agronomy

MDPI

Article

Local Agro-Environmental Conditions Impact Fruit Quality, Sensory Properties and Consumer Acceptance of Long Shelf-Life Tomatoes

Maria Cammareri [1], Fiorella Sinesio [2], Marina Peparaio [2], Clara Pons [3], Roser Romero del Castillo [4,5], Eleonora Saggia Civitelli [2], Antonella Vitiello [1], Antonio Granell [3], Joan Casals [4,5,*] and Silvana Grandillo [1,*]

[1] Institute of Biosciences and Bioresources (IBBR), Research Division Portici, National Research Council of Italy (CNR), Via Università 133, 80055 Portici, Italy; maria.cammareri@ibbr.cnr.it (M.C.); antonella.vitiello@ibbr.cnr.it (A.V.)
[2] Research Centre for Food and Nutrition, Council for Agricultural Research and Economics (CREA), Via Ardeatina 546, 00178 Roma, Italy; fiorella.sinesio@crea.gov.it (F.S.); marina.peparaio@crea.gov.it (M.P.); eleonora.saggiacivitelli@crea.gov.it (E.S.C.)
[3] Instituto de Biología Molecular y Celular de Plantas (IBMCP), Consejo Superior de Investigaciones Científicas (CSIC), Universitat Politècnica de València, 46022 València, Spain; cpons@upvnet.upv.es (C.P.); agranell@ibmcp.upv.es (A.G.)
[4] HorPTA, Department of Agri-Food Engineering and Biotechnology, Campus Baix Llobregat, Polytechnic University of Catalonia-BarcelonaTech, Esteve Terrades, 8, 08860 Castelldefels, Spain; roser.romero.del.castillo@upc.edu
[5] Fundació Miquel Agustí, Esteve Terrades, 8, 08860 Castelldefels, Spain
* Correspondence: joan.casals-missio@upc.edu (J.C.); silvana.grandillo@ibbr.cnr.it (S.G.); Tel.: +34-935521088 (J.C.); +39-0812539489 (S.G.)

Citation: Cammareri, M.; Sinesio, F.; Peparaio, M.; Pons, C.; Romero del Castillo, R.; Saggia Civitelli, E.; Vitiello, A.; Granell, A.; Casals, J.; Grandillo, S. Local Agro-Environmental Conditions Impact Fruit Quality, Sensory Properties and Consumer Acceptance of Long Shelf-Life Tomatoes. *Agronomy* **2023**, *13*, 1265. https://doi.org/10.3390/agronomy13051265

Academic Editors: Leontina Lipan and Agustí Romero

Received: 30 March 2023
Revised: 17 April 2023
Accepted: 24 April 2023
Published: 28 April 2023

Abstract: European long shelf-life (LSL) tomato landraces can be classified into two main groups: the Italian group, including 'Piennolo' landraces, and the Spanish group, including the 'Penjar' and 'Ramellet' landraces. In this study, a partially common set of 'Piennolo' and 'Penjar-Ramellet' varieties was grown in Italy and Spain to evaluate the effect of different agro-environmental and storage conditions on fruit quality and shelf-life. Overall, both Italian and Spanish LSL genotypes lost their peculiar phenotype in terms of physicochemical properties and shelf-life behavior when not grown in their original agro-environment. To better understand the sensory attributes that drive consumers' preferences, all varieties were characterized using descriptive sensory analysis combined with hedonic tests. The evaluations were conducted postharvest on raw and processed products according to the country's culinary tradition (baked in Italy; spread on bread in Spain). Sensory description by trained panels conducted on raw and processed products highlighted different sensory profiles between the two LSL tomato groups. In the 'Piennolo' group, a reduction in sensory diversity among the genotypes was observed in the baked products compared to the raw ones, while this trend was not observed for the 'Penjar-Ramellet' group. None of the varieties fully met the consumers' preferences.

Keywords: *Solanum lycopersicum*; Piennolo; Penjar-Ramellet; physicochemical analyses; shelf-life; descriptive analysis; hedonic tests; raw product; processed product

1. Introduction

The Mediterranean basin holds a rich reservoir of phenotypic tomato (*Solanum lycopersicum* L. var. *lycopersicum*) diversity and is considered a second center of diversification for this species [1,2]. This diversity emerged as a result of the evolution of the genetic variability that was initially introduced from America, plus new mutations that occurred during the plant's long history of cultivation, shaped by the edaphoclimatic conditions found in Southern Europe and the pressure of selection impaired by the agricultural and gastronomic cultures that incorporated this new species in their fields and culinary traditions [1,3–5].

Although threatened by genetic erosion, a part of this diversity has been preserved up to current times and is still cultivated in the form of traditional varieties/landraces [6–10].

In the last 50 years, tomato landraces have been replaced by modern hybrids, characterized by higher yields, disease resistance genes and a better adaptation to commercial practices during the postharvest stage. Nonetheless, several landraces persist in local markets. The conservation of these traditional varieties is driven by cultural factors (the varieties are linked to traditional dishes) and by the existence of singular traits absent in modern varieties. Among them, flavor is usually mentioned by consumers as the key factor driving their preference for tomato landraces over modern varieties [11]. For instance, in Italy, the 'San Marzano' is a well-known landrace appreciated for its cooking properties [12], while other traditional varieties such as 'Pomodoro di Sorrento', 'A Pera Abruzzese' or 'Pomodoro di Albenga' are highly appreciated for fresh consumption [13–16]; in Spain, the 'Pera de Girona-Montserrat', 'Muchamiel' and 'Valenciano' varieties, among many others, are landraces distinguished by their sensory characteristics when consumed raw in a salad [17–19]. These sensorial differences are at the basis of landraces' cultivation and can be explained by the different phenotypic selection strategies followed by farmers for landraces and by plant breeders for modern varieties [11], with consequent negative sensory trade-offs when selecting for high-yielding [20] and disease-resistant varieties [21]. Nevertheless, driven by consumer complaints about the lack of flavor in modern tomato varieties [20,22,23], in recent years, sensory quality has become a major focus of tomato plant breeding [24]. The advances in knowledge about the sensory traits that lead to higher consumer acceptance for fresh-market tomatoes [15,25,26] and about the genetic and chemical basis of these traits [22,26–28], and their inclusion in the ideotypes, seems to have narrowed the sensory distance between modern and traditional varieties [15].

The sensory ideotypes of the different tomato horticultural groups, fresh-market (cherry, salad) and processing, have been widely discussed in the literature [24,25,29–32]; nevertheless, few reports can be found for the long shelf-life (LSL) landraces cultivated in Southern Italy and Eastern Spain. LSL varieties can be defined as a differentiated tomato group [1,33] characterized by an extended fruit shelf-life, which can exceed 5 months (non-LSL tomatoes showing an average shelf-life of 1–2 weeks), under not controlled storing conditions; a small fruit size (<80 g) with a high agro-morphological diversity across accessions; and an abnormal ripening and postharvest behavior [34–37]. European LSL varieties can be classified into two main groups according to their geographic origin: the Italian group, generically referred to as 'da Serbo' landraces, and the Spanish group, including the 'Penjar' and the 'Ramellet' landraces [1,38]. According to Blanca et al. [1], both groups seem to have evolved from independent origins. Despite these different origins, the LSL landraces were incorporated in similar farmer traditions: anciently, they were cultivated in non-irrigated fields, harvested in bunches or individually and tied in a string to be hung in the ceilings of aerated rooms, and consumed after a storage period. The names of the varieties describe this typical method of preservation; for instance 'Penjar' (Catalunya region, Spain) or 'da Appendere' (general name used in Italy) refer to the hanging of the fruits, while 'Ramellet' (Balearic Islands, Spain), and 'Piennolo' (Campania region, Italy) refer to the harvest of the fruits in bunches [33].

The LSL phenotypes of some accessions of the 'Penjar' landraces from Catalonia and Valencia [37] and the 'Ramellet' landrace from the Balearic Islands [35] have been associated with the ripening mutation *alcobaca* (*alc*) in the coding sequence of *NAC-NOR* gene [39], initially described in the 'Alcobaça' landrace (reviewed by Conesa et al. [33]). However, the *alc* mutation has not been reported in Italian LSL landraces such as 'Corbarino' and 'Lucariello' [40], suggesting that other mutations might also be involved in the LSL phenotype. In fact, recently, a multi-omics study conducted on the LSL landrace 'Lucariello' identified the *MADS-RIN* gene as a possible key player in the gene regulatory network leading to the delayed fruit softening of this traditional variety [34].

Among all the tomato groups, the LSL group displays, most probably, one of the most diverse sensory landscapes within tomato. The LSL phenotype is not linked to a specific chemotype, and a wide diversity of chemical profiles have been described in the different LSL landraces. This sensory diversity is probably linked to the multiplicity of preferences and uses that these traditional varieties have across the Mediterranean basin [33]. In addition to the diversity at harvest, LSL fruits usually go through an 'aging' period (at least 1–2 months of storage) before they are consumed, which alters the composition of the fruit [16,36,41–43]. Thus, the sensory characteristics of the LSL fruits evolve during the postharvest stage, resulting in a sensory profile marked by organoleptic attributes not perceptible in fresh tomatoes at harvest. For instance, Casals et al. [44] described that during the postharvest phase, the volatile organic composition (VOC) of the 'Penjar' landrace was altered, resulting in the appearance of new aromas that were masked at the harvest stage.

Additionally, the LSL varieties are usually not consumed raw in a salad but used to prepare different traditional dishes. In Spain, the 'Penjar' and 'Ramellet' landraces are mainly used to prepare 'bread with tomato' ('pa amb tomàquet'), while in Italy, the 'Piennolo' landraces are used to prepare numerous dishes, such as tomato sauces or as a pizza topping, and are only occasionally consumed raw with toasted bread ('bruschetta'). Accordingly, the sensory expectations of consumers for these varieties are related to the quality they bring to these preparations, rather than their sensory value when eaten raw. This link between the sensory ideotype and the culinary use was previously described by a panel of chefs that evaluated 'Penjar' tomato landraces; in comparison with modern fresh-market varieties, they found that all the 'Penjar' landraces had better quality attributes for spreading the fruits on bread or preparing tomato jam but were not interesting for other purposes [45]. Despite the increasing interest in the tomato LSL group [46], to the best of our knowledge, no studies have used sensory panels (trained or consumers) to decipher the organoleptic traits that characterize these varieties at the time of consumption (i.e., after an aging period and using the traditional preparations). Thus, the sensory diversity found behind this tomato group remains unclear, as do the quality traits driving consumer preferences.

Building on these premises, the present study aimed to evaluate the effects of different agro-environmental and postharvest storage conditions on physicochemical attributes and shelf-life of the Italian 'Piennolo' and Spanish 'Penjar-Ramellet' LSL tomato fruits.

For this purpose, a partially common set of 'Piennolo' and 'Penjar-Ramellet' varieties was grown both in Italy and Spain. Moreover, to better understand the sensory attributes that drive consumers' preferences for LSL tomatoes, the Italian 'Piennolo' varieties cultivated in Italy and the Spanish 'Penjar-Ramellet' varieties cultivated in Spain, were evaluated postharvest by trained and consumer panels as raw products, as well as processed products according to the country's culinary tradition (cooked in Italy and spread on bread in Spain), in Italy and in Spain.

2. Materials and Methods

2.1. Plant Material

A partially common set of 'Piennolo' and 'Penjar-Ramellet' varieties was grown both in Italy and in Spain (Table 1), for a total of nine varieties cultivated in each country.

In Italy, the field trial was performed in the locality of Somma Vesuviana (Naples), on the slopes of Mount Vesuvius, in the DOP area of 'Pomodorino del Piennolo del Vesuvio DOP' (hereafter referred to as 'Piennolo DOP'). The genotypes under study were cultivated during the spring–summer of 2017, in collaboration with ARCA2010 S.c.a.r.l. and a local farmer, according to the 'seccagna' (lack of irrigation) cultivation method traditionally adopted for 'Piennolo DOP'. The genotypes under study were cultivated in open field, and the transplant was performed at the beginning of April. The principal stem is traditionally cut just above the first or second inflorescence to allow an early development of two–three new productive secondary shoots. Plant height is typically kept in the range of 60–100 cm.

