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Selection of New Late-Season Mandarin Cultivars Based on Sensory Changes and Consumer Acceptance after Fruit Cold Storage

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Abstract: Late-season mandarins are normally cold-stored to prolong the commercial season. Thus, it is necessary to investigate poststorage consumer acceptance to predict the potential success of new late-season mandarin varieties on the market. The aim of the present work was to evaluate consumer response to three new late-season cultivars preselected in the IVIA breeding programme (Omet, Matiz and Tri-703) after different cold storage periods. The three new cultivars were compared to commercial cultivars Orri, Nadorcott and Ortanique, all of which are widely available in stores. A multidisciplinary approach was used to determine the main changes during storage at 1 °C for up to one month: (1) analysis of physico-chemical parameters; (2) description of the sensory profile by semitrained assessors by the Free Choice Profile technique; (3) evaluation of consumer acceptability and purchase intention. Our results showed that the sensory changes that fruit underwent during storage depended on the variety; these changes allowed us to understand why consumer preferences varied during storage. Of the three new cultivars, two (Omet and Tri-703) showed the greatest potential for success. However, while Tri-703 can be stored for one month, Omet should not be stored longer than 15 days due to its susceptibility to manifest skin damage during storage. Of the commercial cultivars, internal Orri quality was keenly appreciated by consumers, while Ortanique was considered the most attractive variety. The multidisciplinary approach followed in this study proved to be a potent tool for selecting varieties that should be implemented in selection processes of breeding programmes.

Keywords: sensory; external appearance; skin damage; internal quality; purchase intention

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1. Introduction

Over the last few years, consumers have switched from the traditionally dominant citrus fruit, oranges, to mandarins [1]. Thus, the industry is eager to extend the varietal spectrum with mandarin varieties that allow the commercial season to be prolonged. In this context, the Valencian Institute for Agricultural Research (IVIA), located in one of the most important mandarin-growing areas in Spain, now hosts a breeding programme whose main objective is to obtain new seedless, late-season mandarins of high sensory quality. This programme is based on obtaining new triploid hybrids using high quality parental cultivars. Triploid hybrids have extremely low pollen and ovule fertility, resulting in the presence of very few seeds [2].

In a recent study [3], we evaluated the sensory properties of and consumer preferences regarding freshly harvested fruit of some of the varieties which had been preselected for the IVIA breeding programme. However, it is important to bear in mind that fruit from the late cultivars are normally stored at low temperature to prolong the commercial period as much as possible, and to obtain maximal economic profit. Moreover, a large amount of fruit is sold on long-distance markets as a result of globalised trade, which usually involves exposing fruit to low temperatures during overseas transport. Thus, fruit response during cold storage must be a key factor for the selection process of mandarins, as it very much depends on the cultivar [4].

Most studies that have evaluated the behaviour of different mandarins during cold storage have focused on the physico-chemical changes that occur within fruit during this period, and the effect of certain treatments on them [4–6]. Although this is necessary and valuable information, consumers are those who ultimately judge fruit, and they use their senses to do so. This is why it is essential to include sensory studies to determine the extent to which the physico-chemical changes that fruit undergo during storage will affect their sensory attributes. It would also be extremely interesting to determine the sensory changes associated with storage combined with consumer acceptance, because the different studies that have focused on mandarin quality at harvest time have shown that both internal and external attributes condition consumer responses. Thus, appearance is the first attribute evaluated by consumers, and is a decisive factor for purchase decision in grocery stores when any other information is available [7]. During consumption, consumers evaluate internal attributes like taste, flavour or texture, and they globally perceive quality, which will influence their repurchase intention [3].

Descriptions of fruit sensory attributes have been traditionally based on conventional descriptive analyses [8,9] which involve trained panellists and, therefore, are very time-consuming [10]. Besides, information about the spontaneous sensations that actually occur during product consumption is sometimes lost, as the generated vocabulary and attributes can be complex and technical [11]. In the last few years, different, less time-consuming sensory methods have been developed, of which the Free Choice Profile (FCP) combined with the Repertory Grid (RG) has proven to be a good option to obtain information about the sensory characteristics of different products [12–14]. The FCP differs from conventional profiling in that each participant develops an individual list of descriptors using their own terminology, but it remains similar in that they must be able to detect differences among samples [15]. According to Tárrega and Tarancón [16], the selected participants could be either untrained assessors (they nonetheless have to be objective, capable of using scales, and able to consistently use the vocabulary developed) or semitrained assessors, who have some previous experience in performing sensory tests.

It is also important to bear in mind that any newly released cultivar which seeks to replace or compete with the cultivars already available on the market must be of comparable or superior quality for consumers [17]. Therefore, in order to predict market acceptance of new varieties, it is especially interesting to compare the varieties being evaluated to the commercial cultivars that they have to compete with.

In this context, our study objective was to evaluate consumer preferences for six mandarin cultivars cold stored for up to one month, and to relate them to fruit sensory changes during this period. Three of the cultivars were new late-season varieties that were preselected in the IVIA breeding programme, namely Matiz, Omet and Tri-703. The other three were commercial cultivars that can be purchased on the market at the same time during the season, i.e., Nadorcott, Orri and Ortanique. The evaluation of changes in physico-chemical parameters, sensory attributes and consumer acceptance allowed us to identify the new varieties with the most potential for commercial success in a cold storage scenario.

