranked the highest in lycopene content, followed by Roma-type tomatoes while the vine tomatoes ranked the lowest in the lycopene content [19]. β -Carotene and lycopene are also involved in photosynthetic reactions and pigment accumulation, which restore the fruit's bright red color [20,21]. These compounds play key roles in color development and are also synthesized by plants and microorganisms. Due to their ability to neutralize harmful photooxidation products, carotenoids are photoprotectors [22].

Dry matter content in tomatoes usually varies from 5.0% to 7.5% [23]. Depending on the irrigation and fertilization conditions, the average values of the dry matter content were found to range between 4.2% and 6.6% [23–25]. The quantities of dry matter and the ratio between its individual components are essential for the quality of the fruit. Some studies have demonstrated that lower nitrogen levels reduce plant growth and increase the dry matter content of fruits, thus improving fruit quality [26].

Tomato fruits are rich sources of vitamins and minerals that are good for human health. On the other hand, they are rich in trace elements, such as copper, manganese zinc, selenium, and vitamins C, B6, E, and folic acid [12,27]. It was discovered that through the neutralization of free radicals, these trace elements play a vital role in protection mechanisms [28]. Ascorbic acid is one of the most important chemical compounds found in tomatoes, in terms of nutritional value and essential organic acid in fruits and vegetables [29–31]. Organic acids play a key role in plant nutrition and sugars, which are key components that influence tomato quality and consumer preferences [32].

The genotypes (cultivars), plant growing conditions (ecological and technological), the time of fruit harvest, physiological and biochemical changes that fruits undergo after harvest, as well as many other different factors, decisively influence the fruit quality, understood as a complex concept, which includes all agronomic, commercial, nutritional, and gustatory components of fruits [8,15,33]. The physiological activities of the fruit cells, which are still alive after harvest, continue; the post-harvest storage life and the quality of the fruit depend on maturity. In this respect, maturity is an essential characteristic that can influence the organoleptic features of the fruits and the final perceptions of consumers [34]. Fruits that are harvested at the right maturity have the highest quality and sensory parameters [35].

The quality of tomatoes, as with other vegetables and fruits, consists of a multitude of characteristics, which confer their commercial aspects, physical-morphological and organoleptic particularities, and the nutritional and health benefits of the fruits [8,34,36]. Consequently, sensory perceptions of the consumers result from the integration of multiple sensory attributes of the fruits, respectively, perception, i.e., vision—the commercial aspect (shape, color, appearance); olfaction (or odor—sweet, pungent, floral); gustation (sweet

or salt, sharp or bitter, flavor—savor, perfume in mouth); hearing (crunchy); the sense of touch (texture—smooth, rough), temperature, firmness; trigeminal perception (fresh or hot sensations, astringency) [37]. While some quality elements can be measured objectively with appropriate tools and techniques (e.g., color, firmness, juiciness, chemical content, etc.), many others require sensory analyses, which may have a high degree of subjectivity.

Based on the above considerations, the present study aimed to perform a complex analysis of the overall qualities of some tomato genotypes represented by four commercial hybrids. Of these, two hybrids were new creations, obtained as a result of the tomato breeding process carried out in a private breeding unit in northwestern Romania, and two were widespread commercial hybrids, recognized for their productivity and quality. Due to their general value, the last two were used as control samples in the process of breeding and homologation of the two new commercial hybrids. We analyzed the relevant physical–morphological and chemical properties of tomatoes, as well as organoleptic traits, to obtain information on the relationships between important parameters (morphological, chemical, or sensorial) of the tomato quality. We also pursued identifying elements and attributes with greater contributions to the overall quality of the fruit and obtained data of interest for tomato farmers, producers, users, consumers, and breeders. To increase the economic efficiency of tomato crops, productivity is often sought as the most important goal of producers (farmers) and tomato breeders, to the detriments of the intrinsic qualities of fruits and their savors. Through the results of our study related to the importance of fruit quality and organoleptic analysis, we set out to highlight and support the importance of tomato breeding, in the direction of obtaining high-quality fruits.

2. Materials and Methods

2.1. Plant Material and Cultivation Conditions

The plant material was represented by four genotypes of the tomato—two new commercial F1 hybrids (AS 300 and AS 400) were recently created by Agrosel (Romania) and two commercial F1 hybrids (Precos (Geosem, Bulgaria) and Addalyn (Hazera Seeds, France)) were cultivated; they are appreciated for their yield and fruit quality in Romania. AS 300 and AS 400 commercial hybrids were obtained by crossing parental lines in advanced generations of selection (F7) obtained in a pedigree breeding process. The process of creating the new commercial hybrids was based on the creation and selection of their parental lines, followed by the crossing and selection of heterotic hybrids [8]. During the process of breeding and creating the two new commercial hybrids, the commercial hybrids Precos and Addalyn were used as the controls. This was based on some common characteristics, with AS 300 and Precos being comparable to the fruit set features and the time of fruit ripening and yield. On the other hand, AS 400 and Addalyn have similar characteristics, such as growth type, earliness, and yield. Addalyn was also chosen for its proper response to some stressors, including diseases and pests. In previous work, it was demonstrated that the choice of hybrids used as a control was relevant and justified [8].

The tomato crop that constituted the biological material in the research was grown in 2021 at Agrosel Private Research Station, located in Câmpia Turzii, in northwest Romania (coordinates: 46.55957; 23.85992). An unheated solarium with an area of 240 m² was used; the orientation of the plastic tunnel was in the south–north direction. Inside the protected space, the soil's surface was covered with black agro textile in order to control the weeds. The solarium equipment had the following characteristics: automated fertigation system ITU Mix Station 300 (Itumic Oy, Jyväskylä, Finland); automated humidification system K-Rain RPS 1224 (Budapest, Hungary); reverse osmosis irrigation system for irrigation water HIDROFIT (Mineralholding Kft, Budapest, Hungary); Agrosense Base weather station (Sys-Control Kft, Budapest, Hungary).

Tomato seeds were sown in fine peat substrate and the seedlings were grown in a nursery with a temperature and humidity automatic control system. Seven-week-old tomato seedlings were transplanted in the solarium on 15 May, in twin rows, with 0.35 m spacing inside the rows, 0.75 m between the twin rows, and 0.90 m distances between the

rows. From each genotype, two replicates of 50 plants were grown, totaling 400 plants. The main characteristics of the four commercial hybrids used in the study (AS 300, AS 400, Precos, and Addalyn) are presented in Table S1 and Figure S1.

2.2. Soil Properties, Microclimatological Conditions, and Measurements

The pH of the soil was monitored periodically and was quite alkaline, ranging between 7.51 and 8.02. The fertilizers (macro and micronutrients) were administered in three different stages of vegetation, in different doses: growth stages, planting to flowering—2 g/plant/day; flowering to fruit set—3 g/plant/day; fruit setting to the last harvest—4 g/plant/day. The quantities of fertilizers expressed in kg were mixed in separate tanks: A—tanks with nitrates and B—tanks with sulfates (with capacities of 500 L). The total amounts of the fertilizers were: $\text{Ca}(\text{NO}_3)_2$ 35 kg; NH_4NO_3 4 kg; KNO_3 13 kg; CaO , MgO , B , Cu , Fe , Mn , Mo , Zn 2 kg; KH_2PO_4 8 kg; K_2SO_4 5 kg; MgSO_4 15 kg per throughout the experimental period. Correct fertilization was monitored continuously to ensure that vegetative growth (root and foliage) was in a proper balance with reproductive growth (flowers and fruits). Throughout the fertilizer management period, the automated fertilization system measured the pH of the water as well as the electroconductivity (EC mS/cm) of the irrigation water, to assure the desired condition, respectively, EC: 3.3–4 mS/cm and pH: 6.4–6.7.

The meteorological parameters were monitored using an Agrosense Node + Air Temp_Hum + VWC_EC_SoilTemp microclimatological station (Sys-Control Informatikai Kft, Budapest, Hungary). The weather station received the entire sensor data transmitted via various sensors. The climate station allowed the control of the meteorological and microclimatic parameters and accurately measured the most important parameters (Figure 1), i.e., temperature, humidity, wind and sunlight intensity, and much more, every 30 min, from 15 May to 30 September 2021, thus accumulating a total of 16,219 measurements.

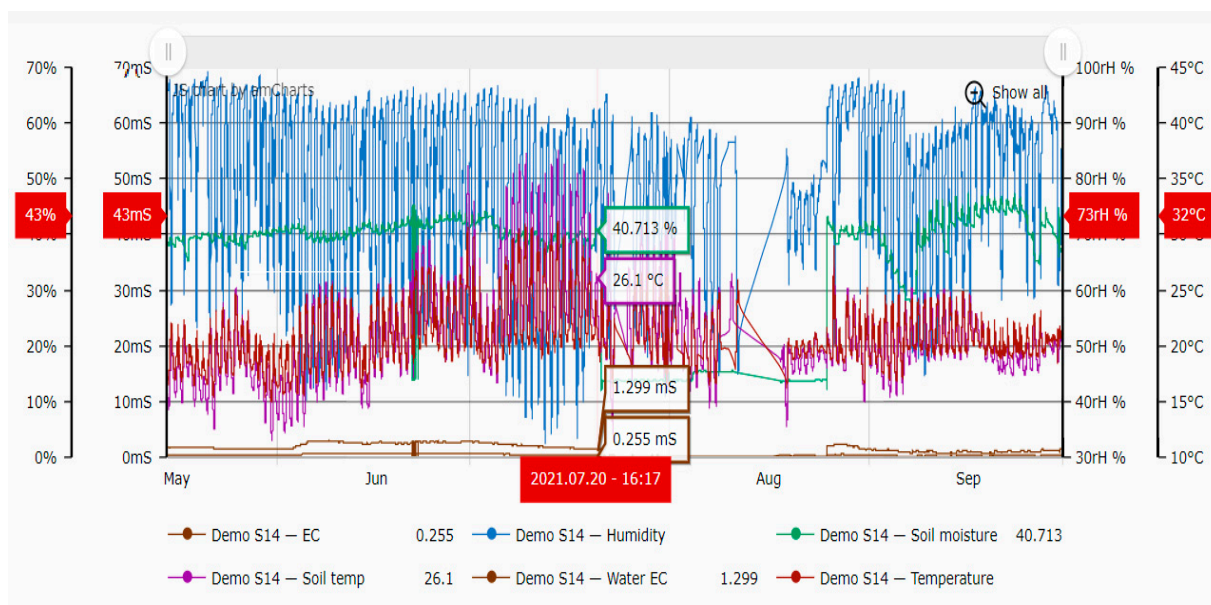


Figure 1. Microclimatological measurements for temperature, humidity, and water electroconductivity throughout the vegetation period.