Table 1. List of LSL tomato varieties (Traditional and Modern/Commercial counterparts) analyzed in Italy and Spain.

Variety	TRADITOM Pedigree N.	Code	Varietal [a] Group	Origin/Seed Company	Tested in Italy	Tested in Spain
Acampora	TRPO0040	ACA	T	Campania (ITA)	√	√
Riccia San Vito	TRPO0130	RSV	T	Campania (ITA)	√	
Lucariello	TRPO0140	LUC	T	Campania (ITA)	√	√
Patanara	TRPO0160	PAT	T	Campania (ITA)	√	√
Gran Borghese	TRMC0470	GBO	M (OP)	Four Sementi (ITA)	√	√
Ramellet	TRBA1140	RAM	T	Balearic Islands (SP)	√	√
Penjar	TRCA0860	PEN1	T	Catalonia (SP)		√
Penjar	TRCA1060	PEN2	T	Catalonia (SP)	√	
De colgar	TRVA0030	DEC	T	Valencia (SP)	√	√
Palamós de Penjar	TRMC0540	PdP	M (Hyb)	Semillas Fitó (SP)	√	√
545	N/A	545	M (Hyb)	Semillas Fitó (SP)		√

[a] T = Traditional; M = Modern/Commercial; OP = open pollinated; Hyb = hybrid; ITA = Italy; SP = Spain.

In Italy, a total of nine varieties were grown, consisting of: (i) four Italian ‘Piennolo’ traditional varieties, Acampora (*ACA*), Riccia San Vito (*RSV*), Lucariello (*LUC*), Patanara (*PAT*) and their commercial counterpart Gran Borghese (*GBO*, open pollinated variety) and (ii) three Spanish ‘Penjar-Ramellet’ traditional varieties, Ramellet (*RAM*), Penjar 2 (*PEN2*) and De colgar (*DEC*) along with Palamós de Penjar (*PdP*, hybrid) as a modern counterpart (Table 1). An experimental design with 3 blocks and 63 plants per plot was used. Harvesting started at the end of June for the Italian varieties and at beginning of July for the Spanish ones.

In Spain, the field trial was performed in the locality of Palafolls (Barcelona) during the spring–summer of 2017 in collaboration with the farmers of the Conca de la Tordera co-operative. The genotypes under study were cultivated in open field, with plants conducted vertically at one stem and managed according to commercial practices of the area. Plants were fully irrigated (100% ETo) using a drip tape. Commercial fertilizers were provided via irrigation, adjusting the conductivity to about 2 dS/m, as described in Casals et al. [47].

In Spain, a total of nine genotypes were grown, consisting of: (i) three Italian ‘Piennolo’ traditional varieties, *ACA*, *LUC* and *PAT,* along with their commercial counterpart *GBO*, and (ii) three Spanish ‘Penjar-Ramellet’ traditional varieties, Ramellet (*RAM)*, Penjar 2 (*PEN2*) and De colgar (*DEC*), along with *PdP* and *545* (both ‘Penjar’ hybrids) as modern counterparts (Table 1). An experimental design with 2 blocks and 50 plants per plot was used. Harvesting was carried out in July 2017, when all the plants had ripe fruits at the third truss.

2.2. Physicochemical Analyses at Harvest

In each country, 10–14 fruits at the red ripe stage (separated in 2–3 replicates in Italy; bulked in Spain) were phenotyped individually for fruit weight (FW, in g); fruit firmness (FIRM, in D.I.), measured with non-destructive durometers, Agrosta®100 USB in Italy and Agrosta®100 Field in Spain (Agrosta, Serqueux, France); and external fruit color (expressed as CIEL*a*b* coordinates and the color indices Chroma C* and Hue Angle h°), measured using Konica Minolta Chroma Meters, CR400 in Italy and CR410 in Spain (Konica Minolta. INC, Tokyo, Japan). Fruit color parameters and fruit firmness were measured on two different positions of the equatorial region of the fruit. Soluble solids content (SSC; 6 fruits measured individually in Spain; 3 pools of 6 fruits measured in bulk in Italy) was measured using a digital refractometer ATAGO PAL-1 (Atago, Tokyo, Japan) in Italy and a handheld Brix refractometer ERMA (0–18%) (Erma, Tokyo, Japan) in Spain.

2.3. Phenotypic Characterization during Postharvest

In Italy, according to the traditional practices, the whole trusses were harvested for the Italian varieties, while for the Spanish ones, single fruits were harvested at red ripe stage. In both cases the fruits were placed in wood boxes and kept in the farmer's traditional storing facility, consisting of an aerated room without temperature and humidity conditioning. According to traditional practices, the fruits were left untouched for the first month, and then the decayed fruits were discarded. For the 'Piennolo' varieties, only the first fruits of each truss were sampled for the analyses. Due to fruit number limitations and to a very poor shelf-life, the Spanish varieties could be sampled and analyzed only at harvest (T0), with measurements taken on the 3 replicates. On the other hand, the five Italian varieties, which produced a higher number of fruits with a longer shelf-life, were sampled and analyzed at harvest (T0) and at T2 (4.5 months postharvest), the latter corresponding to the time when sensory analyses (by trained and consumer panels) were also conducted.

The trends for FW, FIRM, SSC and external fruit color were monitored at T0 and T2, as previously reported. In addition, at T2, titratable acidity (TA) was also measured. For this purpose, for each replicate, 6 fruits were cut longitudinally to obtain 2 halves; one half of each fruit was homogenized using a common kitchen blender Girmi FR75 (Girmi, Rimini, Italy) for 1 min. A part of the homogenate was centrifuged with a Rotina 420 R centrifuge (Hettich Zentrifugen, Tuttlingen, Germany) for 10 min at 4000 rpm, and the supernatant was used to measure TA (g citric acid/100 g) by potentiometric titration of the sample (titration to pH 8.1 with 0.1 M NaOH) using a FiveEasy pH-meter (Mettler Toledo, Columbus, OH, USA). Taste index (TI) was calculated according to Navez et al. [48] from the SS and TA values using the formula $TI = TA + (SS/(20 \times TA))$.

In Spain, single fruits were harvested at the red ripe stage, placed in plastic boxes and stored at controlled temperature (19 °C) and relative humidity (90%) up to the time of the analyses. Fruits were surveyed weekly, and decayed fruits were eliminated. In Spain, the shelf-life (expressed as the % of sound fruits) of the two LSL tomato groups could be analyzed up to 2 months, as the 'Piennolo' varieties did not last longer than that. Moreover, 15 fruits per variety were stored separately and weighted individually at harvest and after 2 months to study the fruit weight loss (in %). Due to the reduced number of sound fruit of the 'Piennolo' group cultivated in Spain, fruit weight loss at 2 months postharvest could only be measured for the 'Penjar-Ramellet' varieties. For these fruits, individual measurements of the external color were also performed to study the color evolution, as previously reported.

2.4. Descriptive Analysis

In Italy, descriptive analysis (DA) by a trained panel was conducted in November, at 4.5 (T2) months after harvest, which falls within the representative period of greater sales for the 'Piennolo'. The five 'Piennolo' varieties cultivated in Italy (*ACA*, *LUC*, *PAT*, *RSV*, *GBO*) were evaluated by a panel consisting of eight professional assessors specifically trained in the sensory evaluation of tomato [15,49]. The 'Piennolo' variety is usually consumed cooked, added to prepared dishes, and is only occasionally raw with toasted bread. For this reason, visual and olfactory descriptors were evaluated on the raw products, whereas 'odor' and 'in mouth' evaluations were performed on the baked tomatoes.

Raw tomatoes were removed from the stalk, washed with tap water, dried with a towel and served to panelists at room temperature (20 ± 2 °C) in containers coded with three-digit numbers. A whole tomato was presented; a kitchen knife was given to each judge. For evaluation of the cooked product, tomatoes were cut lengthwise into two pieces and baked in a professional multifunction combi oven (TOP 6x1/1GN GAS) (Angelo Po Grandi Cucine S.p.A., Modena, Italy) at 215 °C with 20% steam for 4 min. Participants were provided with two halves of baked tomatoes (40 ± 2 °C).

The lexicon included 21 descriptors: 7 attributes (3 appearance, 1 texture, 3 olfactory) were measured directly on the raw fruit (Table 2), while the other 14 were measured on the baked fruit (2 olfactory, 6 in mouth with the skin, and 6 in mouth after removing the skin) (Table 3). Each attribute was rated by using a continuous 0 to 9 line scale, with endpoint labels defined as shown in Tables 2 and 3. Three evaluations were performed on each variety (one for each replicate). The samples were split over two days. Seven or eight products were evaluated in each day in monadic order and best balanced among participants. All the products were tasted, under white light, at CREA-AN sensory laboratory, conforming to international standards approved for sensory analysis [50].

Table 2. Description of sensory attributes used for sensory evaluation of raw fruit in Italy (continuous 0–9 scale) and in Spain (continuous 0–10 scale).

Category	Sensory Attribute	Definition	Endpoint Labels		Italy	Spain
Appearance	Color intensity	Visual examination of the tomato placed on the peduncular side. For tomatoes with a color other than red (green, orange, yellow, pink, streaked, etc.), this criterion was not scored	light red	full red	√	√
	Shriveling	Wrinkling due to loss of moisture	not at all	completely	√	√
	Seeds	Amount of seeds in the internal locular portion	none	many	√	√
Texture	Resistance to cut	Resistance of tomato flesh to penetration with a knife	no resistance	high resistance	√	√
Olfactory	Overall odor	Overall impression perceived by receptors of the olfactory system (via ortho-nasal) after cutting	weak	strong	√	√
	Green odor	Odor resembling green vegetables, grass, stalk, leaf	weak	strong	√	√
	Ripe odor	Odor of tomato at full ripeness	weak	strong	√	√
In-mouth evaluation	Sweet taste	Basic taste produced by sugars (e.g., fructose or glucose)	weak	strong		√
	Acid taste	Basic taste produced by organic acids (e.g., citric or malic acids)	weak	strong		√
	Off-Flavor	Presence of aromatic compounds not characteristic of ripe tomato (e.g., decaying vegetation, metallic, chemical)	null	strong		√
Qualitative measure (presence/absence)						
	Pea, legume odor		yes	no	√	√
	Herbaceous odor		yes	no	√	√
	Stem (stalk, tomato leaf) odor		yes	no	√	√
	Floral odor		yes	no	√	√
	Fruity odor		yes	no	√	√
	Baked tomato (over ripe, tomato paste, tomato juice/sauce) odor		yes	no	√	√
	Undergrowth (hearty, musty, humus, mushroom) odor		yes	no	√	√
	Diacetyl-like odor		yes	no	√	√
	Other odor (to be specified)					

Table 3. Description of sensory attributes used for sensory evaluation of tomato fruit processed according to the culinary tradition of Italy (baked) (continuous 0–9 scale) and flavor notes.