2. Materials and Methods

2.1. Vegetal Material and Storage Conditions

In this study, six mandarin varieties were evaluated. Three were new triploid hybrids belonging to the IVIA breeding programme (Omet, Matiz and Tri-703). The other three were commercial varieties present contemporarily in stores (Nadorcott, Orri and Ortanique) (Figure S1). At the beginning of March (3 March 2019), the commercial varieties were obtained upon their arrival at a commercial packing house in Valencia, while the new varieties were collected the same day in the IVIA experimental orchards. All the fruit were transported to the IVIA Postharvest Department, where they were submitted to commercial handling practices before being stored at low temperature. Then they were selected, sorted based on their uniform size and lack of visual defects, and washed in a foam curtain with biodegradable detergent (Fruit-Cleaner®, Fomesa Fruitech SLU), cleared up and waxed with a commercial coating of 14% total solids with 2000 ppm of Imazalil as a fungicide (Waterwax TTT-2I®, Fomesa Fruitech SLU).

Afterwards, six fruit batches were prepared per variety, three of which consisted of 120 fruit, while the other three had 20 fruit. One of each size was used for the harvest time analysis. The other four batches were stored at 1 °C (90% RH). After 15 and 30 days, one batch of each size was taken from the cool storage chamber. One 20-fruit batch was analysed, while a 120-fruit one was transferred to a 20 °C storage space to simulate a five-day shelf life (SL) period before being analysed.

The performed analyses are summarised in Table 1. For each variety, the following physico-chemical parameters were evaluated at harvest time after both the cold storage periods and the subsequent SL: colour index, juice yield, firmness, total soluble solids content (TSS), titratable acidity (TA), juice ethanol content. Incidence of external disorders was also evaluated throughout the storage period on the 120-fruit batches. Moreover, at harvest time, fruit shape, adhesion of rind to pulp and rind rugosity were evaluated by a trained panel.

At harvest time and after the shelf-life periods that followed the 15 and 30 storage days, two sensory tests were run: (1) the FCP method was used to describe the internal sensory properties of mandarins and how they evolve during storage; (2) acceptance tests were carried out to determine consumer preferences based on external fruit appearance and internal properties.

Table 1. Summary of the performed analyses.

Fruit Analysis		Sample Size (n° Fruit)	Harvest	15 ds at 1 °C	15 ds at 1 °C + SL	30 ds at 1 °C	30 ds at 1 °C + SL
External parameters	Weight	20	x				
	Diammeter	20	x				
	Shape	20	x				
	Skin Rugosity	20	x				
	Rind Adhesion	20	x				
	Colour Index	20	x	x	x	x	x
	Skin damage	120		x	x	x	x
Internal parameters	Firmness	20	x	x	x	x	x
	Juice Yield	4 × 5 *	x	x	x	x	x
	TSS	4 × 5 *	x	x	x	x	x
	Acidity	4 × 5 *	x	x	x	x	x
	Maturity Index	4 × 5 *	x	x	x	x	x
	EtOH Conc.	4 × 5 *	x	x	x	x	x
Sensory Evaluation	Ext. Acceptance & Purchase I.	20	x		x		x
	Int. Free Choice P.	>40	x		x		x
	Int. Acceptance & Purchase I.	50	x		x		x

* 4 × 5 indicates four juices of 5 fruit each one. SL—shelf-life period of 5 days at 20 °C. Ext—external evaluation. Int—evaluation of fruit segments.

2.2. Physico-Chemical Parameters

2.2.1. External Parameters

Peel colour was measured using a Minolta colorimeter (model CR- 300; Minolta Co. Ltd., Osaka, Japan) with 20 fruit per cultivar; two measurements were taken in the equatorial zone of each fruit. The results are expressed as (CI = 1000 a/Lb), where L, a and b are Hunter parameters [18].

After harvest time, size was determined on 20 fruit per cultivar by measuring weight and the maximum equatorial section diameter. Fruit shape and rind characteristics were evaluated on 20 fruit per cultivar by a panel made up of seven trained judges with ample experience in citrus fruit evaluation. To this end, ten fruit of each variety were displayed to each judge, who described their shape and the rind rugosity after observing and touching them. Then, each judge was asked to peel two mandarins to evaluate ease of peeling.

The skin physiological disorders that appeared during cold storage were visually evaluated all over a 120-fruit batch using an index previously described to rate fruit disorders [19,20]. Fruit damage was rated on a 4-point scale according to the damage intensity detected on the rind surface: 0, no damage; 1, slight damage (less than 25% of the rind surface was damaged); 2, moderate (more than 25% and less than 50% of the rind surface was damaged); 3, severe (more than 50% damaged surface). The results were expressed as skin damage index (SDI = Σ(damage intensity) × (numbers of fruit at each damage intensity)/(3 × total number of fruit)).

2.2.2. Internal Parameters

Firmness measurements were taken by an Instron Universal Testing Machine (model 3343, Instron Ltd., Buckinghamshire, UK) using 20 fruit per treatment. The results were expressed as the percentage of millimetres of fruit deformation that resulted from 10 N pressure, applied at constant speed by a 3.5 cm plunger on the longitudinal axis.

For the total soluble solids contents (TSS) and titratable acidity (TA), four samples of five fruit each per treatment were squeezed in an electric juice extractor with a rotating head (Lomi®, Model 4, Lorenzo Miguel, S.L., Madrid, Spain). Firstly, the juice yield was measured and expressed as a percentage, calculated by dividing the volume of juice by the total fruit weight. Then TA was determined by titration in 0.1 N NaOH solution using phenolphthalein as the indicator, expressed as g of citric acid per 100 mL of juice. The TSS in juice was established by a digital refractometer (Atago PR-1, Atago Co., Ltd., Tokyo, Japan). Data were expressed as %. The ripening level was expressed according to the maturity index calculated as TSS/TA.