2.3. Sampling and Analysis of the Qualitative Traits of Tomatoes

A total of five harvestings were performed. For each harvesting, sampling and sample size followed the same rules of homogeneity and equality between genotypes; ten fruits from each genotype were used after reaching physiological maturity. In the samples of each genotype, the same fruits were analyzed for height, diameter, volume, and fruit shape index; the data were finally transformed as the means of all the values. In addition to

the analyses performed on the morphologic, chemical, and organoleptic components, we analyzed external fruit descriptors that completed multiple different requirements, both to the farmers, agri-food markets, and large retail suppliers, but also to the preferences of the final consumer. Thus, we made measurements of the distance from the pedicel to the calyx, the type of joint (jointed and jointless), the size of the calyx, the peduncle scar, and the number of the seminal locus (Figure 2). The analysis was performed at each harvesting stage (i.e., the weight of the fruit) or depending on the positions of the fruits on the levels of clusters I–V (i.e., pedicel–calyx distance; calyx size; peduncle scar; locules/fruit). The fruits were analyzed separately on each cluster. From the four genotypes analyzed, the AS 300 and Precos only had four clusters, while AS 400 and Addalyn had five clusters.

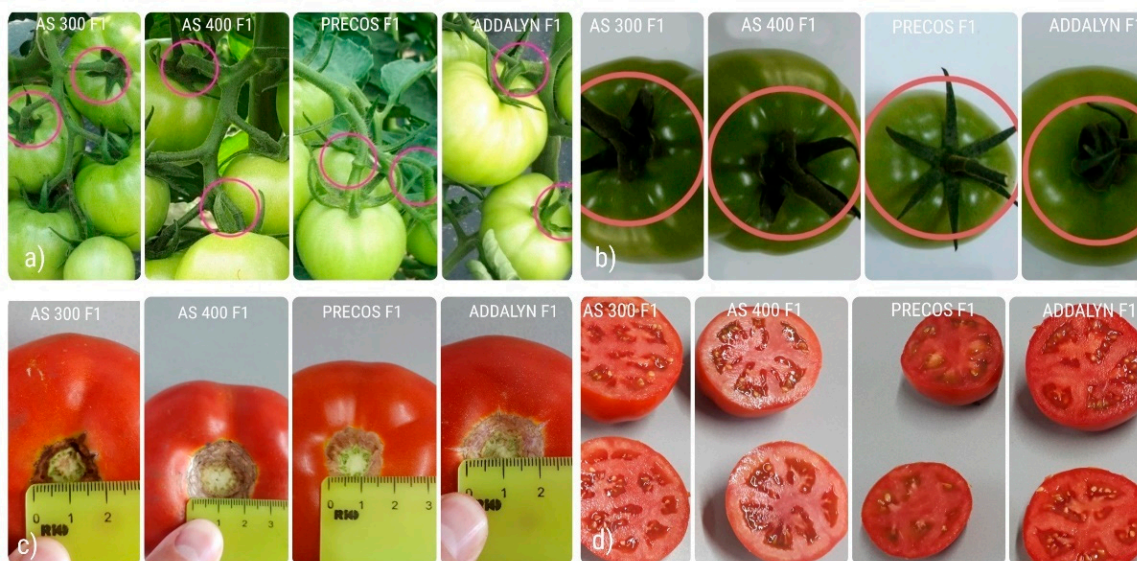


Figure 2. External quality indicators of the four tomato commercial hybrids: (a) distance from pedicel to calyx; (b) size of the calyx; (c) size of the peduncle scar; (d) number of locules.

At the physiological maturity, 10 fruits were randomly harvested from 10 different plants per genotype. A homogeneous sample of tomato juice was made and chemical analyzes were performed in the laboratory of the Department of Food Science and Technology, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Organoleptic analyzes were performed by completing questionnaires, based on the sensory perception of some voluntary consumers (30 women and 30 men). The procedures focused on 12 quality attributes [37], as described below.

2.4. Analysis of Chemical Components

All determinations were performed using the high-performance liquid chromatography–diode array detection (HPLC–DAD) method, utilizing a 1/1/1 (*v/v/v*) methanol/ethyl acetate/petroleum solvent mixture. The compounds were separated at 250 °C on EC 250/4.6 Nucleodur 300–5 C–18 ec. (250 × 4.6 mm, 5 m) (Macherey-Nagel, Düren, Germany).

2.4.1. Determination of Dry Matter Content

To determine the dry matter content, the oven drying method was used: in a porcelain capsule, brought to a constant mass, the sample weighed 15 g on a Kern ALJ 220–5 DNM (Balingen, Germany) analytical balance with an accuracy of 4 decimals, and was introduced into a Venti-Line VWR (Leicestershire, UK) oven for 4 h at a temperature $T = 105\text{ }^{\circ}\text{C}$. After drying, the capsules were cooled in a desiccator and recanted. The dry matter was determined using the formula: $(\%) = (m_{\text{dry}}/m_{\text{wet}}) \times 100$, where m_{dry} = mass of the sample after drying (g) and m_{wet} = mass of the sample before drying (g).

2.4.2. Determination of Total Acidity

The total acidity was determined titrimetrically using a 0.1 N NaOH solution. A sample of 20 g was mixed in a mortar with 20 mL of distilled water. The obtained juice was filtered and titrated with a 0.1 N NaOH solution in the presence of phenolphthalein. The total acidity was calculated using the mathematical relation: $A = V_{\text{NaOH}} \times T \times 100/\text{sqm}$; A = acidity (mg NaOH); V = volume of NaOH solution used in the titration (mL); T = titer of 0.1 N NaOH solution (4 mg/mL); mp = sample mass (g).

2.4.3. Determination of Ascorbic Acid

Ascorbic acid (vitamin C) was determined through the high-performance liquid chromatography–diode array detection–electrospray ionization (HPLC–DAD–ESI+) method. The sample was crushed and 2 g were extracted with 5 mL of metaphosphoric acid and an 8% acetic acid solution. The extract obtained was agitated for 1 min with a vortex, followed by sonication for 30 min, and centrifugation at 8000 rpm for 10 min at $T = 40^\circ\text{C}$ using an Eppendorf AG 5804 centrifuge. Before injection into the HPLC system, the supernatant was filtered through a $0.45\ \mu\text{m}$ nylon filter. To identify and quantify ascorbic acid, an Agilent 1200 (Santa Clara, CA, USA) HPLC system with a UV–vis detector (DAD), coupled with the Agilent single quadrupole mass detector (MS) model 6110, were used. The ascorbic acid was separated using a reverse-phase Eclipse XDB–C18 column ($150 \times 4.6\ \text{mm}$), $5\ \mu\text{m}$ (Agilent Technologies, CA, USA). An isocratic mobile phase was used: water/acetonitrile/formic acid 94/5/1 (*v/v/v*) with a 0.5 mL/min flow rate. The isocratic mobile phase used was: water/acetonitrile/formic acid 94/5/1 (*v/v/v*), at 25°C , for 10 min, with a flow rate of 0.5 mL/min. All chromatograms were monitored at wavelength $\lambda = 240\ \text{nm}$. The HPLC peaks were assigned by comparing the samples with a standard ascorbic L–acid (Santa Clara, CA, USA) and according to the retention times of the ascorbic acid (3.2 min) and UV spectra. The calibration curves were obtained by injecting 5 concentrations of a standard external substance (99% purity). The results are expressed as mg ascorbic acid/100 g of fresh material. For mass spectrometry (MS), a positive ion mode–electrospray ionization (ESI+) was used under the following conditions: capillary voltage: 3000; temperature: 350°C ; nitrogen flow: 8 L/min; *m/z*: 100–600, full scan. Data collection and interpretation were performed using Agilent ChemStation software.

2.4.4. Determination of Carotenoids

A 10 g sample was extracted with 10 mL of 1/1/1 (*v/v/v*) methanol/ethyl acetate/petroleum solvent mixture, followed by vortex agitation for 1 min, sonication for 15 min, and centrifugation at 8000 rpm for 10 min in an Eppendorf AG 5804 centrifuge. Four washes were performed with a saturated NaCl solution and the separation of the organic phase was performed in the separating funnel. The organic phase was initially filtered off with anhydrous Na_2SO_4 . The filter was washed with petroleum ether until complete discoloration. The extract was evaporated to dryness on a rotary evaporator under low pressure. The sample was redissolved in 1 mL of ethyl acetate; after that, it was filtered through a $0.45\ \mu\text{m}$ nylon filter and injected into the HPLC system. An Agilent 1200 series HPLC system equipped with a solvent degasser, quaternary pumps, DAD detector, and automatic injector was used to determine the carotenoids. The carotenoids were separated on a column EC 250/4.6 Nucleodur 300–5 C–18 ec. ($250 \times 4.6\ \text{mm}$, $5\ \mu\text{m}$) (Macherey–Nagel, Germany), at 250°C . The mobile phases used were: acetonitrile/water/triethylamine 90/10/0.25 (A) and ethyl acetate/triethylamine 100/0.25 (B) in the following gradients: at min 0.90% A; at min 10, 50% A. The percentage of solvent A decreased from 50% at min 10, to 10% at min 20. The flow rate was 1 mL/min and the chromatograms were recorded at the wavelength $\lambda = 450\ \text{nm}$. Lycopene and β -Carotene standards from Sigma were used to identify and quantify carotenoids in tomato samples.

2.5. Organoleptic Evaluation of Fruit Quality

The organoleptic qualities of the fruits were evaluated by sensory analysis, in sessions attended by untrained volunteer tasters without specialized knowledge. A total of 60 tasters (30 women and 30 men) were invited to complete the analysis questionnaires at the tomato tasting sessions. The tasting started at 13:00 and ended at 14:00, and each participant could drink or eat one hour before the tastings. Before each evaluation, testers had to rinse their mouths with mineral or distilled water. The accessories they had at their disposal were: chopping boards, plates, forks, knives, napkins, glasses of water, bread cubes (for consumption between samples and cleansing the palate between samples), and the test questionnaire. Each taster received two fruits of each genotype.