Category	Sensory Attribute	Definition	Endpoint Labels	
Olfactory	Overall odor	Intensity of the overall olfactory impression perceived via ortho-nasal	weak	strong
	Baked tomato odor	Ortho-nasal olfactory intensity sensation of baked tomato	weak	strong
In-mouth evaluation				
with the skin	Sweet taste	Basic taste sensation caused by sugars (e.g., sucrose)	weak	strong
	Bitter taste	Basic taste caused by bitter substances (e.g., quinine)	weak	strong
	Overall flavor	Intensity of overall olfactory sensations perceived retro-nasally while chewing	weak	strong
	Baked tomato flavor	Retro-nasal olfactory sensation of baked tomato	weak	strong
	Hardness	Tactile characteristic of hard and thick skin perceived through mechanical and tactile receptors	tender	hard
	Bitter persistence (after swallowing) [a,b]	Basic taste persisting in the mouth after the substance that caused it is no longer present [a,b]	brief	long-lasting
after removing the skin	Sweet taste	Basic taste sensation caused by sugars (e.g., sucrose)	weak	strong
	Salty taste	Basic taste sensation caused by inorganic salts (e.g., sodium chloride)	weak	strong
	Acid taste	Basic taste sensation caused by acid substances (e.g., citric acid)	weak	strong
	Bitter taste	Basic taste caused by bitter substances (e.g., quinine)	weak	strong
	Overall flavor	Intensity of the overall olfactory impression perceived via retro-nasal	weak	strong
	Baked tomato flavor [c,d]	Retro-nasal olfactory sensation of baked tomato	weak	strong

Qualitative measure (presence/absence). [a] Skin-astringency: yes, no. [b] Skin-metallic: yes, no. [c] Pea, legume: yes, no. [d] Green, unripe (unripe fruit, grass, cut grass): yes, no.

In addition to the quantitative evaluations, in Italy, the olfactory impression on the raw products was also explained by 8 comments that the panel could check as either 'yes or no': pea/legume, herbaceous, stem (stalk, tomato leaf), floral, fruity, baked tomato (over ripe, tomato paste, tomato juice/sauce), undergrowth (hearty, musty, humus, mushroom) and diacetyl-like. The panel experts were allowed to give other perceptions, which they had to specify. Flavor impression of the baked products was explained by 2 comments: pea/legume and green/unripe (unripe fruit, grass, cut grass). Moreover, the panelists were asked to specify if they could perceive other flavor notes not included in the list.

In Spain, sensory analyses by the trained panel were conducted at three months (T2) after harvest. Previous studies determined this as the maximum storage period starting from which important sensory attributes are lost in the 'Penjar' tomato [44]. The five 'Penjar-Ramellet' varieties cultivated in Spain (*DEC*, *PEN1*, *RAM*, *PdP*, *545*) were evaluated by a panel composed of seven panelists, specifically trained in the sensory evaluation of tomato [15,17].

'Penjar' and 'Ramellet' tomatoes are mainly used to prepare 'bread with tomato' (fruit is cut in 2 halves and rubbed on bread). For this reason, and to obtain a complete evaluation of the sensory profile, visual, olfactory and taste attributes were measured on the raw fruits (Table 2) and on the culinary preparation ('bread with tomato') (Table 4). Organoleptic traits describing the fruit quality for preparing 'bread with tomato' were added in the sensorial descriptions (i.e., 'spreadability', 'seed presence on bread') (Table 4).

Table 4. Description of sensory attributes used for sensory evaluation of tomato fruit processed according to the culinary tradition of Spain (spread on bread) (continuous 0–10 scale).

Category	Sensory Attribute	Definition	Endpoint Labels	
Olfactory	Overall odor	Intensity of the overall olfactory impression perceived via ortho-nasal	weak	strong
In-mouth evaluation	Sweet taste (on bread)	Basic taste produced by sugars (e.g., fructose or glucose)	weak	strong
	Acid taste (on bread)	Basic taste produced by organic acids (e.g., citric or malic acids)	weak	strong
Dish preparation	Spreadability (on bread)	Amount of bread (surface) that can be rubbed by one half of the fruit	low	high
	Seeds (on bread)	Visual impression of the presence of seeds on the bread	none	many
	Color intensity (on bread)	Visual impression of the intensity of red color of the bread	light red	full red
	Overall flavor	Intensity of the overall olfactory impression perceived via retro-nasal	weak	strong

For the evaluation of the raw tomatoes, a procedure similar the one described for the Italian trial was used, and whole fruits were also served in this case. To evaluate the quality of the different varieties for preparing 'bread with tomato', each panelist was served with a knife and a slice of bread, following the methodology previously described by Romero del Castillo et al. [45]. Panelists were asked to cut the fruit equatorially and then to rub the fruit halves onto the bread and score the 'spreadability'.

Each sample was evaluated twice, using 17 sensory attributes: 10 attributes were measured directly on the raw fruit (Table 2), and the other 7 attributes were measured on the culinary preparation ('spread on bread') (Table 4). Each attribute was rated using a continuous 0 to 10 scale, with endpoint labels defined as shown in Tables 2 and 4. Genotypes and their repetitions were distributed randomly in different sessions, comprising a maximum of five samples per session. Each panelist received a whole fruit to conduct the sensory test in a monadic sequence. Sensory sessions were carried out in a room designed for sensory analyses, under white light, conforming to international standards approved for sensory analysis [50]. Sensory sessions were held in October 2017 at the laboratories of the Barcelona School of Agricultural Engineering.

In addition to the quantitative evaluations, also in Spain, the olfactory impression on the raw products was explained by 8 comments that the panel could answer with 'yes or no' (Table 2).

2.5. Consumer Tests

In parallel to the DA, hedonic tests were conducted in one large city per country: Naples (at T2, 4.5 months postharvest) and Barcelona (at T2, 3 months postharvest).

The Italian consumers tasted the five 'Piennolo' varieties cultivated in Italy (ACA, LUC, PAT, RSV, GBO) and evaluated by the Italian trained panel, while the Spanish consumers tasted the five 'Penjar-Ramellet' varieties cultivated in Spain (*DEC*, *PEN1*, *RAM*, *PdP*, *545*) and evaluated by the Spanish trained panel. In both countries, consumers' recruitment criteria were the following: (i) consumption of the target product (at least once a month) and (ii) interest and willingness to participate. On the other hand, working in the food and drinks industry and suffering from eating disorders, food allergy or intolerance were exclusion criteria. At the screening stage, information on consumers' socio-demographic data including education, responsibility in shopping and tomato consumption frequency, were also collected.

In Italy, hedonic tests were performed in November 2017 with a panel of 103 consumers, balanced for gender (49.5/50.5% F and M), recruited by a service provider in Naples. The distribution in the age classes was the following: 18–24 years: 15.5%; 25–34 years: 16.5%; 35–49 years: 34%; 50–64 years: 34%. Central Location Testing (CLT) was conducted, under white lighting, in a standard sensory lab designed for sensory analyses, according to ISO 8589 [50]. Groups of 9–10 people took part in one 40 min session during which they evaluated the 5 Italian tomato varieties, first as raw and then as baked. Mineral water with low saline content was served in between the samples to neutralize the palate. The same protocol as the one described for descriptive analysis was used for products preparation. The only difference concerned the cooking method, which, for practical reasons, was conducted in a microwave oven (NN-GD38HSSUG, Panasomic, Kadoma, Japan) at 900 W for 4 min (500 g of product). The two cooking procedures were preliminarily compared to ensure that no differences were induced due to the cooking method. The questionnaire comprised four hedonic judgments: 'aspect liking' and 'odor liking' (raw products), 'flavor liking' (baked products) and 'overall liking' (raw and baked products). A 9-point hedonic scale with three labelled categories was used: 1 = Dislike Extremely; 5 = Neither Like nor Dislike; 9 = Like Extremely. Consumers were also asked to answer a consumption habits questionnaire. The products were served in sequential monadic presentation and the order of testing was balanced (Williams Latin square). No dummy sample was served as a first product.

In Spain, the consumer test was held in October 2017 at the facilities of the Barcelona School of Agricultural Engineering (Polytechnic University of Catalonia). The test was carried out in a room designed for sensory analyses, according to ISO 8589 [50]. A total of 94 consumers performed the test, but in the end, 91 were considered valid for completeness of answers. Consumers were recruited by the sensory lab of the Barcelona School of Agricultural Engineering. Groups of 12 people took part in one 40 min session during which they evaluated the 5 Spanish tomato varieties, first as raw product and then as 'bread with tomato'. Mineral water with low saline content was served in between the samples to neutralize the palate. The same product preparation protocol as the one described for descriptive analysis was used. The questionnaire comprised four hedonic judgements: 'aspect liking' and 'odor liking' (raw products), 'overall-liking spreadability' (i.e., acceptance in the process of rubbing the tomato on the bread), and 'overall liking' (spread on bread). A 9-point hedonic scale with three labelled categories was used: 1 = Dislike Extremely; 5 = Neither Like nor Dislike; 9 = Like Extremely.

The samples were presented in a random monadic sequence. Socio-economic data of the consumers show that participants had an equitable distribution between genders (41.6% male, 57% female, 1.4% not declared). Nevertheless, some categories were overrepresented in the population, such as young ages (18–24 years: 42%; 25–34 years: 15%; 35–49 years: 15%; 50–64 years: 20%; >65 years: 8%) or high education levels (high school: 48%; upper secondary school: 35%).

All subjects recruited in Italy and Spain gave their informed consent to participate in the study, which was approved by the CNR Research Ethics and Integrity Committee (IRB, Prot. N. 0070284/2021). Personal data were protected by anonymization according to National Data Protection Regulations.

2.6. Statistical Analyses

At harvest (T0), to study the phenotypic differences between the LSL varieties originating from the two countries, the Italian accessions (*GBO*, *ACA*, *LUC*, *PAT*, *RSV*) were referred to as the 'Piennolo' group and the Spanish ones (*PdP*, *RAM*, *PEN1*, *PEN2*, and *DEC*) were referred to as the 'Penjar-Ramellet' group. The phenotypic differences between genotypes and growing sites were studied by means of a mixed lineal model, considering the genotype × growing site as the whole fixed factor, and the genotypes as the within-unit random factor (lme4 R package [51]). Mean separation was performed with the Tukey's honestly significant difference (HSD) post hoc test ($p < 0.05$). Subsequently, the effect of the growing site, Italy (ITA) or Spain (SP), on each individual genotype was assessed by using the Mann–Whitney–Wilcoxon pairwise test. Median of treatments and the deviation of individual values from the mean were plotted using boxplots with the 'ggplot' R package [52].

The effect of storage on fruit quality traits was recorded separately in each country: in Italy, the study was performed for the 'Piennolo' accessions (Piennolo_ITA) and in Spain for the 'Penjar-Ramellet' ones (Penjar_SP). Accordingly, data were analyzed separately for each country. General trends for each LSL group were studied between the data recorded at harvest (T0) and at the time of sensory analyses (T2 = 4.5 months in Italy, 3 months in Spain) using a linear ANOVA model considering the postharvest times as a fixed factor and the genotype as the random factor. To dig into genotype-by-postharvest interactions, we further analyzed the differences between T0 and T2 postharvest times separately for each genotype, using a one-way ANOVA. Finally, for the shelf-life trait recorded in the 'Penjar-Ramellet' and 'Piennolo' varieties grown in Spain, differences among genotypes were compared using a one-way ANOVA with the genotype as a fixed factor. Mean separation was performed using the Tukey's test.

Sensory, consumer and physicochemical data, collected at 4.5 (T2) months postharvest in Italy and at 3 (T2) months in Spain, were analyzed using the XLStat (ver. 19.4; Addinsoft, New York, NY, USA) software package. Significance of differences ($p < 0.05$) was determined using ANOVA and Tukey's test on quantitative variables and Kruskal–Wallis and multiple pairwise comparisons using Dunn's procedure (two-tailed test) on categorical variables. Principal Component Analysis (PCA) was used to model product differences between the overall of physicochemical, descriptive sensory and hedonic data in Italy and between descriptive sensory and hedonic data in Spain. Consumers' liking scores were analyzed with ANOVA and Fisher's (LSD) post hoc test ($p < 0.05$).

3. Results

3.1. Characterization of LSL Tomato Varieties at Harvest

Regarding the evaluations conducted at harvest, the effect of the agro-environment was significant for both LSL groups ('Piennolo' and 'Penjar-Ramellet') and for all the traits measured (except for the b* color coordinate) (Figure 1).