Five millilitres of juice (four juices per variety and time) was transferred to 10-mL phials with crimp-top caps and TFE/silicone septa seals to be frozen (−20 °C) until analysis. Ethanol levels were determined by carrying out a headspace analysis in a gas chromatograph (model 1020, Perkin Elmer Corp., Norwalk, CT, USA), equipped with a flame ionisation detector and a 1/8 in × 1.2 m Porapak QS 80/100 column. The injector was set at 175 °C, the column at 150 °C, the detector (FID) at 200 °C and the carrier gas at 12.3 psi. A 1-mL aliquot of the headspace was withdrawn from the previously equilibrated phials for 1 h at 20 °C and 10 min at 30 °C to be injected into the gas chromatograph. Ethanol was identified by comparing the retention times with that of a standard solution and was expressed as mg/100 mL.

2.3. *Sensory Evaluation*

2.3.1. The Free Choice Profile Test

A group of 27 semitrained assesors (14 men, 13 women) participated in this part of the study, in which the FCP was used to describe the main changes in the sensory profiles of mandarins during cold storage. Sensory profiling focused on the internal attributes of mandarins.

During the first session, the Repertory Grid Method was used to generate the vocabulary that each assessor would use to describe the differences among mandarins throughout the evaluation period. During individual interviews, samples were presented in triads to each participant and he/she was asked to describe all the similarities and differences that they perceived within each triad in his/her own terms. The samples presented in the Repertory Grid came from the six cultivars under study. Most samples corresponded to recently harvested fruit, but some fruit had been previously stored to obtain a set of samples with wide variability and in such a way that, in the elicited vocabulary, those attributes associated with storage like off-flavours could be considered.

The triad presentation order was balanced among consumers [21] and each consumer assessed three triads. Once the attributes list for each assessor had been drawn up, individual score sheets were prepared for each one. Thus, each assessor used his/her own score sheet to evaluate the sensory characteristics of the six cultivars during three periodical sessions: at harvest time, and after 15 and 30 days cold storage plus SL. Assessors rated the intensity of each term per sample using a 10-centimetre unstructured line scale. The evaluation was made in a standardised testing room. Fruit were hand-peeled, and separated segments were placed in glass cups identified by 3-digit codes. Each sample comprised a mixture of three segments prepared from three different fruit. Samples were presented monadically following a balanced design to avoid a serving order effect and were served at room temperature. Assessors were provided with a glass of water for palate cleansing, which they used between samples. A minimum of forty fruit per variety was evaluated during each session.

2.3.2. Consumer Acceptance Test

In this study, consumer acceptance and purchase intention were separately evaluated for external and internal mandarin properties. It is well-known that one of the main effects of cold storage on mandarins is skin damage, which occurs in varieties which are sensitive to chilling injury [22,23]. As we forecasted that this could be the case of any of the six evaluated varieties, we considered it interesting to independently evaluate the effect of external and internal properties on consumer response. In this way, we could avoid the influence of external aspects on internal perception [24], and vice versa. Consumer tests were carried out at harvest time and after 15 and 30 cold storage days plus SL. The three groups of consumers were respectively made up of 72, 69 and 73 people, who voluntarily agreed to participate in the evaluation sessions. Participants were aged between 19 and 58 years, and the male/female ratio (%) was 41/59, 44/56 and 39/61 depending on the session.

Firstly, consumers evaluated the internal properties of mandarins in a standardised testing room. The preparation and serving procedure was the same as that described for the FCP sessions. Fifty fruit per variety were evaluated during each session.

Secondly, consumers had to evaluate external fruit appearance. To this end, the participants were taken to an adjoining room where they evaluated five fruits per variety placed in plastic baskets that are normally available in markets, which were coded with a three-digit random number (coding samples for external evaluation differed than for the samples for the internal evaluation so that consumers could not relate external and internal properties). A total of twenty fruit per variety were visually evaluated during each session (four lots of five fruits each one).

For both the internal and external evaluations, consumers were firstly asked to score their acceptability on a 9-point hedonic scale ranging from 1 ("dislike extremely") to 9 ("like extremely") and then to indicate their purchase intention using a 5-point scale ranging from 1 ("I definitely would not buy") to 5 ("I definitely would buy").

2.4. *Statistical Analysis*

A one-way ANOVA was performed to evaluate the effect of storage time on the physico-chemical parameters of each variety. Acceptability scores were evaluated by a 2-factor ANOVA (cultivar, storage time). A multiple comparison between means was run by the LSD test (p = 0.05) and the Statgraphics Plus 5.1 software application (Manugistics, Inc., Rockville, MD, USA).

Generalised Procrustes Analysis (GPA) was applied to the FCP data by taking into account the total dataset (harvest, 15 and 30 storage days plus the SL data). These analyses were performed with the software XL-stat (XLSTAT 2019.1.3).

3. Results and Discussion

3.1. Physico-Chemical Parameters

As for the other citrus fruit, sweet and acid attributes are key factors for mandarin quality. In fact, the internal quality requirements for exporting and marketing citrus fruit in the European Union are based on minimum juice yield and maturity index values (MI = TSS/acidity) [25]. In this study, the minimum criteria required for commercialising mandarin hybrids (MI > 7.5 and juice yield > 33%) were met for all the varieties at harvest time (Table 2). It is important to highlight that similar MI values may result from different TSS and acidity values. Varieties Ortanique and Omet were a clear example of this as both obtained an MI close to 9.5 at harvest time, while the TSS and acidity levels were clearly higher in Omet. Globally, our results showed relevant differences in the TSS and acidity levels among the six studied cultivars. At harvest time, the lowest sugar concentration was measured in Nadorcott and Ortanique (11.6–12.3 °Brix), while the other varieties obtained significantly higher values between 14–16 °Brix. In general, TSS did not change during the storage period. Only in Nadorcott did it increase 2 °Brix after the first 15 storage days and then remained constant.