Participants were told how to individually complete organoleptic tasting sheets as well as to grade each trait on a hedonic scale, with grades from 1 ("Extremely Dislike") to 9 ("Extremely Pleasant"). The procedures were the same after each harvest, with tasting sessions taking place four days after the fruit was harvested. The fruits were stored in a room with controlled temperature (15 °C) and humidity (30%).

Four sensory attributes were analyzed, each with one or more descriptors, according to the procedure described by Vindras et al. [37]. The attributes with their 12 corresponding descriptors (in parenthesis), noted on a scale of 1–9, were: odor (tomato aroma); appearance (color, grooved skin surface); taste (salty taste, sweet taste, overall acidity); texture (skin consistency, mealiness, softness, crispness, juiciness, firmness). The obtained values of the grades awarded for each attribute were converted to mean values.

2.6. Statistical and Multivariate Data Analysis

Registered data recorded for the physico-morphological characteristics of the tomato fruits and the chemical parameters were processed as average values and presented in the synthesis tables and figures together with the standard error of the mean (SEM). One-way ANOVA was applied to analyze whether the differences between tomato genotypes were significant. If the null hypothesis was rejected, Duncan's multiple range test (Duncan MRT, $p < 0.05$) was used as the post hoc test for the analysis of differences [38].

The data were subjected to multivariate statistical analysis, namely correspondence analysis (CA), performed using Past software [39]. The principal component analysis (PCA) and Ward's hierarchical clustering algorithm method–Euclidean similarity index were computed for the tomato genotypes and analyzed traits. Pearson correlation coefficients were calculated for the analyzed characteristics ($p < 0.05$). In all cases, Past software was used [39], combining data with graphs made in Microsoft Excel software [40]. Comparisons of the four commercial hybrids based on 12 qualitative organoleptic descriptors, were performed using the Kruskal–Wallis test ($p < 0.05$); Ward's method was applied for hierarchical relationships of the organoleptic parameters.

3. Results

3.1. Main Physico-Morphological Traits of the Fruits

There were obvious differences among the four genotypes for the main fruit traits (Table 1). The highest values of fruit heights were recorded for the commercial hybrid AS 300 (10.65 cm), followed by the other new hybrid created at Agrosel, AS 400 (10.45 cm). Out of the two commercial hybrids used as controls, Precos had the fruit with the lowest height (6.75 cm). The fruit diameter in the four hybrids ranged between 6.50 and 8.45 cm, and the fruit shape index was between 1.04 and 1.42. The shape index close to 1 of Precos indicates an almost spherical shape of the fruits of this genotype, while the maximum value of AS 300 indicates the slightly elongated shape of its fruits. There were significant differences in fruit volume between the four hybrids. Compared to Precos, with the lowest value (48.38 cm³), at AS 400 the fruits had double volume (124.24 cm³).

Based on the coefficients of variability (CV%), the lowest variability among genotypes (and also within them) was recorded for the diameter of the fruit (values below 10% for all four genotypes; Table 1). Among the hybrids, greater uniformity of the morphological

characteristics of the fruits was registered for AS 400 (generally, CV less than 10%), while at AS 300, some characteristics had a high variability (CV between 20 and 30%), or even very high (CV over 30%).

Table 1. Main physico-morphological attributes of the fruits and their coefficients of variability (CV%) in the four F1 commercial hybrids.

Genotype/ Trait	Fruit Height (cm)		Fruit Diameter (cm)		Fruit Shape Index		Fruit Volume (cm ³)	
	Mean \pm SEM	CV%	Mean \pm SEM	CV%	Mean \pm SEM	CV%	Mean \pm SEM	CV%
AS 300	10.65 ^a \pm 1.00	29.8	7.60 ^b \pm 0.21	8.7	1.42 ^a \pm 0.15	34.4	101.88 ^a \pm 8.96	27.8
AS 400	10.45 ^a \pm 0.17	5.3	8.45 ^a \pm 0.16	5.9	1.24 ^{ab} \pm 0.03	7.9	124.24 ^a \pm 5.00	12.7
Precos	6.75 ^b \pm 0.21	10.0	6.50 ^c \pm 0.20	9.6	1.04 ^b \pm 0.02	6.6	48.38 ^b \pm 4.20	27.5
Addalyn	9.45 ^a \pm 0.32	10.7	8.15 ^{ab} \pm 0.18	7.1	1.16 ^{ab} \pm 0.04	10.9	105.17 ^a \pm 6.77	20.4

Values are expressed as mean \pm SEM. For each trait, any two means in a column followed by the same letter are not significantly different (Duncan's test, $\alpha < 0.05$).

Addalyn and AS 400 showed the highest marketable yields (Table 2); the results were very similar to the fruit weight. Addalyn had the highest fruit weight in the fifth harvest (228.5 g) and AS 400 in the third harvest (226.0 g). The lowest fruit weight value was recorded in Precos in the third harvest (102.5 g).

Table 2. The average weight of the tomato fruit (g) at different harvests during an annual production cycle.

Genotype/ Trait	1st Harvest		2nd Harvest		3rd Harvest		4th Harvest		5th Harvest	
	Mean \pm SEM	CV%	Mean \pm SEM	CV%	Mean \pm SEM	CV%	Mean \pm SEM	CV%	Mean \pm SEM	CV%
AS 300	210.0 ^a \pm 1.0	0.7	216.0 ^a \pm 3.0	2.0	208.0 ^a \pm 1.0	0.7	208.5 ^a \pm 4.4	3.7	-	-
AS 400	222.5 ^a \pm 16.5	10.5	222.0 ^a \pm 11.0	7.0	226.0 ^a \pm 4.0	2.5	221.0 ^a \pm 3.8	5.0	220.5 ^a \pm 9.5	6.1
Precos	108.5 ^b \pm 1.5	2.0	107.0 ^b \pm 2.0	2.6	102.5 ^b \pm 3.5	4.8	107.0 ^b \pm 1.3	8.8	-	-
Addalyn	225.0 ^a \pm 14.0	8.8	219.5 ^a \pm 4.5	2.9	223.0 ^a \pm 13.0	8.2	224.0 ^a \pm 5.7	6.1	228.5 ^a \pm 10.5	6.5

All values are expressed as mean \pm SEM. AS 300 and Precos did not form fruits in the 5th harvest. For each trait, any two means in a column followed by the same letter are not significantly different (Duncan's test, $\alpha < 0.05$).

External fruit quality parameters that may contribute to the overall quality of the fruit, intended for current consumption, respectively, fresh market tomatoes, are shown in Table 3, depending on the position of the fruit at the cluster (I–V). The two hybrids and two controls were jointed pedicel-type tomatoes. One of the parental lines of the AS 400 hybrid had the desired trait of ‘jointless pedicel’ but did not inherit it. However, the insertion distance and size of the pedicel, as external features of the fruits that could influence the quality of the finished market product were investigated. The lowest value was reported for the second cluster of the AS 400 hybrid (2.08 cm), as opposed to Addalyn, which had the highest values corresponding to the third inflorescence (2.94 cm). The highest value in terms of calyx length was recorded at Addalyn, with an average value of 3.56 cm reported in the third cluster. The lowest values of the peduncle scar, assessed according to the UPOV Guide, International Union for the Protection of New Varieties of Plants, TG/44/10, the test of distinction, uniformity, and stability on tomatoes [41], were recorded at Precos, with an average value of 1.94 cm. The highest value was recorded at Addalyn (2.60 cm). The hybrid AS 300 had the highest number of locules (7.5 locules per fruit), a trait that directly influences the shapes and sizes of the fruits.

For all the elements that contribute to the productive capacity (number of fruits per plant, fruit weight, and production per plant), Precos had significantly lower values than the other three hybrids (Figure 3). The average number of fruits per plant ranged between 12 (Precos) and 19 (AS 400). The weight of the fruits was similar in the hybrid Addalyn, AS 400, and AS 300, all significantly exceeding Precos for this trait. Fruit production was extremely different within the four genotypes, with the most productive hybrid being AS 400, followed by Addalyn and AS 300, with Precos ranking last in production potential.

Table 3. External quality parameters of the tomato genotypes, depending on the positions of the fruits on the levels of clusters (I–V): pedicel–calyx distance (cm); calyx size (cm); peduncle scar (cm); and internal parameter, respectively, locules/fruit.