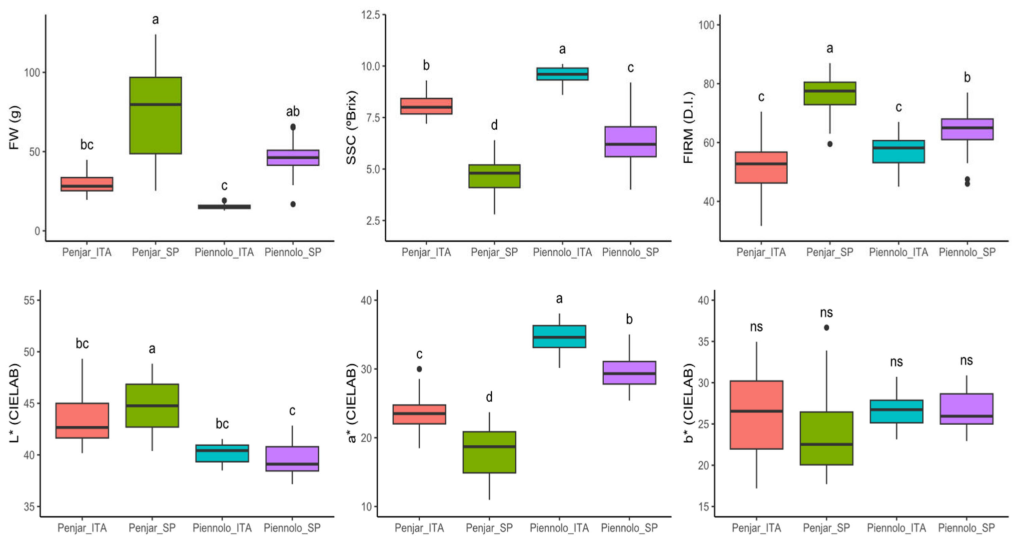

Figure 1. Fruit weight (FW), soluble solids content (SSC), firmness (FIRM) and fruit external color CIELAB coordinates (L*, a*, b*) of the 'Penjar-Ramellet' and 'Piennolo' varieties grown under low input and no irrigation in Italy (ITA) and high input and full irrigation in Spain (SP) (see Table 1), evaluated at harvest (T0). For each variable, different letters indicate significant differences (Tukey's test, $p < 0.05$; ns, not significant).

When grown under their original conditions (ITA, low input and no irrigation), the 'Piennolo' accessions were characterized by significantly lower FW (14–16 g), higher SSC (9–10 °Brix), lower FIRM (55–60% D.I.) and more intense redness (a*, 32–37) than when they were grown in Spain (SP) under high input and full irrigation (Figure 1). Similarly, significant differences were found with the 'Penjar-Remellet' accessions, which showed higher FW (67–110 g), lower SSC (3.2–5.2 °Brix), higher FIRM (74–80% D.I.), higher lightness (L*, 43–46) and lower redness (a*, 16–21) when grown in SP under their original management practices than when they were grown in ITA. Thus, phenotypically, both groups were clearly different when grown under their original agro-environmental conditions. These differences were confirmed when the genotypes were analyzed individually (Figure S1). The specific agro-environment of the ITA field, which included lack of irrigation and low-input conditions, determined in both LSL groups a significant increase in SSC and redness (a*) and a decrease in FW and FIRM, while lightness (L*) was solely affected in the 'Penjar-Ramellet' group (Figure 1).

3.2. Shelf-Life and Effect of Postharvest on Fruit Quality Traits

The strong impact of the typical agro-environment of each country trial on the postharvest behavior of the various genotypes has led to a reduced shelf-life of the Spanish genotypes bred in Italy and vice versa. Specifically, in the Italian trial, the 'Penjar-Ramellet' varieties showed a very poor shelf-life, which prevented postharvest evaluations of these genotypes. A similar trend was observed for the Spanish trial, where, after 2 months of storage, the 'Piennolo' varieties showed a significantly lower shelf-life (<25%) than the 'Penjar-Ramellet' varieties, which reached a shelf-life higher than 55% (Figure 2). In addition, fruit weight loss recorded on the 'Penjar-Ramellet' varieties during storage ranged between 6.0 (*RAM*) and 8.4% (*PdP*), with significant differences observed between genotypes (Figure S2).

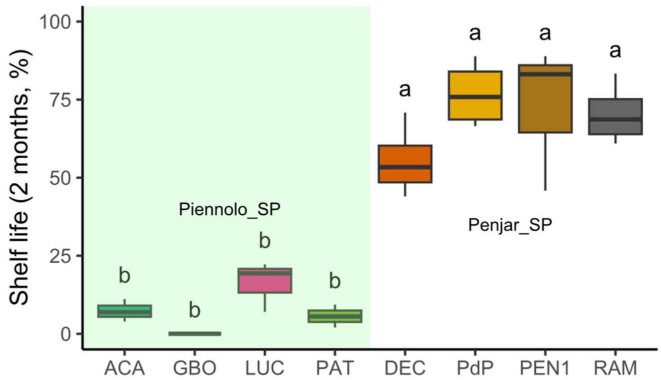

Figure 2. Shelf-life (% sound fruits left) at 2 months postharvest of the 'Piennolo' and 'Penjar-Ramellet' varieties grown in Spain. Variety codes are listed in Table 1. Different letters indicate significant differences at $p < 0.05$ (Tukey's HSD test).

With respect to the phenotypic traits recorded at T0 and T2 (4.5 months postharvest) on the five 'Piennolo' varieties cultivated in Italy, a clear mean reduction in FIRM (56%), SSC (22%) and FW (13%) was reported during storage (Figure S3). Furthermore, overall, significant increases were observed for the external fruit color coordinates L* and b*, while a* significantly decreased (Figure 3). For a*, the trend was confirmed for all genotypes, while for b*, it was observed for three of the five accessions, and for L*, only *PAT* showed a significant increase (Figure S4). In Spain, overall, the pattern of color evolution recorded on the four 'Penjar-Ramellet' varieties showed a significant difference only for the a* coordinate, which increased between T0 and T2 (3 months postharvest) (Figure 3). This trend was confirmed for all genotypes, except for *PEN1*, which showed a significant increase in the b* coordinate (Figure S4).

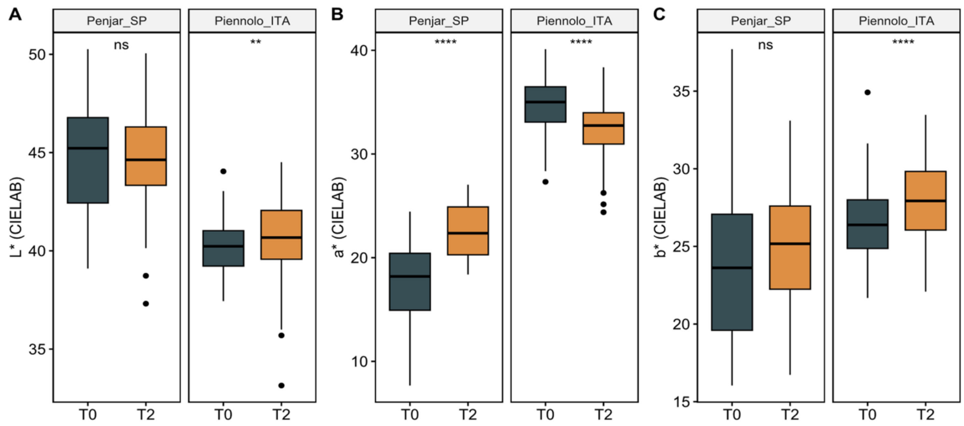

Figure 3. Evolution of the fruit external color CIELAB coordinates L*(**A**), a* (**B**), b*(**C**) from harvest (T0) to the time sensory analyses were conducted in each country (T2 = 4.5 months in Italy, 3 months in Spain). Penjar_SP: 'Penjar-Ramellet' varieties grown in Spain; Piennolo_ITA: 'Piennolo' varieties grown in Italy. Comparisons between T0 and T2 were assessed using the Mann–Whitney–Wilcoxon (MWW) pairwise test. Significance levels: ** $p < 0.01$, **** $p < 0.0001$; ns, not significant.

3.3. Sensory Quality and Consumer Preferences in Postharvest

To better understand the sensory attributes that drive consumers' preferences for LSL varieties postharvest, the Italian and Spanish genotypes were characterized by an objective description of sensory properties and by a hedonic test. After a postharvest storage period, each variety was evaluated raw and as processed products according to the country's culinary tradition (cooked in Italy and 'spread on bread' in Spain).

3.3.1. Italian Evaluation

In Italy, four 'Piennolo' landraces (*ACA*, *LUC*, *PAT*, *RSV*) and their commercial counterpart *(GBO)* were evaluated at 4.5 (T2) months after harvest, which falls within the representative period of higher sales for these LSL tomatoes.

ANOVA was performed on descriptive analysis data using sample, replicate and their interaction as variation factors. The analyses conducted on the raw products highlighted statistically significant differences among the varieties for the sensory descriptors 'color intensity', 'shriveling', 'seeds', 'resistance to cut', 'green odor' and 'ripe tomato'. A significant replicate effect was found for 'shriveling' and 'ripe odor' (Table S1). With respect to baked tomatoes, a significant variety effect was observed only for 'skin–bitter persistence', which was scored higher in *GBO* (3.4) compared to the four 'Piennolo' landraces. In addition, a significant replicate effect was observed for 'skin-sweet', 'skin-bitter', 'skin-bitter persistence' and 'bitter taste' (Table S1).

The tomato products (raw and baked) were also characterized for olfactory and flavor notes. Occurrences of these sensory notes, expressed as percent frequencies, are illustrated in Table S2. For the raw products, 'herbaceous' and 'stem' odors were the most represented olfactory notes, which were confirmed in all varieties with a frequency higher than 72.7% and 40%, respectively. Statistically significant differences were observed only for the 'green-unripe flavor' note checked on baked tomato products; the frequency of this flavor note was significantly higher for *PAT* than for all other varieties.

As regards the physicochemical parameters, measured on the raw products at T2, a highly significant variety effect was observed for all parameters except for FW (Table S3). In addition, ANOVA showed a significant replicate effect on five traits: TA, pH, SSC, SSC/TA and TI.

The three sets of quantitative data (physicochemical, descriptive sensory and hedonic) obtained for the raw and baked 'Piennolo' products and samples were modelled in a PCA (Figure 4). The first (PC1) and second (PC2) principal components of the PCA accounted for 44.22% and 26.96% of the total variation in the data, respectively.