Regarding acidity level, the lowest acids concentration at harvest time was determined in Nadorcott and Orri with values close to 1 g of citric ac./100 mL, while Omet had the highest acidity (1.6 g citric ac./100 mL). Acidity evolution during the storage period followed a similar pattern in all the varieties. While fruit was kept at low temperature, the acidity level remained constant or slightly and gradually declined. When fruit were transferred to the SL conditions, acidity significantly lowered, which became more marked after 30 storage days. Loss of acidity is one of the main changes described during the storage of not only mandarins, but also oranges [26–28]. As observed in Table 2, the MI values increased in parallel to the decline in acidity, and this effect was especially marked in Nadorcott, which also increased in TSS.

In addition to sugars and acids, mandarins possess a unique rich flavour which may be attributed to the presence of a mixture of dozens of aroma volatiles in the pulp [29]. During prolonged cold storage, the risk of excessive ethanol accumulation exists, which has been associated with off-flavour manifestation [30]. In this study, the initial ethanol concentration at harvest time remained constant in all the cultivars, while fruit was stored at low temperature. However, when fruit were transferred to 20 °C to simulate the SL conditions, the ethanol concentration markedly increased in all the cultivars. The highest values after SL, close to 200 mg/100 mL, were detected in Nadorcott and Omet.

As previously mentioned, juice yield is one of the quality marketing requirements given its relation to juiciness. At harvest time, all the varieties had juice yield values between 46% and 52%, which was much higher than the minimum requirement of 33% [25]. During the storage period, no changes were observed in this parameter so juiciness perception was not expected to be affected by storage time.

Regarding texture, the firmest fruits at harvest time were those of Ortanique, Orri and Omet, while Nadorcott were the softest. Generally during storage at 1 °C, the firmness values remained constant or slightly lowered. Only the Matiz fruit underwent a marked decline in firmness during cold storage. When fruit were transferred to the SL conditions, fruit firmness decreased in all the cultivars except for Matiz, in which softening had previously happened. At the end of the storage period, the firmest fruits were those of Ortanique, Orri and Omet, with deformation values below 4%, and the lowest firmness was displayed by Nadorcott fruits with more than 6% deformation.

Finally, the skin damage index (SDI) revealed a different susceptibility among cultivars to display skin damage during cold storage (Table 2). The varieties that showed susceptibility to low temperatures were Nadorcott, with several fruit displaying slight skin damage at the end of the study period (SDI = 0.15), and Omet, that manifested moderate damage after 30 storage days plus SL (SDI = 0.39). Skin damage was manifested as brown pitted-like depression on flavedo (Figure 1). For Tri-703, incipient skin damage was detected after

30 storage days in only a few fruit, which resulted in an extremely low SDI value, 0.07, after SL.

Table 2. Changes in the main physico-chemical parameters of the six mandarin cultivars during storage at 1 °C for 15 and 30 days plus the subsequent shelf-life periods of five days at 20 °C (SL).

Cultivars	Storage Time	Firmness (% Def)	TSS (°Brix)	Acidity (g ac. 100mL^{-1})	MI (TSS/Ac)	EtOH (mg. 100mL^{-1})	JY (% juice)	SDI
Ortanique	Harvest	2.5 a ^{A}	12.3 a ^{A}	1.31 b ^{C}	9.4 a ^{A}	60.5 a ^{D}	52.8 a ^{A}	—
	15 ds 1 °C	2.5 a	12.2 a	1.29 b	9.5 a	54.0 a	51.7 a	0.00
	30 ds 1 °C	2.7 b	12.4 a	1.04 a	12 b	50.4 a	52.0 a	0.00
	15 ds 1 °C + SL	3.0 b	12.1 a	1.24 b	9.7 a	148.7 c	51.6 a	0.00
	30 ds 1 °C + SL	3.3 b	11.7 a	1.03 a	11.4 b	107.7 b	49.8 a	0.00
Orri	Harvest	2.2 a ^{A}	15.8 a ^{C}	0.93 c ^{A}	16.9 a ^{D}	30.8 a ^{B}	52.2 a ^{A}	—
	15 ds 1 °C	2.7 b	15.5 a	0.86 bc	18.0 b	24.1 a	49.2 a	0.00
	30 ds 1 °C	2.9 b	15.2 a	0.79 b	19.2 c	15.5 a	52.0 a	0.00
	15 ds 1 °C + SL	3.8 d	15.6 a	0.85 bc	18.3 b	149.2 b	50.5 a	0.00
	30 ds 1 °C + SL	3.3 c	15.2 a	0.64 a	23.7 d	166.2 b	49.8 a	0.00
Nadorcott	Harvest	5.4 ab ^{D}	11.6 a ^{A}	0.94 c ^{A}	12.3 a ^{B}	17.8 a ^{A}	46.1 a ^{A}	—
	15 ds 1 °C	5.2 a	13.6 b	0.85 bc	16.0 b	30.7 a	46.9 a	0.09
	30 ds 1 °C	5.8 b	13.3 b	0.68 a	19.6 c	25.9 a	47.2 a	0.09
	15 ds 1 °C + SL	6.7 c	13.6 b	0.87 bc	15.6 b	171.8 b	48.5 a	0.10
	30 ds 1 °C + SL	6.3 c	14.0 b	0.75 ab	18.6 c	195.8 b	47.3 a	0.15
Omet	Harvest	2.3 a ^{A}	15.8 a ^{C}	1.60 b ^{D}	9.9 a ^{A}	58.4 a ^{D}	51.9 ab ^{A}	—
	15 ds 1 °C	3.3 bc	15.7 a	1.54 b	10.2 a	56.4 a	49.5 a	0.00
	30 ds 1 °C	3.5 bc	16.0 b	1.51 b	10.6 ab	50.2 a	50.7 ab	0.05
	15 ds 1 °C + SL	3.3 b	15.7 a	1.41 a	11.0 b	189.1 b	52.5 b	0.10
	30 ds 1 °C + SL	3.7 c	16.0 b	1.34 a	12.0 c	223.8 c	50.5 ab	0.39
Matiz	Harvest	3.8 a ^{C}	14.1 a ^{B}	1.38 c ^{C}	10.2 ab ^{A}	57.4 a $^{C.D}$	49.7 a ^{A}	—
	15 ds 1 °C	5.4 b	14.1 a	1.42 c	10.0 a	52.2 a	49.0 a	0.00
	30 ds 1 °C	5.4 b	14.5 a	1.33 bc	10.9 bc	52.4 a	48.4 a	0.00
	15 ds 1 °C + SL	5.2 b	14.2 a	1.24 b	11.5 c	175.0 b	50.1 a	0.00
	30 ds 1 °C + SL	5.6 b	14.3 a	1.04 a	13.7 d	164.4 b	51.9 a	0.00
Tri-703	Harvest	3.1 a ^{B}	16.1 a ^{C}	1.16 b ^{B}	13.9 ab ^{C}	45.8 a ^{C}	51.1 a ^{A}	—
	15 ds 1 °C	4.7 c	16.1 a	1.17 b	13.7 a	32.4 a	48.8 a	0.00
	30 ds 1 °C	3.8 b	16.4 a	1.14 b	14.4 ab	32.6 a	44.9 a	0.05
	15 ds 1 °C + SL	4.4 c	16.2 a	1.06 ab	15.3 bc	160.9 c	45.1 a	0.00
	30 ds 1 °C + SL	4.6 c	16.1 a	0.97 a	16.6 c	122.9 b	48.6 a	0.07