Genotype/ Trait	I Cluster		II Cluster		III Cluster		IV Cluster		V Cluster	
	Mean \pm SEM	CV%	Mean \pm SEM	CV%	Mean \pm SEM	CV%	Mean \pm SEM	CV%	Mean \pm SEM	CV%
Pedicel–calyx distance (cm)										
AS 300	2.16 ^b \pm 0.08	11.6	2.41 ^a \pm 0.11	14.0	2.33 ^b \pm 0.07	9.7	2.44 ^b \pm 0.06	8.0	-	-
AS 400	2.37 ^{ab} \pm 0.09	11.9	2.08 ^b \pm 0.10	15.5	2.30 ^b \pm 0.09	12.0	2.46 ^b \pm 0.06	7.9	2.46 ^b \pm 0.06	7.9
Precos	2.44 ^a \pm 0.03	4.4	2.62 ^a \pm 0.03	3.9	2.40 ^b \pm 0.06	7.9	2.66 ^a \pm 0.03	4.0	-	-
Addalyn	2.54 ^a \pm 0.06	7.9	2.65 ^a \pm 0.07	8.2	2.94 ^a \pm 0.05	5.4	2.66 ^a \pm 0.05	5.9	2.67 ^a \pm 0.06	6.8
Calyx size (cm)										
AS 300	2.59 ^c \pm 0.06	7.4	2.81 ^b \pm 0.08	9.6	2.80 ^b \pm 0.07	8.2	2.84 ^a \pm 0.03	3.8	-	-
AS 400	2.84 ^b \pm 0.05	5.0	2.66 ^b \pm 0.03	3.2	2.63 ^b \pm 0.03	3.6	2.63 ^a \pm 0.03	3.6	2.74 ^b \pm 0.05	5.5
Precos	2.21 ^d \pm 0.07	10.3	2.28 ^c \pm 0.03	8.7	2.38 ^{bc} \pm 0.08	11.0	2.38 ^b \pm 0.08	11.0	-	-
Addalyn	3.30 ^a \pm 0.08	7.4	3.43 ^a \pm 0.06	3.1	3.56 ^a \pm 0.08	7.4	2.38 ^b \pm 0.08	11.0	3.36 ^a \pm 0.04	4.0
Peduncle scar (cm)										
AS 300	2.14 ^c \pm 0.06	9.1	2.22 ^b \pm 0.02	3.6	2.34 ^b \pm 0.02	2.2	2.26 ^b \pm 0.03	3.7	-	-
AS 400	2.38 ^b \pm 0.02	3.3	2.36 ^b \pm 0.07	9.2	2.44 ^{ab} \pm 0.05	5.9	2.54 ^a \pm 0.04	5.0	2.40 ^a \pm 0.04	5.6
Precos	1.96 ^c \pm 0.03	5.5	1.98 ^c \pm 0.06	9.2	1.96 ^c \pm 0.06	10.0	1.94 ^c \pm 0.05	8.8	-	-
Addalyn	2.58 ^a \pm 0.07	8.9	2.60 ^a \pm 0.04	5.1	2.60 ^a \pm 0.04	4.4	2.52 ^a \pm 0.05	6.1	2.40 ^a \pm 0.04	5.6
Number of locules per fruit										
AS 300	7.5 ^a \pm 0.5	9.4	7.5 ^a \pm 0.5	9.4	7.5 ^a \pm 0.5	9.4	7.5 ^a \pm 0.5	9.4	-	-
AS 400	6.5 ^a \pm 0.5	10.9	6.5 ^b \pm 0.5	10.9	6.5 ^b \pm 0.5	10.9	6.5 ^b \pm 0.5	10.9	5.5 ^a \pm 0.5	12.9
Precos	4.5 ^b \pm 0.5	15.7	5.5 ^c \pm 0.5	12.9	6.5 ^b \pm 0.5	10.9	5.5 ^c \pm 0.5	12.9	-	-
Addalyn	4.5 ^b \pm 0.5	15.7	5.5 ^c \pm 0.5	12.9	5.5 ^c \pm 0.5	12.9	5.5 ^c \pm 0.5	12.9	5.5 ^a \pm 0.5	12.9

All values are expressed as mean \pm SEM. AS 300 and Precos did not form fruits on cluster V. For each trait, any two means in a column followed by the same letter are not significantly different (Duncan's test, $\alpha < 0.05$).

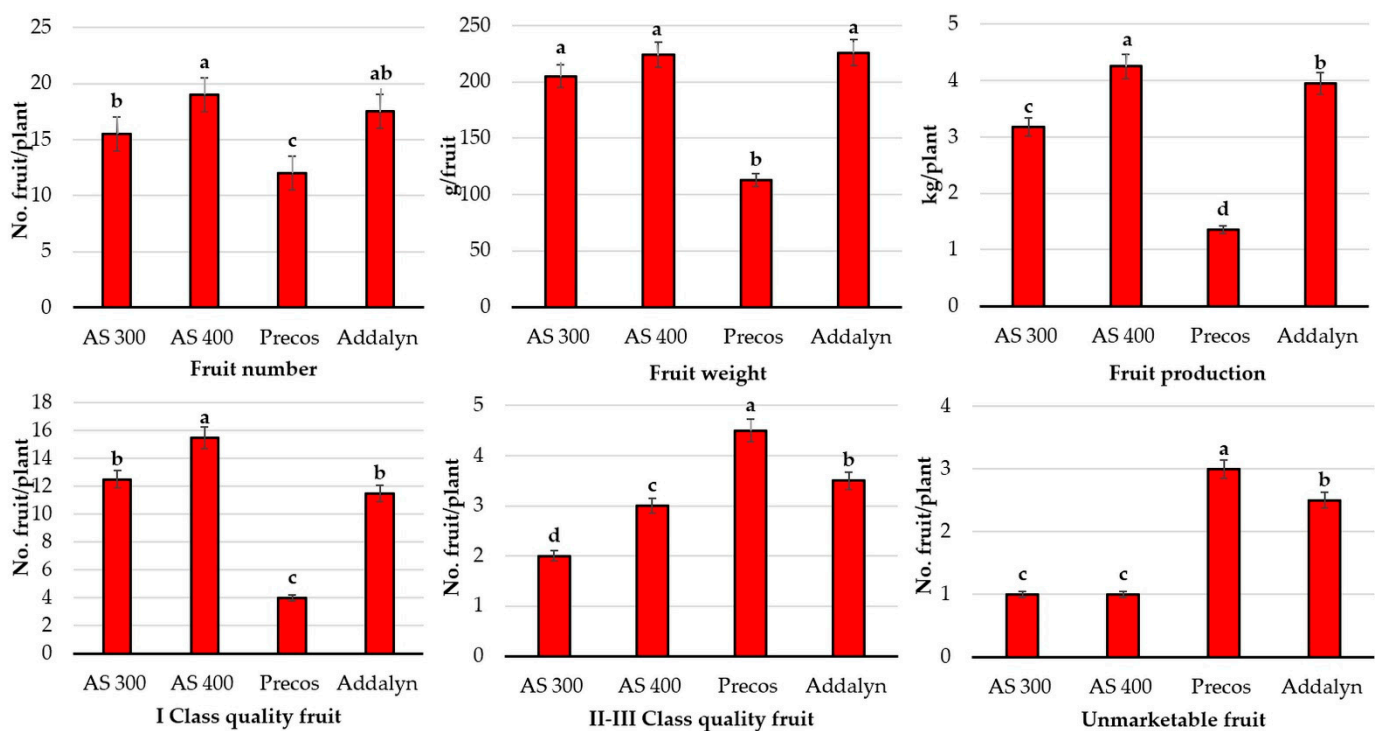


Figure 3. The main elements of productivity and the classification of tomato fruits in quality classes and unmarketable fruits in four tomato genotypes. All values are expressed as mean \pm SEM. For each trait, any two means followed by the same letter are not significantly different (Duncan's test, $\alpha < 0.05$).

The best average results for first-class fruits were obtained for AS 400 (almost 16 fruits/plant), followed by AS 300 and Addalyn (both with approximately 12 fruits/plant). With about four fruits per plant in the first class at each harvest, Precos had the lowest number of first-class fruits. In contrast, Precos recorded the highest number of fruits framed in quality classes II and III, as well as non-marketable fruit.

3.2. Chemical Analyses and Content of Fruit in Compounds of Interest

Significantly different values were reported for all four tomato genotypes in the chemical components (Figure 4). The dry matter ranged from 3.77% (AS 300) to 6.88% (AS 400). Amongst these values, Addalyn had a slightly lower value, insignificant compared to AS 300, while the value recorded at Precos was significantly lower than Addalyn and AS 300, but significantly higher than AS 400.

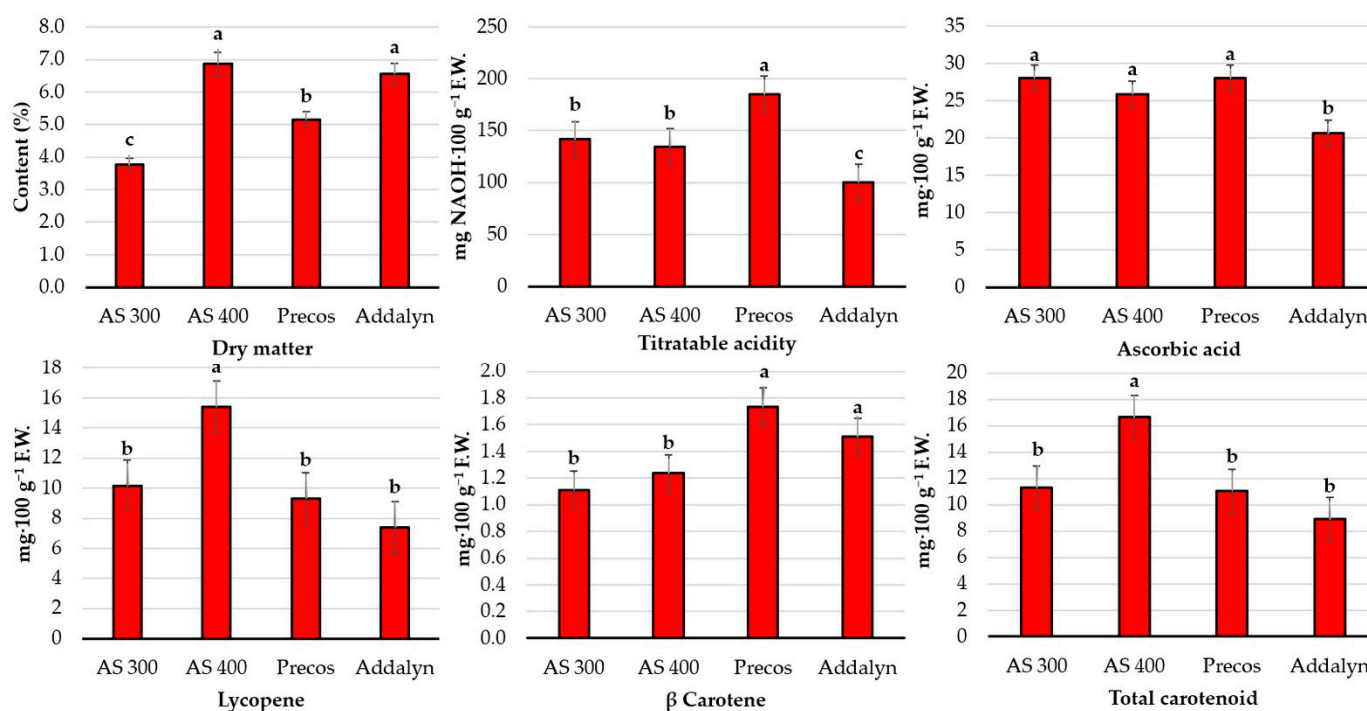


Figure 4. The main antioxidant compounds in tomato fruits depending on the genotypes analyzed. Values are expressed as mean \pm SEM. For each trait, any two means followed by the same letter are not significantly different (Duncan's test, $\alpha < 0.05$).