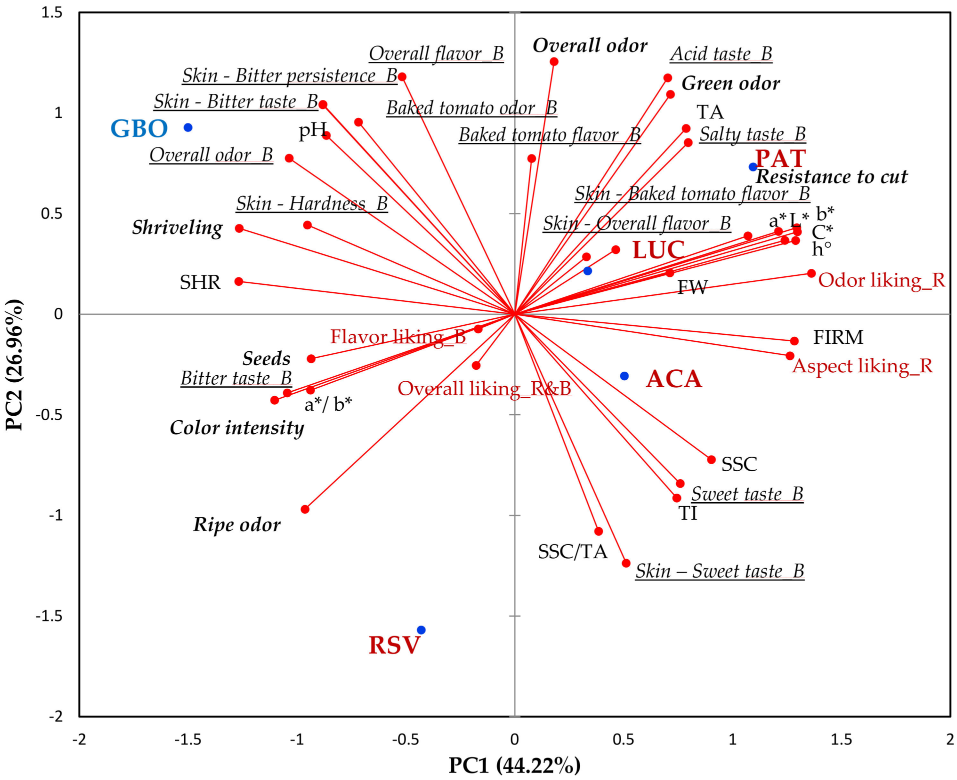

Figure 4. Principal component analysis (PCA) Bi-plot of the physicochemical, sensory and consumers' liking data of the raw and baked products of the five 'Piennolo' varieties tested in Italy (*ACA*, *LUC*, *PAT*, *RSV*, *GBO*). Sensory descriptors evaluated on the raw products are indicated in bold italics; sensory descriptors evaluated on the baked products are indicated in underlined italics and with a _B; consumers' hedonic judgments are indicated in red (_R = raw; _B = baked). Traditional varieties are shown in red, while the commercial counterpart is indicated in blue. Physicochemical parameters evaluated on raw products: FW = fruit weight, FIRM = firmness; CIEL*a*b* coordinates (L*, a*, b*) and the color indices (C* and h°); SSC = soluble solids content, TA = titratable acidity, SHR = shriveling, TI = taste index. Variety codes are listed in Table 1.

The PC1 was positively correlated mainly with FIRM, the five external color parameters (L*, a*, b*, h° and C*), 'resistance to cut', 'aspect liking_R' and 'odor liking_R'. These attributes and hedonic judgments were opposed by the physicochemical parameters SHR and a*/b* and by the sensory attributes 'shriveling', 'color intensity', 'seeds' and 'ripe odor', all evaluated on raw products. In addition, the PC1 also correlated negatively with descriptors evaluated on the baked products with ('skin-hardness' and 'skin-bitter taste') and without the skin ('overall odor' and 'bitter taste').

The PC2 was positively associated mainly with 'overall odor', 'green odor', TA and pH when evaluated on the raw products and with numerous sensory attributes evaluated on baked products, including 'overall flavor', 'acid taste', 'skin-bitter persistence', 'skin-bitter taste' and 'baked tomato odor'. The variables that contributed the most to the variance explained by the negative semi-axis of PC2 were: 'skin-sweet taste', SSC/TA, 'ripe odor' and taste index (TI). The projection of the five Italian 'Piennolo'genotypes in the PCA plot revealed a clear separation of the three landraces *PAT*, *LUC* and *ACA*, showing higher positive coordinates along the PC1, from the landrace *RSV* and the commercial counterpart *GBO*. In addition, there is also a separation of *RSV*, and to a minor extent of *ACA*, on the negative semi-axis of PC2 from the other genotypes, particularly from *GBO*.

For the four consumers' liking judgments, the average scores of the tomato products (raw and baked) ranged between 5.1 and 6.1, showing that no product was rejected (Table S4). However, the ANOVA results revealed small significant differences in appreciation only for 'aspect liking' evaluated on the raw tomato products, with consumers preferring the traditional varieties *ACA* and *PAT* compared to the commercial counterpart *GBO* (Table S4).

The analysis of the impact of socio-demographic factors on hedonic judgments showed a significant ($p < 0.05$) influence of gender and education level on 'aspect liking', 'flavor liking' and 'overall liking', with higher scores observed for males in all cases. Age significantly influenced only 'flavor liking' of the baked products, and the genotypes tested were appreciated more by elderly consumers (5.8) than by the young ones (4.9) (Table S5). In addition, socio-professional status had a significant ($p < 0.05$) effect on all liking judgments, with the highest scores recorded for the 'retired' consumers. Finally, the consumption frequency had a significant effect on 'aspect', 'odor' and 'overall liking'.

3.3.2. Spanish Evaluation

In Spain, the five Spanish 'Penjar-Ramellet' varieties, three landraces (*DEC*, *PEN1*, *RAM*) and two modern counterparts (*PdP* and *545*), were tested at T2 (3 months) after harvest, both as raw and processed ('spread on bread') products.

ANOVA conducted on descriptive analysis data revealed significant differences among varieties for 5 of the 10 sensory attributes evaluated on raw tomatoes: 'color intensity', 'shriveling', 'overall odor', 'acid taste' and 'off-flavor' (Table S6). On the other hand, for the processed products (tomatoes spread on bread), statistically significant differences were found for the sensory attributes 'spreadability', 'seeds' and 'color intensity' (Table S6). The landrace *PEN1* showed a different sensory profile, with the highest values for 'overall odor' and the lowest values for 'color intensity' and 'shriveling'. In addition, this genotype had good scores when spread on bread, showing an intermediate 'spreadability', low 'seeds' and high 'sweet taste'. No significant session effect was found either for the raw or the processed tomatoes (Table S6).

The characterization by the Spanish trained panel of olfactory impression on raw tomatoes of the 'Penjar-Ramellet' group identified 'fruity', 'floral', 'stem' and 'undergrowth' as the most cited odor notes, with higher frequencies obtained for 'fruity odor' (>40%) (Table S7). The Kruskal–Wallis test did not reveal any significant difference between accessions; however, it is worth noting that the 'baked tomato odor' was perceived only in the modern variety *PdP*.

A PCA was conducted to map sample data, descriptive sensory data and consumer data obtained for the five 'Penjar-Ramellet' varieties (Figure 5).

The results show that the first two PCs accounted for 71.33% of the total variation in the data, with PC1 and PC2 representing 48.37% and 22.96% of the variance, respectively. The PC1 was positively correlated mainly with 'color intensity' of both raw and bread spread with tomato, 'seeds', 'seeds_on bread', 'aspect liking' and 'overall liking-spreadability' related to ease of making bread with tomato. Whereas the negative semiaxis of PC1 was mainly associated with the sensory descriptors 'sweet taste', 'ripe odor', 'overall odor' and 'acid taste', all evaluated on raw products. The second axis (PC2) was positively correlated with 'odor liking' (raw product) and negatively with 'overall odor' and 'green odor'. The projection of the five genotypes in the PCA plot showed a separation between *545* and *RAM*, positioned on the positive semi-axis of PC1, and the three genotypes *PdP*, *DEC* and *PEN1*.

Different liking judgments were scored by the consumers on raw ('aspect liking' and 'odor liking') and processed ('spread on bread') products ('overall liking-spreadability' and 'overall liking'). Analysis of variance revealed that highly ($p \leq 0.001$) significant differences in appreciation among the products were detected for 'aspect liking', 'overall liking-spreadability' and 'overall liking_on bread'; additionally, significant ($p < 0.05$) differences were found also for 'odor liking'. Specifically, the variety *545* and the landrace *DEC* were the most appreciated for 'aspect liking'; however, while *DEC* was also appreciated in terms of 'overall liking (on bread)', 545 showed the lowest value for this liking judgment (Table S8).

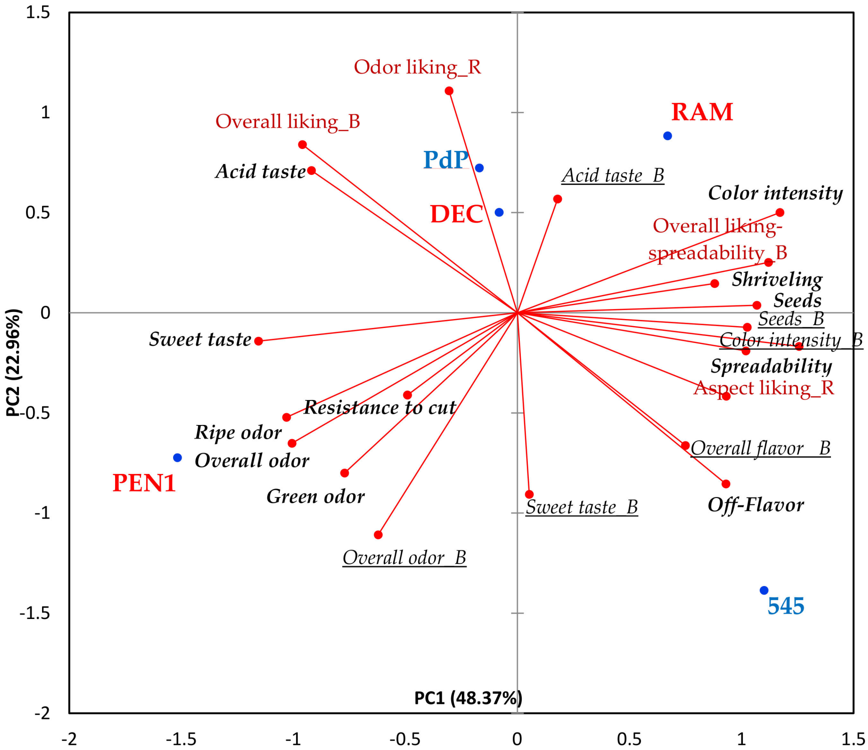

Figure 5. Principal component analysis (PCA) Bi-plot of sensory attributes and consumers liking data of the raw and processed products of the five 'Penjar-Ramellet' varieties tested in Spain (*DEC*, *PEN1*, *RAM*, *PdP*, *545*). Sensory descriptors evaluated on the raw products are indicated in bold *italics;* sensory descriptors evaluated on bread are indicated in *italics* underlined and with a_B; consumers' hedonic judgments are indicated in red (_R = raw; _B = on bread). Traditional varieties are indicated in red, while modern varieties are indicated in blue. Variety codes are listed in Table 1.

The analysis of the impact of socio-demographic factors on hedonic judgments showed a highly significant ($p < 0.001$) effect of gender on all liking judgments, with higher scores observed for males in all cases. In addition, socio-professional status showed a significant ($p < 0.05$) influence on 'overall liking-spreadability' (Table S9).

4. Discussion

European LSL landraces represent a singular horticultural group within the diversity of cultivated tomato. Spain (e.g., 'Penjar', 'Ramellet', 'de Colgar') and Italy (e.g., 'Piennolo', 'da Serbo', 'da Appendere,' 'd'Inverno') are the most important areas where these landraces are grown [33]. Italian and Spanish LSL landraces share common postharvest behaviors and consumption habits which generally involve the use of the fruit after a long storage period (2–6 months postharvest) and as an ingredient in different culinary preparations rather than as raw products. Despite these common properties, phenotypic [2] and genomic analyses [1,38] have revealed a clear distinction between these two tomato LSL groups. The uniqueness of each group is determined not only by genotypic characteristics but, above all, by the interaction of the genotypes with very peculiar local growing and consumption conditions. In fact, these LSL tomato groups have been selected for their adaptation to the local environmental conditions, for low-input cropping and for their use [16,53].

In this study, the effects of different agro-environmental and postharvest storage conditions on fruit quality attributes of Italian 'Piennolo' and Spanish 'Penjar-Ramellet' LSL tomato accessions have been evaluated at harvest and postharvest. Specifically, a subset of five Italian 'Piennolo' (four landraces and one commercial counterpart) and six Spanish 'Penjar-Ramellet' (four landraces, two modern varieties) genotypes were studied. The results obtained at harvest indicate that despite all being classified as LSL tomatoes, the

'Piennolo' and 'Penjar-Ramellet' groups showed clearly distinct fruit phenotypes. Furthermore, the 'Piennolo' group grown in Italy was characterized by a significantly lower FW (with very low variability among genotypes), higher SSC, lower FIRM and higher redness than when it was grown in Spain. On the other hand, the 'Penjar-Ramellet' group cultivated in Spain was characterized by significantly higher FW (with high variability among genotypes), lower SSC, higher FIRM and lower redness than when it was cultivated in Italy. These results are in accordance with those reported by Pons et al. [2] and Conesa et al. [33]; however, in the present study, the phenotypes of the two LSL groups were compared when grown under the original agro-environments, a condition which might have accentuated the differences.