Different letters in the same column (a, b, ab, c, bc, d) for each variety indicate significant differences depending on the time of storage ($p < 0.05$). Different superscript letters (A, B, C, D) at harvest time indicate significant differences among varieties ($p < 0.05$). TSS—total soluble solids, MI—maturity index, JY—juice yield, SDI—skin damage index.

Figure 1. Skin damages. The most severe damage manifested by each of the varieties are shown.

Our results showed that skin damage was more intense as the storage period was prolonged. It is well-known that the severity of chilling injury symptoms depends not only on the storage temperature, but also on exposure time [4,31]. However, we cannot affirm that the skin damage manifested by three of the six studied varieties was actually chilling injury symptoms because only one storage temperature was evaluated in this study. That is, such damage may also appear during moderate temperature storage.

3.2. Sensory Profile

The FCP test combined with the Repertory Grid was selected in this study to determine the internal characteristics of the six mandarin varieties at harvest time and the main changes that they underwent during cold storage.

The descriptors used by the panellists to define the sensations perceived when mandarins were tasted can be grouped into aroma characteristics, flavour (including off-flavours) and textural properties (including perception of texture in the mouth and in the hand). The individual descriptors set generated by the panellists ranged from 6 to 14 attributes.

A two-dimensional GPA plot was obtained from the panellists' evaluations during the three assessed periods [at harvest time (cv name_H) and after the SL period following 15 (cv name_15) and 30 (cv name_30)] cold storage days (Figure 2). The total amount of variance explained by the first two dimensions (Dim.) of the average configuration for the consensus map was 48.75% (28.09% the Dim. 1 and 20.65% the Dim. 2). Each dimension can be interpreted through its correlation coefficients with attributes, and those attributes whose correlation was higher than 0.6 (negative or positive) were herein considered to interpret the GPA and are, therefore, listed next to each dimension (Figure 2).