The total acidity (expressed in mg NaOH 100 g⁻¹ FW) oscillated between 100.11 and 184.87; these extreme values were recorded in the two hybrids used as the controls. The new hybrids AS 300 and AS 400 had intermediate values, significantly lower compared to Precos, but significantly higher compared to Addalyn.

The levels of ascorbic acid content ranged from 20.65 to 28.03 mg 100 g⁻¹ FW. The highest value was recorded at the hybrid AS 300, followed closely by Precos and AS 400. Addalyn presented the lowest content, significantly lower than the other three genotypes. The average values for lycopene ranged between 7.4 and 15.4 mg 100 g⁻¹ FW; for total carotenoid content, the range was between 8.91 and 16.64 mg 100 g⁻¹ FW. For both parameters, the AS 400 stood out with statistically superior values compared to the other three commercial hybrids. The β -Carotene content ranged from 1.10 to 1.74 mg 100 g⁻¹ FW (the lowest value was recorded at AS 300, and the highest at Precos).

The ascorbic acid HPLC chromatogram, recorded at wavelength, is presented in Figure S2. Calibration curves (by injecting five concentrations of a 99% purity standard substance) were positive and significant, as shown in Figure S3. Figure S4 shows the conventional HPLC chromatogram for carotenoids obtained at a wavelength of 450 nm and

a flow rate of 1 mL/min. The retention time (Rt) and absorption spectra (max) for lutein, lycopene, and carotene were distinct, as shown by a typical chromatogram: Rt = 5.98 min, Rt = 12.37 min, and Rt = 13.52 min (Figure S5).

3.3. Organoleptic Evaluation of Fruits

The results of the ranking test using the hedonic scale (1–9 notes, or grades) based on 12 sensory descriptors on four distinct attributes [37] are presented in Figure 5. The results differentiate the hybrids for different quality and savor elements of the tomatoes, but for all sensory characteristics, the differences between the four commercial hybrids were not significant. In addition, the calculated values of ‘p’ (Kruskal–Wallis test) were not significant for the differences between female and male tasters, and so the aggregated results are presented.

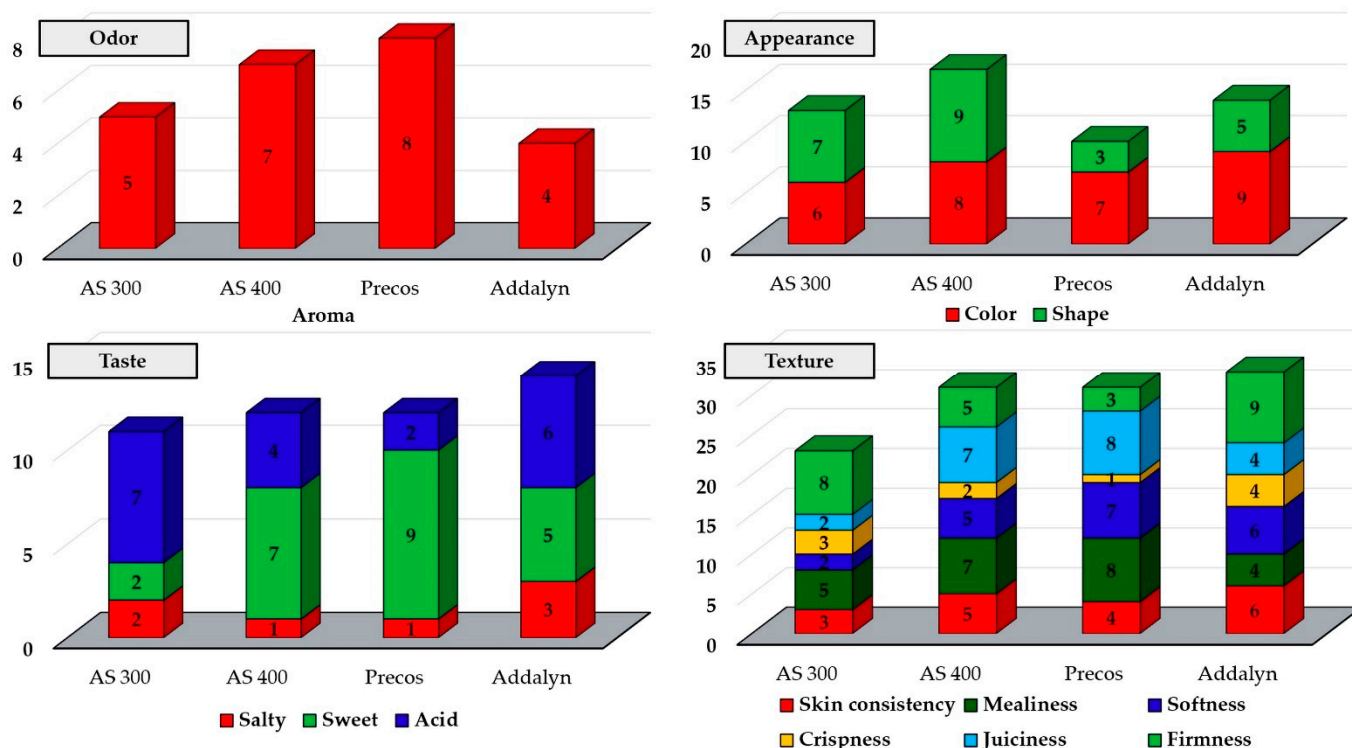


Figure 5. Rounded average values for the main organoleptic characteristics of tomato fruits, following evaluations attended by 60 tasters (30 women and 30 men). The evaluations were performed by completing questionnaires, using a hedonic scale with grades from 1 (‘Extremely dislike’) to 9 (‘Extremely pleasant’) for the overall preference of sensory attributes. The evaluation, also based on the 12 sensory descriptors, framed in four distinct attributes, was performed according to Vindras et al. [37]. Due to the lack of significant differences between women and men, the aggregated results are presented.

For the fruit aroma (as odor descriptor), the grades ranged from 4 (Addalyn) to 8 (Precos). Apart from Addalyn, with the lowest grade, a high value was recorded in the new hybrid AS 400 and Precos. For the two elements scored on the fruit’s appearance, the color ranged from 6 to 9, the highest grade was obtained at Addalyn. The shape of the fruit was a feature with great amplitude between the four genotypes. AS 400 received the highest grade, while the Precos received a low grade, respectively 3.

Salty, sweet, and acidic—the three attributes considered defining for the taste of the tomatoes—were appreciated quite differently by the tasters, from one genotype to another. For the salty attribute, the tasters did not find large differences between genotypes, but large variations were registered for the sweet and acidic tastes of the fruits. The sweet taste was well appreciated, especially for Precos, but also for AS 400 and even Addalyn. However, the ‘character’ was very weakly highlighted in AS 300. In contrast, AS 300 scored

highest on acidic taste, followed by Addalyn. A lower grade was recorded for AS 400, especially Precos, with a grade close to the minimum of the assessment scale.

For the six elements of fruit textures, the cumulative notes highlighted the Addalyn hybrid (33 points), closely followed by AS 400 and Precos (both with a total of 31 points). At a distance, with an inferior difference of 8 or 10 points, was AS 300. For AS 300, the greatest contribution was made by the individual elements represented by firmness and mealiness. Regarding the individual attributes of each genotype, greater contributions to the overall textures were relevant: firmness, softness, and skin consistency (in Addalyn); juiciness, mealiness, and softness (Precos); juiciness and mealiness (AS 400).

3.4. Correlations between the Analyzed Characteristics and the Multivariate Analysis

The Pearson correlation coefficients allowed identifying some close links, statistically significant ($p < 0.05$) between the different physical–morphological characteristics of the fruits and the chemical content of the fruits or elements perceived organoleptically by the tasters (Figure 6). Some of these were to be expected, for example, the positive, significant correlation between fruit diameter and fruit volume, which could be anticipated. Others, on the other hand, were less predictable, such as between the shape index and the carotene content of the fruit or between the shape index and softness (both negative).

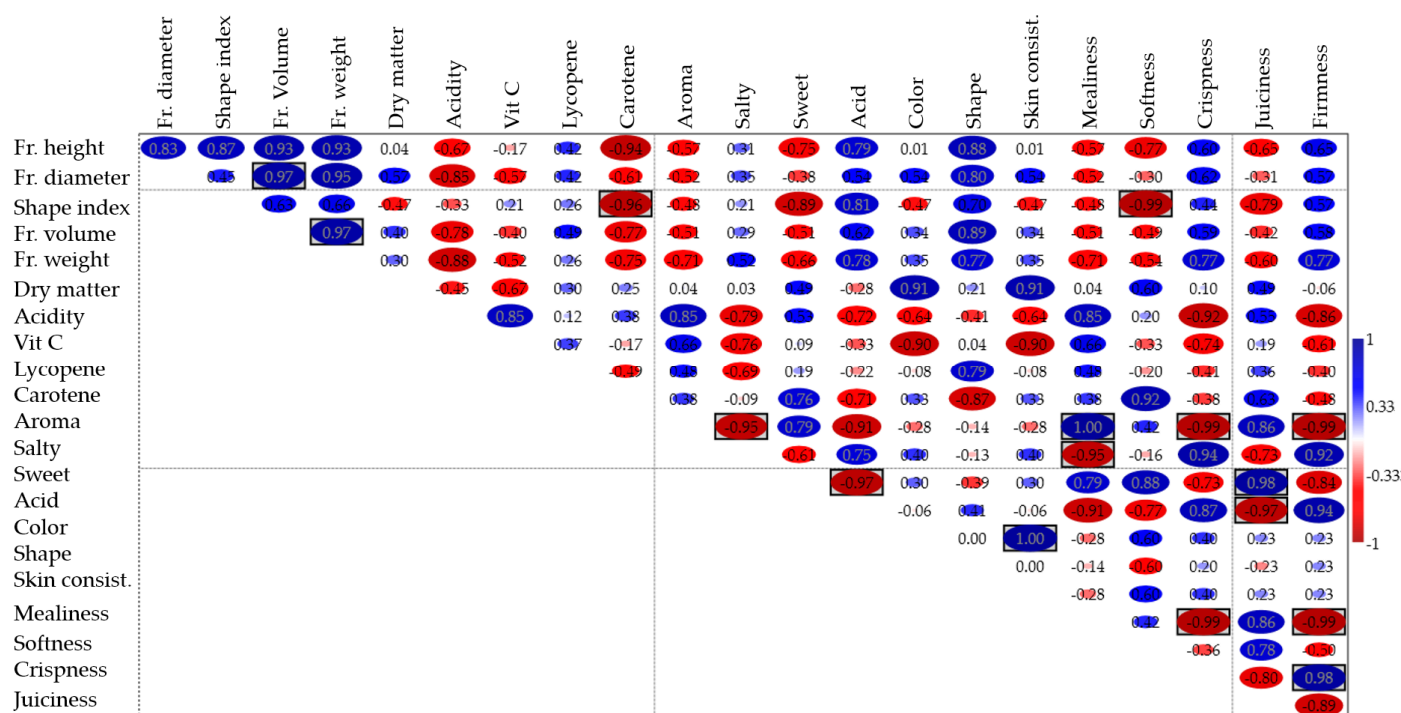


Figure 6. Phenotypic correlations between the pairs of traits analyzed. Correlations were calculated from the mean values of each of the four genotypes characterized. Positive correlations are displayed in blue and negative correlations in red. The color intensity and the size of the circle are proportional to the correlation coefficients. The grey background boxes illustrate the significant values at the level of $p < 0.05$ (two-tailed).