Our results have shown that the agro-environmental conditions traditionally adopted for the 'Piennolo' variety, which also include a "seccagna" (lack of irrigation) cultivation method, significantly increased SSC and redness while reducing FW and FIRM in both the 'Penjar-Ramellet' and 'Piennolo' groups. These effects of water deficit on fruit quality traits have been widely reported in the literature for the LSL tomato group [36,54–56] and are similar to those described for tomatoes in general [24]. Taken together, our data show that the 'Piennolo' and 'Penjar-Ramellet' accessions analyzed in this study lost their peculiar phenotype when not cultivated in their original agro-environmental conditions.

The present study also revealed that the agro-environmental factors of each locality (Spain and Italy) impact the postharvest behavior of both 'Piennolo' and 'Penjar-Ramellet' groups. In fact, in Spain, the 'Piennolo' group did not express the long shelf-life trait, while in Italy, this trend was observed for the 'Penjar-Ramellet' group. This indicates that the long shelf-life of each LSL group has been selected and optimized under the original agro-environmental conditions, which may include both abiotic and biotic factors, and points to the effect of those conditions on the LSL trait. Previous works aiming to decipher the impact of preharvest factors on the LSL phenotype have revealed a positive impact of water deficit [57] and low-input conditions [47] on the shelf-life of Spanish LSL landraces. Of note, and as also highlighted in the present study, these effects are genotype-dependent, which has limited the advancements in deciphering the preharvest factors that drive a long storage in the tomato LSL group.

Regarding the evolution of fruit color during the postharvest period, the 'Piennolo' (grown in Italy) and 'Penjar-Ramellet' (grown in Spain) groups showed a different pattern, the most important being the increase and the decrease in redness for the 'Penjar-Ramellet' and the 'Piennolo' groups, respectively. Moreover, a reduction in SSC, FIRM and FW was observed during postharvest in the 'Piennolo' group; this trend was also previously described in 'Penjar' landraces [36,41].

In the past, tomato breeding has been focused on yield and resistance to biotic and abiotic stresses, neglecting the fruits' sensory quality [11]. Consumer dissatisfaction with the flavor of modern tomato varieties has made sensory quality become another important goal of tomato breeding. Along these lines, in recent decades, several studies have outlined the main drivers of tomato liking for fresh-market tomatoes [15,25,26,49,58]. However, the identification of the sensory traits that determine consumer acceptance has not been addressed in the LSL tomato group, a fact that limits the drawing of ideotypes for breeding programs and the design of cultivation systems that maximize the quality of the fruits that are marketed.

To the best of our knowledge, the present work constitutes the first sensory description conducted postharvest of the Italian 'Piennolo' and Spanish 'Penjar-Ramellet' LSL tomato groups using both trained and consumer panels. Our results refer to the sensory profiles and consumer preferences obtained postharvest for the 'Piennolo' group, cultivated and evaluated in Italy, and the 'Penjar-Ramellet' group, cultivated and evaluated in Spain. The data show that apart from the different fruit physicochemical characteristics, the 'Piennolo' and 'Penjar-Ramellet' groups also present different sensory profiles. In fact, when the 'Piennolo' genotypes were evaluated raw, all the descriptors, except for 'ripe odor', were characterized by intermediate to high scores. In contrast, the 'Penjar-Ramellet' group was characterized by low scores for the descriptors 'overall odor' and 'green odor', as well as for 'sweet taste' and 'acid taste'. The latter two, however, were not evaluated in the raw products of the 'Piennolo' genotypes, which are generally not eaten raw. Moreover, for the 'Penjar-Ramellet' group, a wide sensory variation was perceived by the panel for 'color intensity', 'shriveling' and 'off-flavor', and overall, this LSL group showed a weak flavor.

With regard to the evaluations of the culinary preparations, for the 'Piennolo' group, a reduction in sensory diversity among the genotypes was observed for the baked tomatoes compared to the raw products; in fact, for the baked tomatoes, only 1 ('bitter persistence of skin') out of 14 descriptors showed a statistically significant difference. In contrast, in the 'Penjar-Ramellet' group, the raw products and the culinary preparations (bread with tomato) were both characterized by sensory diversity. Therefore, cooking might have flattened the sensory differences among the 'Piennolo' accessions. In line with these results, Hongsoongnern et al. [59] found that after a higher degree of tomato processing, the differences in flavor due to the genotypic effect became minimal.

In addition, 'Piennolo' baked tomatoes were characterized by intermediate 'baked tomato' odors and flavors, low taste intensity ('sweet', 'acid', 'bitter' and 'salty') and intense 'overall flavor'. The skin was highly perceived in this culinary preparation (high 'hardness') and it seems to have an important contribution to the 'overall flavor'. For the bread with tomato of the 'Penjar-Ramellet' group, a wide range of variation for 'color intensity' and 'seeds' was observed. For the other sensory traits, there was much less diversity, and the bread with tomato products were characterized by low 'sweet taste' and 'acid taste'. Moreover, most of the 'Penjar-Ramellet' genotypes showed a high 'spreadability'; this sensory characteristic can be related to the singular evolution of fruit firmness and turgidity in this LSL group, caused by the downregulation of most of the cell wall-modifying genes, as described by Kumar et al. [60].

The weak sweet taste and acid taste of both LSL tomato groups at the time of consumption (T2) are consistent with the decreases in reducing sugars (glucose, fructose) and organic acids (malic, citric) that occur during the postharvest period, as has been previously reported for the 'Penjar' [36,41,60], 'Ramellet' [35] and 'Piennolo' landraces [42,43]. As for the intensity of odor and flavor descriptors, evaluated in both raw fruits and culinary preparations, the 'Piennolo' group was characterized by higher scores than the 'Penjar-Ramellet' group. This can be the result of a different volatilome of the two LSL tomato groups after the storage period. In fact, despite the scarcity of studies analyzing the evolution of volatile organic compounds (VOC) in LSL tomato landraces during the postharvest period, the works of Casals et al. [44] on the 'Penjar' landraces and of Manzo et al. [43] and Parisi et al. [16] on the 'Piennolo' landraces point out a different VOC pattern between the two tomato LSL groups. For the 'Penjar' landraces, Casals et al. [44] described a general reduction in the concentration of all the VOCs (with some exceptions such as nonanal and α-pinene), while for the 'Piennolo' landraces, Parisi et al. [16] and Manzo et al. [43] reported a general increase in the main VOCs contributing to tomato odor and flavor (alcohols, carbonyl compounds, phenolic derivates, and terpenes) during storage. The high intensity of 'green odor' perceived by the Italian trained panel in the 'Piennolo' group is consistent with the high concentration of VOCs such as €-2-hexenal and hexanal previously reported in the 'Piennolo' landraces [16,43] and described as 'green leaf volatiles' for their characteristic 'fresh aroma of cut grass' [61].

To better understand the sensory attributes that drive consumers' preferences for LSL tomato, in the present study, hedonic tests were conducted on both raw and culinary preparations of the 'Piennolo' and 'Penjar-Ramellet' genotypes. Overall, the PCAs revealed that sensory attributes driving consumer acceptance are specific for each LSL tomato group. For the 'Piennolo' group, there were differences only in the 'aspect liking_on raw' associated with the CIELAB color parameters (except a*/b*) and higher firmness (FIRM, and 'resistance to cut'). In contrast, in the 'Penjar-Ramellet' group, the major contributors to 'aspect liking_on raw' were 'color intensity' and 'seeds' (evaluated on raw and on bread), 'shriveling_on raw' and 'spreadability' (evaluated on bread). Furthermore, in the 'Penjar-

Ramellet' group, a negative relationship was observed between the hedonic judgments related to smell and taste ('odor liking', 'overall liking_on bread') and those related to appearance ('aspect liking').

In the 'Piennolo' group, the raw products of landraces *ACA* and *PAT* were preferred by consumers for their evaluated aspect attributes, while the commercial counterpart *GBO* was the least appreciated variety. This result was largely driven by the fruit textural characteristics, as *GBO* was perceived as the most 'shriveled' genotype, while *ACA* and *PAT* had the highest scores for 'resistance to cut' and instrumental FIRM. In contrast, in the 'Penjar-Ramellet' group, no clear separation linked to consumer preferences was observed between modern and traditional varieties. In fact, the modern variety *PdP* and the landrace *DEC* were both associated with 'odor liking_on raw' and 'overall liking_on bread'; the least appreciated variety was the landrace *PEN1*. This latter variety received the lowest scores for 'aspect liking_on raw' and 'overall liking-spreadability_on bread' and for the sensory descriptors 'color intensity' (raw and on bread), 'shiriveling_on raw' and 'seeds_on bread'. Several studies have compared the sensory profiles and/or the sensory-related instrumental traits of modern and traditional tomato varieties for fresh consumption [14,15,18,27,62–64], and in some cases, the traditional varieties have shown better properties [18,64]. However, this trend cannot be generalized because it can depend on the intra-landrace genetic variation and the choice of the modern varieties used in the comparison, which are often the result of successful breeding programs [15].

5. Conclusions and Future Work

The results obtained in this study showed that 'Piennolo' and 'Penjar-Ramellet' varieties lost their corresponding peculiar phenotypes in terms of physicochemical properties and postharvest behavior when not grown in their original agro-environmental conditions.

Sensory description by a trained panel of the raw and culinary preparations of both LSL tomato groups highlighted different sensory profiles. A reduction in sensory diversity among the genotypes was observed in the 'Piennolo' group for the baked tomatoes compared to the raw products, while this trend was not observed in the 'Penjar-Ramellet' group. Cooking at high temperature (215 °C) by itself, modifying the consistency and chemical composition, could flatten the perceptible differences in the raw products.

These results point out the importance of studying sensory profiles using a culinary preparation as close as possible to that used by consumers (i.e., baked tomatoes, tomato spread on bread), as the results can be very different if they are studied on raw fruits. The participation of chefs and the inclusion of culinary traits in sensory studies can improve the efficiency of breeding programs [65].