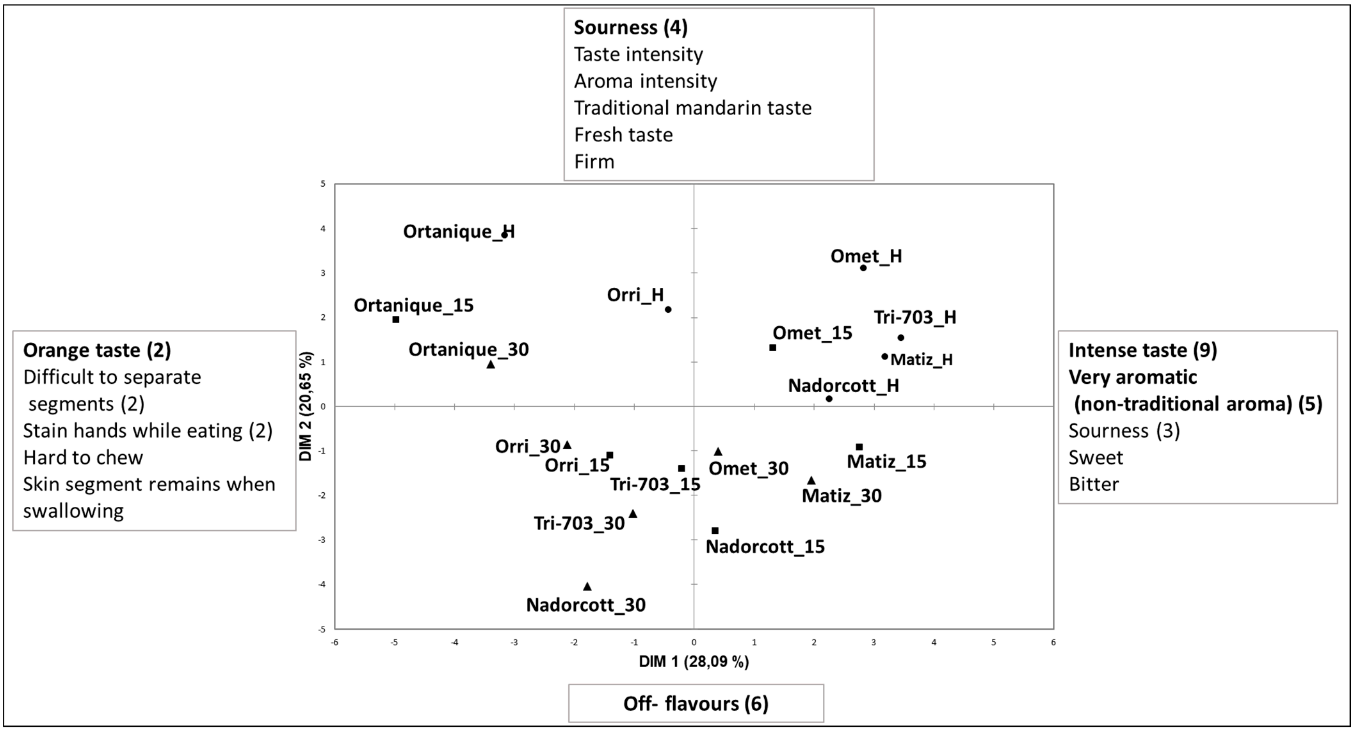

Figure 2. Two dimensions Generalised Procrustes Analysis plot of the differences among mandarins at harvest time and after 15 and 30 days of storage at 1 °C plus a shelf-life period of 5 days at 20 °C. The main descriptors correlated with the first two dimensions are listed together on the boxes with the times that the descriptor was mentioned.

The six mandarin samples evaluated at harvest time (H) were allocated in the upper part of the space (with positive values on Dim. 2). This was associated mainly with the acidity level as sourness was the most frequently cited descriptor by the assessors, and to a lesser extent with taste and aroma intensity, traditional mandarin and refreshing taste and firmness. Samples Ortanique_H and Omet_H were those with the highest positive values on Dim. 2, which was related to their high acidity level and firmness (low deformation values), as analytically determined at harvest time (Table 2), while Nadorcott_H obtained the lowest positive values on Dim. 2 in accordance with its lower acidity and firmness values (Table 2). Of the samples collected at harvest time, a group of four varieties was clearly separated from the other two. Thus, Nadorcott_H, Matiz_H, Tri-703_H and Omet_H were displayed close to one another on the right part of Dim. 1. They were described mainly by the assessors as having an intense mandarin taste, high sourness and having a non-traditional intense aroma. Unlike the aforementioned cultivars, Ortanique was characterised by its orange taste notes and attributes related to the messy factor (the difficulty in separating segments and consequent hand staining when doing so). It was also described as being hard to chew and swallow. The Orri_H sample was displayed at the centre of the plot, which indicates that it presented intermediate characteristics between Ortanique_H and the group made up of the other four cultivars (Omet_H, Tri-703_H, Matiz_H, Nadorcott_H).

Regarding the sensory changes that occurred during storage, except for cultivars Ortanique (Ortanique_15, Ortanique_30) and Omet (Omet_15), the samples that underwent storage generally moved to a greater or lesser extent to the bottom of the plot in relation to samples collected at harvest time. This storage time-related movement of samples led them to obtain negative values on Dim. 2, which indicates that mandarins gradually lost sourness, aroma and taste intensity, freshness and firmness. Moreover, those samples allocated to the lower part of the GPA space were characterised by the appearance of off-flavours. Thus, off-flavours were slightly perceived in Nadorcott after 15 storage days ('Nadorcott_15'), but became more marked after 30 storage days ('Nadorcott_30'). At this storage point, off-flavours were also detected slightly by some assessors in the 'Tri-703_30' samples.

It is worth mentioning that for Ortanique, no remarkable sensory evolution occurred during storage because after the two storage periods, these samples still remained very close to the sample at harvest time. Similarly, sample Omet_15 was also allocated close to Omet_H.

As previously mentioned, for the other varieties, storage led samples to move downward. Moreover, all the samples moved to the left part of the plot to some extent compared to the sample collected at harvest time. This movement from right to left was especially marked in samples Tri-730_30 and Nadorcott_30, and was associated mainly with a loss of intensity for attributes like mandarin intense taste, sourness and aroma intensity.

3.3. Consumer Acceptance and Purchase Intention

The mean acceptability scores and purchase intention based on the external and internal evaluations made by consumers at harvest time and after the SL period that followed 15 and 30 cold storage days are shown in Figure 3.