Significant positive correlations were identified between the following character pairs: aroma–mealiness; sweet–juiciness; fruit color–skin consistency; crispness–firmness. Although the aroma was positively correlated with mealiness, it was negatively correlated with other descriptors of fruit quality, such as salty, crispness, and firmness. Moreover, a (very close) negative correlation was identified between sweet and acidic. This is even more interesting as it is not one analyzed at the chemical level (measurable with the rigor of some chemical analysis tools), but by the perception of the assessors (known to be

sometimes extremely subjective). A negative correlation was also determined between acid and juiciness, mealiness and crispness, and mealiness and firmness.

The multivariate analysis applied for the physical–morphological and chemical features studied for the four tomato genotypes performed with the correspondence analysis (CA) offers an interesting relationship of the characteristics in the four quadrants of the graph and provides a simple visualization of the relationships among different attributes (Figure 7a).

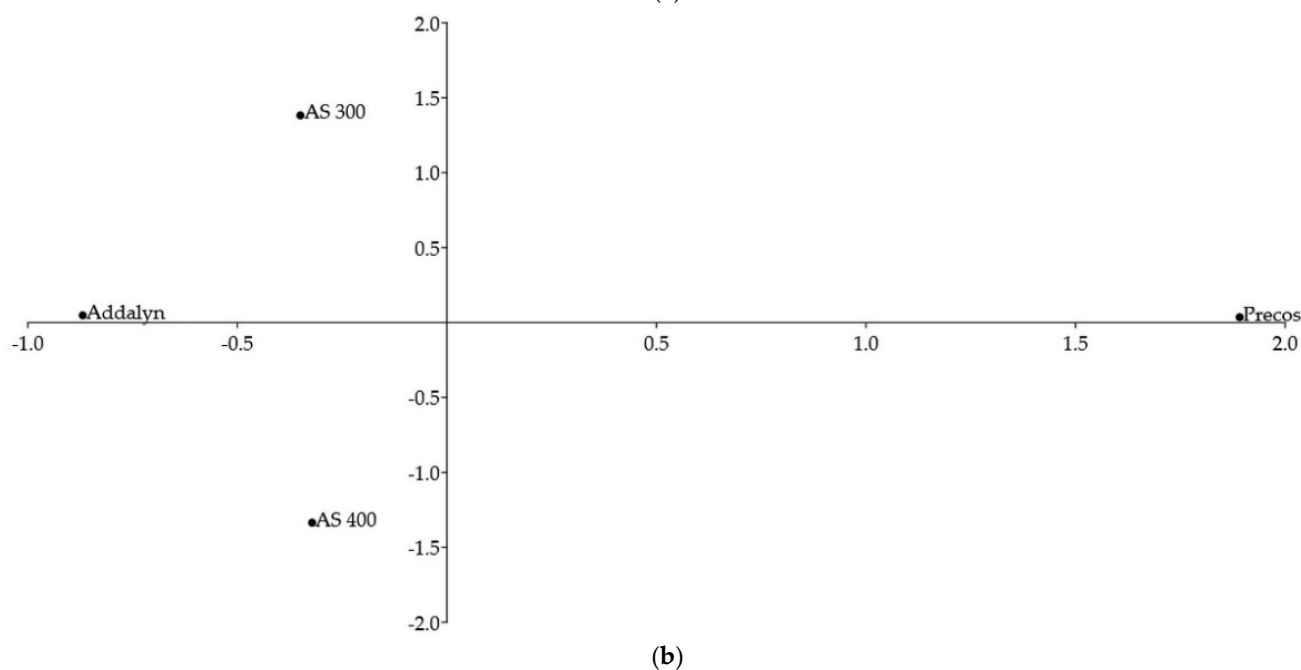
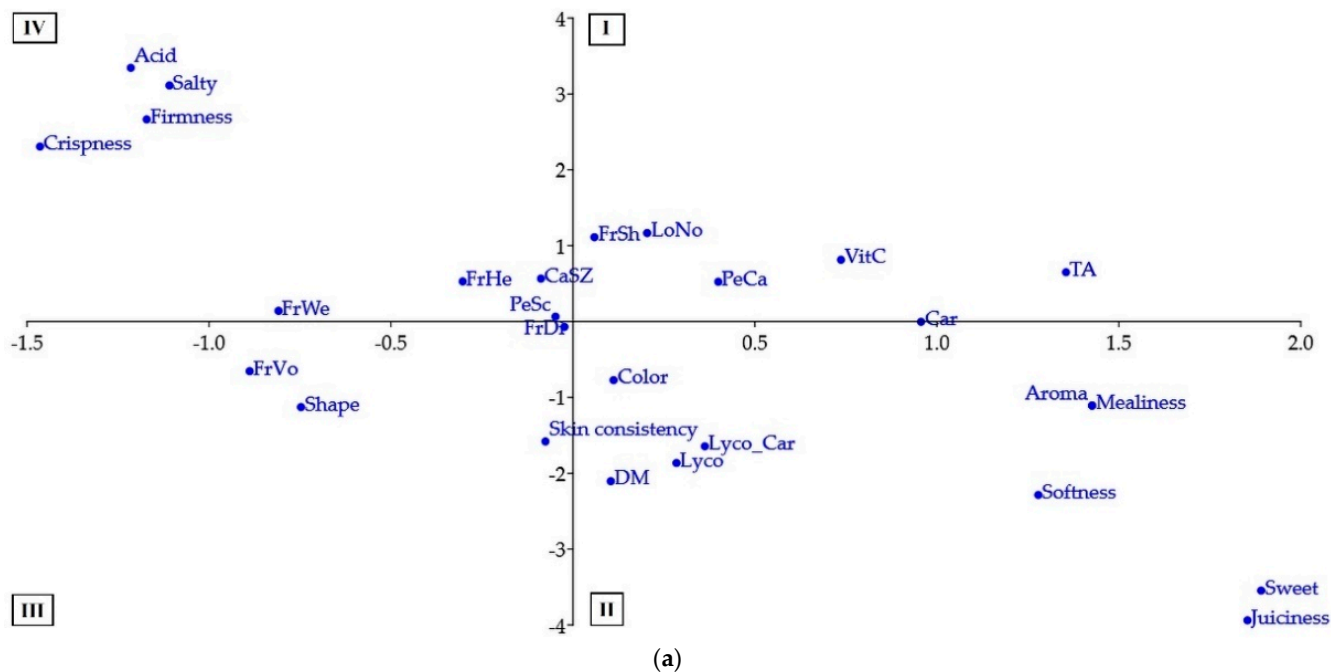


Figure 7. Cont.