Finally, hedonic tests conducted on both raw and culinary products revealed that sensory attributes driving consumer acceptance are specific to the 'Piennolo' and 'Penjar-Ramellet' genotypes. However, none of the tested varieties were associated with all the hedonic judgments, suggesting the need to develop breeding programs to obtain LSL tomato genotypes that fulfill consumer preferences.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agronomy13051265/s1, Figure S1. Effect of the agro-environmental conditions (Italy, low-input, no irrigation; Spain, high-input, full-irrigation) on fruit quality traits at harvest (T0) of each variety belonging to the 'Piennolo' (*ACA*, *GBO*, *LUC*, *PAT*, *RSV*) and 'Penjar-Ramellet' (*DEC*, *PdP*, *PEN1*, *PEN2*, *RAM*) groups; Figure S2. Fruit weight (FW) loss during the first 2 months of postharvest in the 'Penjar-Ramellet' varieties grown in Spain; Figure S3. Evolution of (A) fruit firmness (FIRM), (B) fruit soluble solids content (SSC), and (C) fruit weight (FW) from harvest (T0) to the time sensory analyses were conducted in Italy (T2= 4.5 months after harvest) on the 'Piennolo' varieties grown in Italy; Figure S4. Evolution of fruit external color (CIELAB space coordinates L*, a* and b*) during postharvest for each variety belonging to the 'Piennolo' (*ACA*, *GBO*, *LUC*, *PAT*, *RSV*) and 'Penjar-Ramellet' (*DEC*, *PdP*, *PEN1*, *PEN2*, *RAM*) groups grown in Italy (Piennolo_ITA) and Spain (Penjar_SP), respectively; Table S1. Analysis of variance and means of sensory descriptors of the Italian 'Piennolo' varieties (raw and baked products) evaluated in Italy at 4.5 months after harvest (T2); Table S2. Frequency (%) of the olfactory and flavor notes checked on raw and baked tomato products of the 'Piennolo' varieties evaluated in Italy at T2 (4.5 months after harvest); Table S3. Analysis of variance and means of physicochemical parameters of the Italian 'Piennolo' varieties (raw and baked products) evaluated in Italy at T2 (4.5 months after harvest); Table S4. Analysis of variance and means of consumers' liking judgments for raw and baked tomato products of the 'Piennolo' varieties evaluated in Italy at T2 (4.5 months after harvest); Table S5. Effects of socio-demographic categories on tomato liking for the Italian consumers; Table S6. Analysis of variance and means of sensory descriptors of the Spanish 'Penjar-Ramellet' varieties (raw and spread on bread) evaluated in Spain at T2 (3 months after harvest); Table S7. Frequency (%) of the olfactory notes checked on raw products of the 'Penjar-Ramellet' varieties evaluated in Spain at T2 (3 months after harvest); Table S8. Analysis of variance and means of consumers' liking judgments for tomato products (raw and spread on bread) of the Spanish 'Penjar-Ramellet' varieties evaluated in Spain at T2 (3 months after harvest); Table S9. Effects of socio-demographic categories on tomato liking for the Spanish consumers

Author Contributions: Conceptualization, M.C., F.S., J.C. and S.G.; methodology, F.S., M.C., J.C., and S.G.; formal analysis, F.S. and J.C.; investigation, F.S., M.C., M.P., C.P., R.R.d.C., E.S.C., A.V., J.C. and S.G.; resources, A.G.; data curation, F.S., C.P., J.C. and M.C.; writing—original draft preparation, M.C., F.S., J.C. and S.G.; writing—review and editing, M.C., F.S., J.C., S.G. and A.G.; supervision, J.C. and S.G.; funding acquisition, A.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the European Commission H2020 research and innovation program through TRADITOM grant agreement No. 634561. Joan Casals is a Serra Húnter Fellow at Universistat Politècnica de Catalunya.

Institutional Review Board Statement: This study was approved for the two countries by the CNR Research Ethics and Integrity Committee (IRB, Prot. N. 0070284/2021).

Data Availability Statement: The data that support the findings of this study are available from the corresponding authors upon reasonable request.

Acknowledgments: The authors acknowledge the service provider Adacta International (in Italy) for the recruitment of the participants in the consumer study. The authors also wish to express their gratitude to the sensory panel of CREA (Research Centre for Food and Nutrition), of Balandran CTIFL and of Barcelona School of Agricultural Engineering for carrying out the descriptive analysis of the tomato cultivars. We are grateful to Patrizia Spigno and Riccardo Riccardi (Arca 2010 Srl) for the kind assistance in field experiments.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Blanca, J.; Pons, C.; Montero-Pau, J.; Sanchez-Matarredona, D.; Ziarsolo, P.; Fontanet, L.; Fisher, J.; Plazas, M.; Casals, J.; Rambla, J.L.; et al. European Traditional Tomatoes Galore: A Result of Farmers' Selection of a Few Diversity-Rich Loci. *J. Exp. Bot.* **2022**, *73*, 3431–3445. [CrossRef] [PubMed]
2. Pons, C.; Casals, J.; Palombieri, S.; Fontanet, L.; Riccini, A.; Rambla, J.L.; Ruggiero, A.; de Rosario Figás, M.; Plazas, M.; Koukounaras, A.; et al. Atlas of Phenotypic, Genotypic and Geographical Diversity Present in the European Traditional Tomato. *Hortic. Res.* **2022**, *9*, uhac112. [CrossRef] [PubMed]
3. Rodriguez, G.R.; Munos, S.; Anderson, C.; Sim, S.-C.; Michel, A.; Causse, M.; Gardener, B.B.M.; Francis, D.; van der Knaap, E. Distribution of SUN, OVATE, LC, and FAS in the Tomato Germplasm and the Relationship to Fruit Shape Diversity. *Plant Physiol.* **2011**, *156*, 275–285. [CrossRef] [PubMed]
4. Robertson, L.D.; Labate, J.A. Genetic Resources of Tomato (*Lycopersicon Esculentum* Mill.) and Wild Relatives. In *Genetic Improvement of Solanaceous Crops. Volume 2: Tomato*; Razdan, M.K., Mattoo, A.K., Eds.; Science Publishers: Enfield, NH, USA, 2007; Volume 2, pp. 25–75.
5. Peralta, I.; Spooner, D. History, Origin and Early Cultivation of Tomato (Solanaceae). In *Genetic Improvement of Solanaceous Crops: Tomato*; Razdan, M., Mattoo, A., Eds.; Science Publishers: Enfield, NH, USA, 2006; pp. 1–24.
6. Casañas, F.; Simó, J.; Casals, J.; Prohens, J. Toward an Evolved Concept of Landrace. *Front. Plant Sci.* **2017**, *08*, 145. [CrossRef] [PubMed]
7. Sacco, A.; Ruggieri, V.; Parisi, M.; Festa, G.; Rigano, M.M.; Picarella, M.E.; Mazzucato, A.; Barone, A. Exploring a Tomato Landraces Collection for Fruit-Related Traits by the Aid of a High-Throughput Genomic Platform. *PLoS ONE* **2015**, *10*, e0137139. [CrossRef]

8. Corrado, G.; Caramante, M.; Piffanelli, P.; Rao, R. Genetic Diversity in Italian Tomato Landraces: Implications for the Development of a Core Collection. *Sci. Hortic.* **2014**, *168*, 138–144. [CrossRef]
9. Terzopoulos, P.J.; Bebeli, P.J. Phenotypic Diversity in Greek Tomato (*Solanum lycopersicum* L.) Landraces. *Sci. Hortic.* **2010**, *126*, 138–144. [CrossRef]
10. Cebolla-Cornejo, J.; Roselló, S.; Nuez, F. Phenotypic and Genetic Diversity of Spanish Tomato Landraces. *Sci. Hortic.* **2013**, *162*, 150–164. [CrossRef]
11. Tieman, D.; Zhu, G.; Resende, M.; Lin, T.; Nguyen, C.; Bies, D.; Rambla, J.L.; Beltran, K.S.O.; Taylor, M.; Zhang, B.; et al. A Chemical Genetic Roadmap to Improved Tomato Flavor. *Science* **2017**, *355*, 391–394. [CrossRef]
12. Dono, G.; Picarella, M.E.; Pons, C.; Santangelo, E.; Monforte, A.; Granell, A.; Mazzucato, A. Characterization of a Repertoire of Tomato Fruit Genetic Variants in the San Marzano Genetic Background. *Sci. Hortic.* **2020**, *261*, 108927. [CrossRef]
13. Mazzucato, A.; Ficcadenti, N.; Caioni, M.; Mosconi, P.; Piccinini, E.; Sanampudi, V.R.R.; Sestili, S.; Ferrari, V. Genetic Diversity and Distinctiveness in Tomato (*Solanum lycopersicum* L.) Landraces: The Italian Case Study of "A Pera Abruzzese". *Sci. Hortic.* **2010**, *125*, 55–62. [CrossRef]
14. Sinesio, F.; Moneta, E.; Peparaio, M. Sensory Characteristics of Traditional Field Grown Tomato Genotypes in Southern Italy. *J. Food Qual.* **2007**, *30*, 878–895. [CrossRef]
15. Sinesio, F.; Cammareri, M.; Cottet, V.; Fontanet, L.; Jost, M.; Moneta, E.; Palombieri, S.; Peparaio, M.; Romero del Castillo, R.; Saggia Civitelli, E.; et al. Sensory Traits and Consumer's Perceived Quality of Traditional and Modern Fresh Market Tomato Varieties: A Study in Three European Countries. *Foods* **2021**, *10*, 2521. [CrossRef] [PubMed]
16. Parisi, M.; Lo Scalzo, R.; Migliori, C.A. Postharvest Quality Evolution in Long Shelf-Life "Vesuviano" Tomato Landrace. *Sustainability* **2021**, *13*, 11885. [CrossRef]
17. Casals, J.; Pascual, L.; Canizares, J.; Cebolla-Cornejo, J.; Casanas, F.; Nuez, F. The Risks of Success in Quality Vegetable Markets: Possible Genetic Erosion in Marmande Tomatoes (*Solanum lycopersicum* L.) and Consumer Dissatisfaction. *Sci. Hortic.* **2011**, *130*, 78–84. [CrossRef]
18. Alonso, A.; Garcia-Aliaga, R.; Garcia-Martinez, S.; Ruiz, J.J.; Carbonell-Barrachina, A.A. Characterization of Spanish Tomatoes Using Aroma Composition and Discriminant Analysis. *Food Sci. Technol. Int.* **2009**, *15*, 47–55. [CrossRef]
19. Brugarolas, M.; Martinez-Carrasco, L.; Martinez-Poveda, A.; Ruiz, J.J. A Competitive Strategy for Vegetable Products: Traditional Varieties of Tomato in the Local Market. *Span. J. Agric. Res.* **2009**, *7*, 294–304. [CrossRef]
20. Folta, K.M.; Klee, H.J. Sensory Sacrifices When We Mass-Produce Mass Produce. *Hortic. Res.* **2016**, *3*, 16032. [CrossRef]
21. Rubio, F.; Alonso, A.; García-Martínez, S.; Ruiz, J.J. Introgression of Virus-Resistance Genes into Traditional Spanish Tomato Cultivars (*Solanum lycopersicum* L.): Effects on Yield and Quality. *Sci. Hortic.* **2016**, *198*, 183–190. [CrossRef]
22. Tieman, D.; Bliss, P.; McIntyre, L.; Blandon-Ubeda, A.; Bies, D.; Odabasi, A.Z.; Rodríguez, G.R.; van der Knaap, E.; Taylor, M.G.; Goulet, C.; et al. The Chemical Interactions Underlying Tomato Flavor Preferences. *Curr. Biol.* **2017**, *22*, 1035–1039. [CrossRef]
23. Schouten, H.J.; Tikunov, Y.; Verkerke, W.; Finkers, R.; Bovy, A.; Bai, Y.; Visser, R.G.F. Breeding Has Increased the Diversity of Cultivated Tomato in the Netherlands. *Front. Plant Sci.* **2019**, *10*, 1606. [CrossRef] [PubMed]
24. Causse, M.; Zhao, J.; Diouf, I.; Qang, J.; Lefebvre, V.; Caromel, B.; Génard, M.; Bertin, N. Genomic Designing for Climate-Smart Tomato. In *Genomic Designing of Climate-Smart Vegetable Crops*; Kole, C., Ed.; Springer International Publishing: Berlin/Heidelberg, Germany, 2020; pp. 47–159. ISBN 978-3-319-97415-6.
25. Causse, M.; Friguet, C.; Coiret, C.; LéPicier, M.; Navez, B.; Lee, M.; Holthuysen, N.; Sinesio, F.; Moneta, E.; Grandillo, S. Consumer Preferences for Fresh Tomato at the European Scale: A Common Segmentation on Taste and Firmness. *J. Food Sci.* **2010**, *75*, S531–S541. [CrossRef]
26. Piombino, P.; Sinesio, F.; Moneta, E.; Cammareri, M.; Genovese, A.; Lisanti, M.T.; Mogno, M.R.; Peparaio, M.; Termolino, P.; Moio, L.; et al. Investigating Physicochemical, Volatile and Sensory Parameters Playing a Positive or a Negative Role on Tomato Liking. *Food Res. Int.* **2013**, *50*, 409–419. [CrossRef]
27. Carli, P.; Arima, S.; Fogliano, V.; Tardella, L.; Frusciante, L.; Ercolano, M.R. Use of Network Analysis to Capture Key Traits Affecting Tomato Organoleptic Quality. *J. Exp. Bot.* **2009**, *60*, 3379–3386. [CrossRef]
28. Causse, M.; Buret, M.; Robini, K.; Verschave, P. Inheritance of Nutritional and Sensory Quality Traits in Fresh Market Tomato and Relation to Consumer Preferences. *J. Food Sci.* **2003**, *68*, 2342–2350. [CrossRef]
29. Serrano-Megías, M.; López-Nicolás, J.M. Application of Agglomerative Hierarchical Clustering to Identify Consumer Tomato Preferences: Influence of Physicochemical and Sensory Characteristics on Consumer Response. *J. Sci. Food Agric.* **2005**, *86*, 493–499. [CrossRef]
30. Le, S.; Ledauphin, S. You like Tomato, I like Tomato: Segmentation of Consumers with Missing Values. *Food Qual. Prefer.* **2006**, *17*, 228–233. [CrossRef]
31. Bucheli, P.; Voirol, E.; de la Torre, R.; Lopez, J.; Rytz, A.; Tanksley, S.D.; Petiard, V. Definition of Nonvolatile Markers for Flavor of Tomato (*Lycopersicon Esculentum* Mill.) as Tools in Selection and Breeding. *J. Agric. Food Chem.* **1999**, *47*, 659–664. [CrossRef]
32. Grandillo, S.; Zamir, D.; Tanksley, S.D. Genetic Improvement of Processing Tomatoes: A 20 Years Perspective. *Euphytica* **1999**, *110*, 85–97. [CrossRef]
33. Conesa, M.À.; Fullana-Pericàs, M.; Granell, A.; Galmés, J. Mediterranean Long Shelf-Life Landraces: An Untapped Genetic Resource for Tomato Improvement. *Front. Plant Sci.* **2020**, *10*, 1651. [CrossRef]