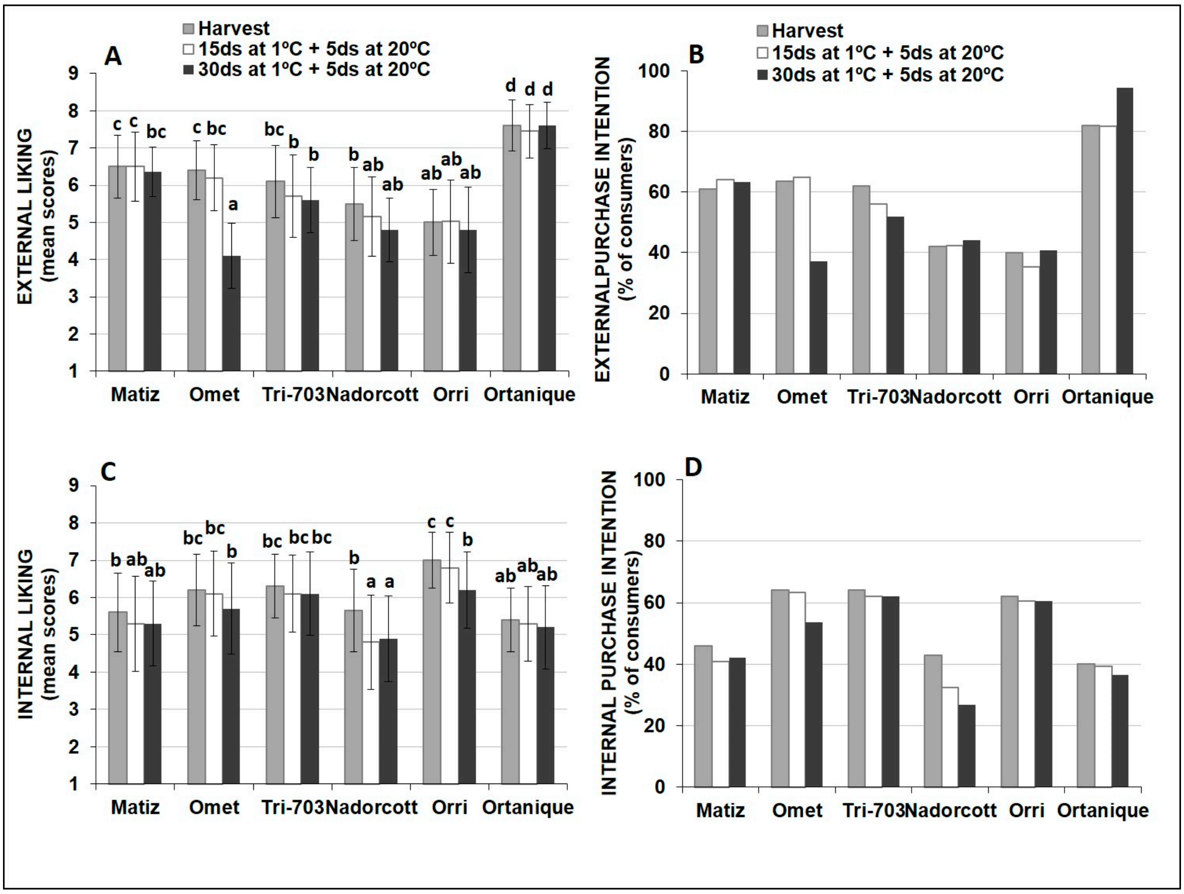

Figure 3. Mean acceptance scores (**A**,**C**) and purchase intention (**B**,**D**) of consumers based on external and internal evaluation of mandarins at harvest and after 15 and 30 days of storage at 1 °C plus a shelf-life period of 5 days at 20 °C. Purchase intention is expressed as the percentage of consumers that responded that they were willing to buy (probably would buy + definitely would buy). Vertical bars indicate standard deviation. Different letters indicate significant differences among varieties and storage times according to the LSD test (p = 0.05).

3.3.1. External Perception

It is known that colour, size and shape crucially influence consumer attention and appreciation based on external observations [32]. Therefore, some of the main external characteristics of the different varieties are shown in Table 3 in order to help to better understand the acceptability scores.

Table 3. Parameters related to physical appearance at harvest time.

Cultivars	Weight (g)	Diammeter (mm)	Shape	CI (1000a/Lb)	Adhesion of Rind to Pulp	Skin Rugosity
Ortanique	139	64	Oblate	16.8	Tight	Medium
Orri	109	62	Oblate, Flatenned	12.8	Medium	Smooth
Nadorcott	81	61	Oblate, Flatenned	17.8	Slight	Very smooth
Omet	120	62	Round	23.7	Medium-tight	Medium
Matiz	106	62	Round	17.4	Medium	Medium
Tri-703	147	69	Oblate	24.4	Slight-medium	Medium-high

The mean acceptability scores based on external appearance ranged between 4.1 and 7.6. The cultivar that consumers most liked externally was Ortanique, which was scored approximately 7.5 irrespectively of storage time (Figure 3A), and more than 80% of consumers were willing to purchase it (Figure 3B). The fruit from this cultivar are large-sized, are regular and oblate-shaped, are dark orange in colour, and their skin is tightly attached to the pulp and not too rugous (Figure S1, Table 3).

The cultivars that proved less attractive to consumers at harvest time and also after 15 storage days were the commercial ones Orri and Nadorcott, with acceptability scores close to 5 (Figure 3A). Indeed only 40% of the consumers stated being interested in purchasing these mandarins (Figure 3B). According to the physico-chemical data, Orri was highlighted for its lower colour index values (CI = 12.8), which was associated with more yellowish skin tones than the other varieties (Table 3, Figure S1). Similarly, the Nadorcott colour also differed compared to the other varieties in this study as it was the only one which was heterogenous to some extent, with some dark orange skin areas and other paler parts (Figure S1). Our results corroborate that although peel colour bears no relation to citrus fruit palatability, maturity or flavour, consumers expect the characteristic colour for specific fruit [33]. Moreover, these two varieties were similar in shape and size. The shape of both was oblate flattened and they were small-sized, with a mean weight of 109 g and 81 g, respectively, for Orri and Nadorcott (Table 3 and Figure S1).

Of the three new cultivars, Matiz and Omet received the highest scores at both harvest time and after 15 storage days. Consumers found them more attractive than commercial cultivars Nadorcott and Orri, and their purchase intention values were about 60% (Figure 3A,B). Both new cultivars bear quite large fruit that are dark orange in colour and are rounded. Their skin is ostensibly adhered to the pulp and rugosity is medium (Table 3 and Figure S1). Finally, the new cultivar, Tri-703, with a more rugous skin, obtained similar acceptability and purchase intention values at harvest time and after 15 storage days than Matiz and Omet.

After 30 storage days at low temperature, the acceptability scores and purchase intention values obtained by Ortanique, Orri, Nadorcott, Matiz and Tri-703 did not change compared to the scores obtained after 15 days. However, a significant decrease in acceptability to scores below 5 was detected in cultivar Omet (Figure 3A), which was associated with the susceptibility of this variety to manifest skin damage during cold storage as shown by the SDI of 0.39 (Table 2). Manifestation of moderate skin damage in Omet fruit was reflected by a sharp drop in purchase intention, which is likely associated with consumers perceiving lack of freshness. Previous studies have shown that appearance plays a significant role in consumer perception of fruit freshness [34], and freshness is one of the main drivers for consumer choice of different fruit, including mandarins [35,36].