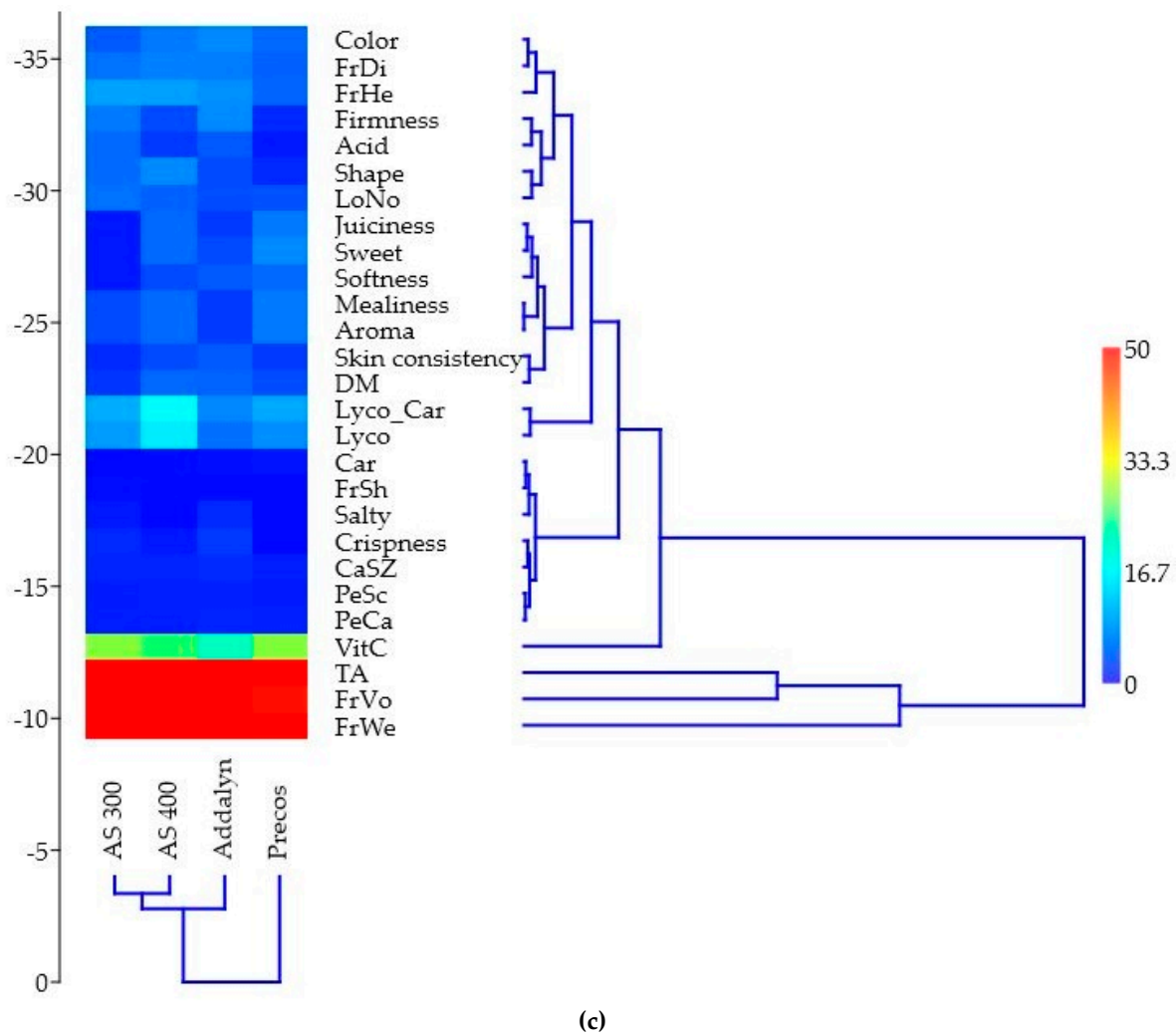


Figure 7. Multivariate analyses for the studied characteristics in the four tomato genotypes: (a) correspondence analyses performed for 42 physico-morphological and chemical traits; the following abbreviations are used: FrHe (Fruit height), FrDi (Fruit diameter), FrSh (Fruit shape index), FrVo (Fruit volume), FrWe (Fruit weight, as mean of all clusters), PeCa (Pedicel–calyx distance, as mean of all clusters), CaSZ (Calyx size, as mean of all clusters), PeSc (Peduncle scar, as mean of all clusters), LoNo (Locus number, as mean of all clusters), DM (dry matter), TA (total acidity), VitC (vitamin C), Lyco (lycopene), Car (β -Carotene), Lyco_Car (total lycopene + β -Carotene), aroma, salty, sweet, acid, color, shape, skin consistency, mealiness, softness, crispness, juiciness, firmness; (b) principal component analysis (PCA) for the four tomato F1 commercial hybrids; (c) Ward’s hierarchical clustering algorithm method–Euclidean similarity index of the four tomato F1 commercial hybrids.

There are relatively compact groupings of some morphological characteristics of the fruits, considered external quality parameters, such as fruit shape, fruit diameter, fruit height, fruit weight, and fruit volume; these are distributed in the central area of the CA graph, but in different quadrants (I, III, and IV). Other morphological traits such as calyx size, peduncle scale, pedicel–calyx distance, and the internal parameter, respectively, the number of locules per fruit, are also compactly grouped in the same area. Most of the organoleptic quality descriptors evaluated on a hedonic scale are in quadrant IV, in the form of a subgroup, for example: acid, salty, firmness, and crispness. In quadrant II, characteristics such as sweetness and juiciness, respectively aroma and mealiness, as two small subgroups, were placed. In the same quadrant (II), and close to them, softness was placed. The locations of these characteristics in opposite quadrants confirm the inversely

proportional links between them, partially highlighted by the correlation coefficients. In the correspondence analysis (CA), axis 1 explains 83.18% of the total variance, axis 2—9.07%, and axis 3—7.75%.

Both the principal component analysis (PCA) (Figure 7b) and hierarchical clustering paired group UPGMA (Figure 7c) for the four tomato genotypes illustrate a certain closeness of the two new commercial tomato hybrids, AS 300 and AS 400, even if they do not have a common origin or a very strong degree of kinship [8]. Based on PCA, Addalyn is closer to these two new commercial hybrids, while Precos is as close to the horizontal axis as Addalyn, but at an opposite diagonal dial, at a fairly large distance. The dendrogram highlights the hierarchical relationship between the genotypes, confirming the closeness between the two new commercial hybrids as well as their distance from Addalyn and (especially) from Precos.

The final organoleptic hierarchy of tomato genotypes established, based on the sensory descriptors, reveals higher average values at AS 400 and Addalyn, followed by Precos (Figure 8a). The weakest position, as a qualitative perception by the assessors, was recorded by AS 300. However, the Kruskal–Wallis test shows that there are no significant differences between the four tomato genotypes. Of the 12 organoleptic parameters (salty, sweet, acid, color, shape, skin consistency, floury, softness, crunchy, juicy, firmness), some had larger contributions on the hedonic scoring scale 1–9 (Figure 5); they compensated each other, resulting in final (general) values relatively close to the sensory perceptions and organoleptic qualities of the four tomato genotypes (Figure 8a).

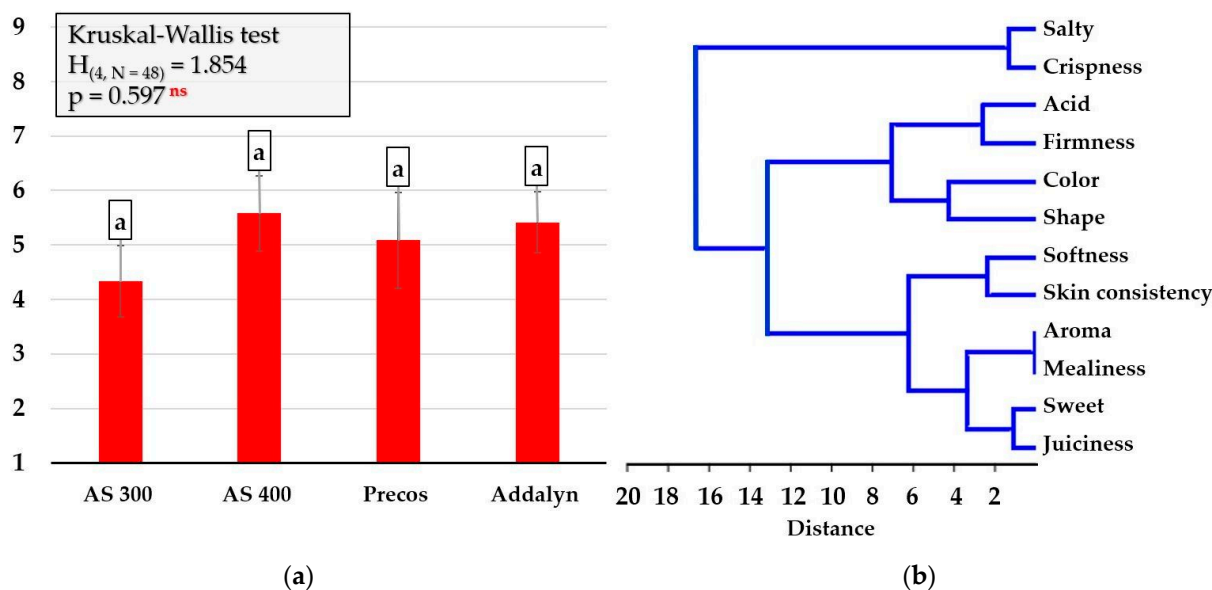


Figure 8. The final organoleptic hierarchy of tomato genotypes and the multivariate analysis of the relationship between sensory descriptors used to assess the quality of tomatoes: (a) mean values for the 12 organoleptic descriptors of the tomato fruits (salty, sweet, acid, color, shape, skin consistency, mealiness, softness, crispness, juiciness, firmness), following evaluations performed using a hedonic scale with grades from 1 ('Extremely dislike') to 9 ('Extremely pleasant'), according to Vindras et al. [37]. Comparison of the four genotypes based on 12 sensory descriptors; means followed by the same letter do not differ by the Kruskal–Wallis test ($p < 0.05$). (b) The hierarchical relationship (hierarchical clustering, Ward's method) between sensory descriptors used to assess the organoleptic qualities of tomatoes in the four commercial hybrids.

The dendrogram performed by Ward's method (Figure 8b) confirms the relationships between the sensory attributes revealed by correspondence analyses (CA—Figure 8a) and hierarchical clustering (Ward's method, Euclidean similarity index—Figure 8b) of the four tomato F1 commercial hybrids. It is interesting how the sensory elements are grouped at the last levels in simple pairs, with two attributes each. At the bottom of the dendrogram is the

sub-cluster represented by the pairs sweet–juiciness and aroma–mealiness, and also noticed in the second quadrant of the CA. They are furthest from the small cluster represented by the salty–crispness pair but are closer to the softness–skin consistency pair. Finally, the color–shape and acid–firmness pairs are in a common subcluster.

4. Discussion

The correspondence between the morphological characteristics of the fruits, the chemical content of the fruits in useful alimentary, nutritional, and healthy components, and the commercial traits and overall gustatory qualities of the fruits are of great importance for the success of new tomato cultivars. After all, these characteristics are influenced by the characteristics of the cultivar, determined both by the genotype, the environment, and the technological factors of the culture, as well as by the interactions between them [8,42]. In tomato breeding, the commercial aspect of the fruits is of great interest, and for the cultivars destined for fresh consumption, the main elements that attract the consumers are those with visual impacts, such as the size, shape, and color.

The exterior fruit attributes can significantly influence the quality of tomatoes after the harvesting or storage stages. A loss of 10–30% of the yield can occur in fresh tomatoes in harvesting, handling, and transport. Mechanical harvesting of tomatoes requires varieties with pedicels without joints, but so far, not many varieties of this kind have been created [43]. The potential benefits of the pedicel trait without joints are well known, and molecular markers for the causal gene for this trait can be used [44].

Thus, in the research project regarding the creation of hybrids, we emphasized the external quality of the fruits, because the newly created hybrids will be destined for fresh consumption. Before establishing a product profile, we considered the desires and needs of the final consumers. Some quality attributes are closely connected to genotypes, such as the shapes and sizes of fruits, lycopene content, vitamin C, and soluble solids. The latter traits have their own specific heritabilities and are highly dependent on the expressions of the genotypes in combination with the environment (respectively, the crop peculiarities) [8,45]. The shapes and sizes of the fruits in our experiment were not significantly influenced by hybrids, while the AS 400 genotype showed a larger fruit diameter than Addalyn and a smaller fruit height than AS 300.