34. Aiese Cigliano, R.; Aversano, R.; Di Matteo, A.; Palombieri, S.; Termolino, P.; Angelini, C.; Bostan, H.; Cammareri, M.; Consiglio, F.M.; Della Ragione, F.; et al. Multi-Omics Data Integration Provides Insights into the Post-Harvest Biology of a Long Shelf-Life Tomato Landrace. *Hortic. Res.* **2022**, *9*, uhab042. [CrossRef] [PubMed]
35. Bota, J.; Conesa, M.À.; Ochogavia, J.M.; Medrano, H.; Francis, D.M.; Cifre, J. Characterization of a Landrace Collection for Tomàtiga de Ramellet (*Solanum lycopersicum* L.) from the Balearic Islands. *Genet. Resour. Crop Evol.* **2014**, *61*, 1131–1146. [CrossRef]
36. Casals, J.; Rull, A.; Giné-Bordonaba, J. Changes in Ripening-Related Quality Traits of Long Shelf Life Tomatoes as Influenced by Water Deficit and Short-Term Postharvest Storage. *Agronomy* **2021**, *11*, 2304. [CrossRef]
37. Casals, J.; Pascual, L.; Canizares, J.; Cebolla-Cornejo, J.; Casanas, F.; Nuez, F. Genetic Basis of Long Shelf Life and Variability into Penjar Tomato. *Genet. Resour. Crop Evol.* **2012**, *59*, 219–229. [CrossRef]
38. Esposito, S.; Cardi, T.; Campanelli, G.; Sestili, S.; Díez, M.J.; Soler, S.; Prohens, J.; Tripodi, P. DdRAD Sequencing-Based Genotyping for Population Structure Analysis in Cultivated Tomato Provides New Insights into the Genomic Diversity of Mediterranean 'Da Serbo' Type Long Shelf-Life Germplasm. *Hortic. Res.* **2020**, *7*, 134. [CrossRef]
39. Gao, Y.; Wei, W.; Fan, Z.; Zhao, X.; Zhang, Y.; Jing, Y.; Zhu, B.; Zhu, H.; Shan, W.; Chen, J.; et al. Re-Evaluation of the nor Mutation and the Role of the NAC-NOR Transcription Factor in Tomato Fruit Ripening. *J. Exp. Bot.* **2020**, *71*, 3560–3574. [CrossRef]
40. Tranchida-Lombardo, V.; Aiese Cigliano, R.; Anzar, I.; Landi, S.; Palombieri, S.; Colantuono, C.; Bostan, H.; Termolino, P.; Aversano, R.; Batelli, G.; et al. Whole-Genome Re-Sequencing of Two Italian Tomato Landraces Reveals Sequence Variations in Genes Associated with Stress Tolerance, Fruit Quality and Long Shelf-Life Traits. *DNA Res.* **2018**, *25*, 149–160. [CrossRef]
41. Casals, J.; Martí, R.; Casañas, F.; Cebolla, J. Sugar-and-Acid Profile of Penjar Tomatoes and Its Evolution during Storage. *Sci. Agric.* **2015**, *72*, 314–321. [CrossRef]
42. Renna, M.; Durante, M.; Gonnella, M.; Buttaro, D.; D'Imperio, M.; Mita, G.; Serio, F. Quality and Butritional Evaluation of Regina Tomato, a Traditional Long-Storage Landrace of Puglia (Southern Italy). *Agriculture* **2018**, *8*, 83. [CrossRef]
43. Manzo, N.; Pizzolongo, F.; Meca, G.; Aiello, A.; Marchetti, N.; Romano, R. Comparative Chemical Compositions of Fresh and Stored Vesuvian PDO "Pomodorino Del Piennolo" Tomato and the Ciliegino Variety. *Molecules* **2018**, *23*, 2871. [CrossRef]
44. Casals, J.; Cebolla-Cornejo, J.; Rosello, S.; Beltran, J.; Casanas, F.; Nuez, F. Long-Term Postharvest Aroma Evolution of Tomatoes with the Alcobaça (Alc) Mutation. *Eur. Food Res. Technol.* **2011**, *233*, 331–342. [CrossRef]
45. Romero del Castillo, R.; Puig-Pey, M.; Biarnés, J.; Vilaseca, H.; Simó, J.; Plans, M.; Massanés, T.; Casañas, F. Using Trendsetting Chefs to Design New Culinary Preparations with the "Penjar" Tomato. *J. Culin. Sci. Technol.* **2014**, *12*, 196–214. [CrossRef]
46. Juan-Cabot, A.; Galmés, J.; Conesa, M.À. The Tomato Long Shelf-Life Fruit Phenotype: Knowledge, Uncertainties and Prospects. *Sci. Hortic.* **2022**, *291*, 110578. [CrossRef]
47. Casals, J.; Martí, M.; Rull, A.; Pons, C. Sustainable Transfer of Tomato Landraces to Modern Cropping Systems: The Effects of Environmental Conditions and Management Practices on Long-Shelf-Life Tomatoes. *Agronomy* **2021**, *11*, 533. [CrossRef]
48. Navez, B.; Letard, M.; Graselly, D.; Jost, J. Les Critères de Qualité de La Tomate. *Infos-CTIFL* **1999**, *155*, 41–47.
49. Sinesio, F.; Cammareri, M.; Moneta, E.; Navez, B.; Peparaio, M.; Causse, M.; Grandillo, S. Sensory Quality of Fresh French and Dutch Market Tomatoes: A Preference Mapping Study with Italian Consumers. *J. Food Sci.* **2010**, *75*, S55–S67. [CrossRef]
50. *ISO 8589:2007*; Sensory Analysis—General Guidance for the Design of Test Rooms. ISO: Genova, Italy, 2017.
51. Bates, D.; Mächler, M.; Bolker, B.; Walker, S. Fitting Linear Mixed-Effects Models Using Lme4. *J. Stat. Softw.* **2015**, *67*, 1–48. [CrossRef]
52. Villanueva, R.A.M.; Chen, Z.J. Ggplot2: Elegant Graphics for Data Analysis (2nd Ed.). *Meas. Interdiscip. Res. Perspect.* **2019**, *17*, 160–167. [CrossRef]
53. Rosa-Martínez, E.; Adalid, A.M.; Alvarado, L.E.; Burguet, R.; García-Martínez, M.D.; Pereira-Dias, L.; Casanova, C.; Soler, E.; Figàs, M.R.; Plazas, M.; et al. Variation for Composition and Quality in a Collection of the Resilient Mediterranean 'de Penjar' Long Shelf-Life Tomato under High and Low N Fertilization Levels. *Front. Plant Sci.* **2021**, *12*, 441. [CrossRef]
54. Patanè, C.; Scordia, D.; Testa, G.; Cosentino, S.L. Physiological Screening for Drought Tolerance in Mediterranean Long-Storage Tomato. *Plant Sci.* **2016**, *249*, 25–34. [CrossRef]
55. Fullana-Pericàs, M.; Conesa, M.À.; Douthe, C.; El Aou-ouad, H.; Ribas-Carbó, M.; Galmés, J. Tomato Landraces as a Source to Minimize Yield Losses and Improve Fruit Quality under Water Deficit Conditions. *Agric. Water Manag.* **2019**, *223*, 105722. [CrossRef]
56. Siracusa, L.; Patane, C.; Avola, G.; Ruberto, G. Polyphenols as Chemotaxonomic Markers in Italian "Long-Storage" Tomato Genotypes. *J. Agric. Food Chem.* **2012**, *60*, 309–314. [CrossRef] [PubMed]
57. Conesa, M.À.; Galmés, J.; Ochogavía, J.M.; March, J.; Jaume, J.; Martorell, A.; Francis, D.M.; Medrano, H.; Rose, J.K.C.; Cifre, J. The Postharvest Tomato Fruit Quality of Long Shelf-Life Mediterranean Landraces Is Substantially Influenced by Irrigation Regimes. *Postharvest Biol. Technol.* **2014**, *93*, 114–121. [CrossRef]
58. Casals, J.; Rivera, A.; Sabaté, J.; Romero del Castillo, R.; Simó, J. Cherry and Fresh Market Tomatoes: Differences in Chemical, Morphological, and Sensory Traits and Their Implications for Consumer Acceptance. *Agronomy* **2018**, *9*, 9. [CrossRef]
59. Hongsoongnern, P. *Understanding the Sensory Characteristics of Fresh and Processed Tomatoes Using Descriptive Sensory Analysis*; Kansas State University: Manhattan, KS, USA, 2007.
60. Kumar, R.; Tamboli, V.; Sharma, R.; Sreelakshmi, Y. NAC-NOR Mutations in Tomato Penjar Accessions Attenuate Multiple Metabolic Processes and Prolong the Fruit Shelf Life. *Food Chem.* **2018**, *259*, 234–244. [CrossRef]

61. Rambla, J.L.; Tikunov, Y.M.; Monforte, A.J.; Bovy, A.G.; Granell, A. The Expanded Tomato Fruit Volatile Landscape. *J. Exp. Bot.* **2014**, *65*, 4613–4623. [CrossRef]
62. Carbonell-Barrachina, A.A.; Agusti, A.; Ruiz, J.J. Analysis of Flavor Volatile Compounds by Dynamic Headspace in Traditional and Hybrid Cultivars of Spanish Tomatoes. *Eur. Food Res. Technol.* **2006**, *222*, 536–542. [CrossRef]
63. Cortina, P.R.; Santiago, A.N.; Sance, M.M.; Peralta, I.E.; Carrari, F.; Asis, R. Neuronal Network Analyses Reveal Novel Associations between Volatile Organic Compounds and Sensory Properties of Tomato Fruits. *Metabolomics* **2018**, *14*, 57. [CrossRef]
64. D'Angelo, M.; Zanor, M.I.; Sance, M.; Cortina, P.R.; Boggio, S.B.; Asprelli, P.; Carrari, F.; Santiago, A.N.; Asís, R.; Peralta, I.E.; et al. Contrasting Metabolic Profiles of Tasty Andean Varieties of Tomato Fruit in Comparison with Commercial Ones. *J. Sci. Food Agric.* **2018**, *98*, 4128–4134. [CrossRef]
65. Dawson, J.; Healy, G. Flavour Evaluation for Flant Breeders. In *Plant Breeding Reviews*; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2018; pp. 215–261.