To market high-quality fruit, in most cases the tomato fruits are harvested and distributed with the attached calyx, to be recognized as rich in freshness—National Agricultural Products Quality Management Service, NAQS [46]). On the plus side, many consumers are attracted to the tomato flavor provided by the green side of the fruit [47]. However, tomatoes are infected with many pathogens; the calyx is the first part of the tomato where various phytopathogenic fungi can appear and grow very quickly and easily [48]. The largest number of bacteria and fungi were detected in samples with the calyx attached to the tomato fruit. Thus, the calyx is the main source of potential microorganisms harmful to fruit quality [49]. In terms of calyx length, the highest values in our study were reported for Addalyn. The removal of the calyx delayed the ripening stage and reduced the firmness and physiological weight loss of the fruit [50].

The peduncle scar is an undesirable trait, manifested especially in Addalyn. At the same time, covering the scar of the tomato pedicel can reduce the ripening rate and prolong the shelf life of the fruit, inducing better firmness [50]. Because there is an extensive gas exchange at the scar site on the stem, removing the pedicel and calyx from the fruit can cause delayed ripening by decreasing O₂ and increasing the level of carbon dioxide.

Frusciante et al. [51] found high concentrations of dry matter for certain tomato lines, between 12.34 and 20.04%; the dry matter is largely represented by the content of dietary fiber and organic acids, which contribute to determining the antioxidant capacity. Significant differences in dry matter content were found between tomato genotypes by Hallmann et al. [52], between 5.97% for the Kmici variety and 13.09% for the Koralik variety. In research conducted by Caruso et al. [53], the dry matter content of a cherry tomato variety ranged from 8.4% to 9.0%, depending on the culture system and biostimulant application.

Optimization of irrigation in tomato culture can influence the dry matter content, with variations between 4.20 and 5.00% [23]. These values were close to those obtained by us (3.77–6.88%), AS 400 was recorded with the highest content. Our higher values were likely not only due to improved (modern) genotypes but also to the culture conditions, as well as the application of balanced fertilizers, with optimal doses in different phases of vegetation. Similar values, i.e., between 5.09 and 9.49%, were also obtained in other studies [15,54,55].

Since the levels of bioactive compounds can vary by genotype [56], we considered it necessary to study the antioxidant compounds contained in the tomato fruits in the four commercial hybrids in order to analyze their beneficial attributes. Vitamin C is a major natural antioxidant in tomato fruit, which directly reacts with oxygen, thus eliminating it in a closed system. In the analyzed genotypes, the vitamin C content ranged from 20.65 to 28.03 mg 100 g⁻¹ FW. The highest value was recorded in AS 300, followed by Precos and AS 400. Addalyn presented significantly lower content than the other three genotypes. The result is comparative with that reported by Riadh et al. [57], who found vitamin C content ranging from 22.18 to 27.16 mg 100 g⁻¹ FW. Other studies also reported close content values of vitamin C in the commercial hybrids, ranging between 18.26 and 33.77 mg 100 g⁻¹ FW [52,58].

Fruit color is an important quality feature of tomatoes. The color changes during the ripening of tomatoes from light green to bright red are consistent with the breakdown of chlorophyll and the synthesis of carotenoid pigments [59]. This pigment synthesis is closely correlated with the initiation and acceleration of ripening, and the red color of the fruit results from a higher accumulation of lycopene [60]. This important compound, lycopene, is considered by researchers to be an essential carotenoid in tomato fruit (80–90%), followed by β -Carotene (5–10%) [61].

Due to climatic and growing conditions (temperature and light), the lycopene content of the tomato is prone to variations. Higher levels of lycopene were found in tomatoes grown in open fields compared to fruits growing in protected areas [62]. Thirty-nine tomato genotypes have a lycopene content ranging from 0.6 to 6.4 mg 100 g⁻¹ FW and from 0.4 to 11.7 mg 100 g⁻¹ FW in tomatoes grown in protected fields, respectively [63]. Various research studies have shown that different cultivars have varying concentrations of lycopene [62,64–66]. According to Grierson and Kader [67], tomatoes that reach physiological maturity show changes in chemical components, such as pigment (β -Carotene and lycopene), aromatic compounds, and some acids (e.g., malic and citric), components that are responsible for the development of color, aroma, and taste.

The lycopene content of fruits can fluctuate quite widely, with some studies showing values between 1.86 and 14.62 mg 100 g⁻¹ FW [68–71]. In our study, lycopene content values were between 7.4 and 15.4 mg 100 g⁻¹ FW (the highest value recorded for the AS 400 hybrid), which were quite close to the Rio Grande tomato variety, with large fruits, excellent for fresh market and processing (sauces, juices, drying, making tomato paste, etc.), which contains 9.7 mg 100 g⁻¹ FW, meanwhile other varieties ranged from 18.4 to 25.4 mg 100 g⁻¹ FW [72]. Among antioxidants, lycopene is found mainly in tomato fruits, with a percentage of over 85% of all the detected carotenoids [73]. After buying tomatoes, consumers keep them in the refrigerator until they are ready for consumption. Storage of tomatoes at temperatures below 12 °C can cause lycopene degradation. Consequently, a reduction in the supposed value of promoting health and in the external visual quality of tomatoes may occur [74]. Depending on the research, crop system, and genotype, the value of β -Carotene content of tomatoes can vary between 4.4 and 11.3 mg 100 g⁻¹ FW [75], and in organic culture, in accordance with the type of soil, location, and technology, between 0.35 and 0.64 mg 100 g⁻¹ FW [58], these values being close to those obtained in our study.

Preferences of tomato consumers can vary greatly depending on various socio-economic, psychological, educational, cultural, etc., factors [8]. Because many factors can act in this regard, differences in consumer perceptions regarding the quality of tomatoes and their sensory characteristics may differ from country to country, where the market segments may have different target compositions [76]. Comparisons between modern and

traditional commercial varieties may vary and lead to different opinions depending on the specific set of varieties used in a study [77]. Specifying the importance of the environment, genotype, and the effects of the interaction of abiotic factors on tomato fruit sensory quality [78–80], sensory variation should also be explored by repetitive tests under the influence of different growing conditions in accordance with consumer preferences and perceptions. In a previous study, Carli et al. [79] found more pronounced effects of the growth parameters on traits related to taste (salt, sourness, sweetness) than those related to the texture (juicy, granularity, hardness). Likewise, Casals et al. [80], in a study performed in the open field and a greenhouse, reported a more pronounced effect, depending on the cultivation conditions on taste-related traits (sweetness, acidity, intensity of taste), but no significant effect on the texture-related features (firmness and persistence of the skin).

Our results confirm that many quality elements contribute to the overall quality of fruits and interact with others to provide the general parameters of high-quality tomatoes. As in previous studies on sensory assessment, it has been shown that the importance to consumers is related to the general appearance of the fruit, as well as to specific ones, such as the color of fresh tomatoes [81–83], sweetness [82–84], aroma [78,81], and succulence [76,82,85]. In our study, based on the proximity and distance from the origin, a correspondence analysis offered a relevant picture of the relationships between physico-morphological and chemical attributes, as well as the descriptors used in tomato quality organoleptic assessments. Regarding the share of the participation or contribution of each sensory element of the tomatoes to the overall quality of the fruit, the correlations identified between some quality elements that could be indices of indirect selections, the hierarchical relationships identified between sensory descriptors, etc., could provide new information that is beneficial for consumer testing studies, market requirements, and new directions for tomato breeding. Tieman et al. [86], comparing modern commercial cultivars with old tomatoes, concluded that modern cultivars had lower flavor qualities compared to old varieties. Likely, the type of tomato reproduction and the inheritance of fruit taste from one's ascendants to the generative descendants are not always in favor of a better taste [87]. In previous research [8], we highlighted how important the qualitative analyses of tomatoes are for producers, users, processors, consumers, and tomato breeders. Certainly, tomato breeding involves much effort, resources, costs, time, efficiency, and pragmatic-impactful perspectives. Consequently, regarding the perspective and anticipatory nature of the market and consumer trends and preferences, the processing industry and users are key elements on which research to create new cultivars must be based, to ensure the success of tomato breeding in the future.

5. Conclusions

The success of tomato breeding projects is closely linked to adequate knowledge of the market and consumer requirements, but also of the users, processors, and the preferences and needs of growers. The hypothesis of this study was based on the creation of new commercial hybrids that could meet the needs of the consumer and market chains, regarding the overall quality of the tested genotypes.

The results obtained based on the analyzed genotypes indicate that the modern breeding of tomatoes for the commercial aspect of the fruit, the composition traits related to nutritional or bioactive properties, as well as the organoleptic parameters are heading in the right direction. The new commercial hybrids created have some characteristics of agronomic interest at a higher level than those used as controls, and the commercial and sensory qualities are not inferior. We emphasized the importance of the analyzed components and their contributions to the quality of tomatoes, the relationships between them, as well as the possible use of such information in order to obtain new varieties with superior quality and added value. The results may also be of interest in prospective breeding and are extremely important when anticipating the new requirements of fresh tomatoes and the directions of the market and consumers.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/agronomy12051232/s1>, Figure S1: Fruit set and fruit traits of the four genotypes of tomatoes: (a) AS 300; (b) AS 400; (c) Precos; (d) Addalyn; Figure S2: (a) UV absorption spectrum for ascorbic acid: $\lambda_{\max} = 246$ nm; (b) Retention time ($R_t = 3,254$); Figure S3: Calibration curves for ascorbic acid, by injecting five different concentrations of 99% purity standard substance, with $\mu\text{g/mL}$ concentration ($R^2 = 0.9947$, $p < 0.05$); Figure S4: (a) UV–Vis absorption spectrum for lycopene: $\lambda_{\max} = 448, 474, 508$ ($R_t = 12.37$); (b) UV–Vis absorption spectrum for β -Carotene: $\lambda_{\max} = 455, 480$ ($R_t = 13.52$); Figure S5: Calibration curves by injecting five different lycopene and β -Carotene concentrations: (a) $R^2 = 0.9976$ lycopene; (b) $R^2 = 0.9931$ β -Carotene; $p < 0.05$; Table S1: Descriptions of the tomato genotypes used in the study.

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