According to our results, it would seem that a minimum SDI value is necessary for skin damage to affect consumer acceptance and purchase intention. Thus, while SDI of 0.39 (Omet_30) had a marked effect on consumer perception, the lower SDI values detected for Nadorcott_15, Nadorcott_30, and Tri-703_30 (SDI values between 0.05 and 0.15) did not influence consumer acceptance or purchase intention. Therefore, a minimum number of damaged fruit in a lot and/or minimum damage intensity seems necessary to modify consumer acceptance.

3.3.2. Internal Perception

The mean acceptability scores based on the evaluation of mandarin internal properties at harvest time and after the two storage periods ranged between 4.9 and 7 (Figure 3C).

Our results agree with Morales et al. [7], who showed that the external mandarin quality perceived by consumers may not correspond to internal quality. In fact, when the consumers in this study were asked to evaluate fruit segments at harvest time, the most liked cultivar with scores of 7 was Orri; that is, the variety whose aspect was less attractive. New varieties Omet and Tri-703 scored slightly higher values than 6, while Matiz, Nadorcott displayed somewhat lower acceptance with scores between 5.5 and 6. The variety less liked by consumers was Ortanique, with scores of 5.2. If we bear in mind the FCP results, we can state that the medium intensity of attributes like sourness, taste and aroma of Orri mandarins at harvest time was very much appreciated by consumers. The texture of Ortanique, which was associated with a messy factor and difficult chewing and swallowing, together with its orange taste notes, was a negative attribute for consumers, who gave this variety lower scores. The characteristics shared by the three new varieties and Nadorcott (intense mandarin taste and aroma, and sourness) at harvest time led to similar and intermediate liking scores.

Fruit storage had no significant effect on consumer acceptability of Matiz, Omet, Tri-703 and Ortanique. However, the consumer acceptability scores for Orri and Nadorcott were negatively affected after storage. This effect was detected in Orri after 30 storage days, while Nadorcott acceptability had decreased after 15 days compared to the values recorded at harvest time. The reduced acceptability detected in Nadorcott after 15 storage days was associated mainly with the development of off-flavours, but also with loss of sourness, taste and aroma intensity. However, off-flavours were not described in the Orri samples and, therefore, the reduction in storage-related liking for this variety must probably be due to excess loss of sourness and taste and aroma intensity, especially if we consider that the flavour of this variety was not too intense at harvest time. It is also worth mentioning that despite some semitrained assessors perceiving a slight off-flavour level in the Tri-703 samples stored for 30 days, it did not affect consumer acceptance.

Purchase intention based on internal evaluation was clearly related to consumer acceptability responses (Figure 3C,D). Between 55–60% of the consumers were willing to buy Orri, Omet and Tri-703 at both harvest time and during the whole storage period.

A lower percentage of consumers (40%) were willing to purchase Matiz and Ortanique, on which storage time had no effect. Finally, for Nadorcott, which was the variety with the lowest acceptability scores, 40% of the consumers were willing to buy it at harvest time, but a lower percentage (20–30%) would buy it after storage.

It is worth noting that although the ethanol level analytically detected in most cultivars was higher than 150 mg/100 mL after 30 storage days (Table 2), off-flavour was detected only in Nadorcott after 15 days and in Tri-703 after 30 days. In Nadorcott, the presence of off-flavour was evident and affected consumer liking and purchase intention. However in Tri-703, it was detected only by a few semitrained assessors and had no significant effect on consumer perception. Therefore, the ethanol threshold of 150 mg/100 mL for off-flavour manifestation reported by Hagenmaier [37] did not seem to be generally applicable to all the varieties.

3.4. Relation between Physico-Chemical and Sensory Properties and Consumer Acceptance

An overview of our results allowed us to assess the relationships among the different evaluated parameters. The main physico-chemical changes that took place during the cold storage of the different mandarin cultivars were loss of acidity, increased ethanol and slightly decreased firmness. Of these, increased ethanol concentration and firmness loss were detected after 15 storage days plus SL in all the varieties, while a lowering acidity level was generally detected after 30 storage days plus SL. Therefore, based only on the physico-chemical data, we could expect the sensory changes undergone during storage to be similar in all the varieties and to be manifested as softening and off-flavour after 15 storage days [37], while a decline in sourness could be expected only after 30 storage days. Nonetheless, the FCP technique revealed quite a different reality as cold storage differently affected the sensory properties of the evaluated cultivars. Indeed, no relevant changes were detected in Ortanique, but noticeable changes were more or less marked in the other varieties depending on variety. In general, loss of sourness was detected after 15 storage days and became more evident as the storage period advanced. In addition to sourness loss, storage was associated with less taste and aroma intensity, but this sensory change was less evident in Omet than in Orri, Tri-703 and Nadorcott. Despite all the varieties having similar ethanol levels, off-flavours were detected mainly in Nadorcott, even after 15 storage days.

Therefore, it is obvious that FCP allowed us to obtain much more knowledge of the fruit changes taking place during store than by only the physico-chemical analysis. Sensory changes description also allowed us to explain consumer preferences. It was also interesting to observe how preferences based on external appearance were not at all related to those based on internal properties. Our data revealed that Ortanique was the most externally attractive variety for consumers at both harvest time and after storage. Therefore, in a pre-purchase situation, it is likely that consumers would buy this fruit. However, consumers were not satisfied after tasting and, therefore, a repurchase is unexpected. Contrarily, the internal properties of Orri were those that consumers liked most, but its external appearance was not appreciated.

The variety in which the relation between the sensory profile and consumer acceptance was more evident was Nadorcott because the off-flavour manifestation from 15 storage days clearly led to lower liking and purchase intention scores.

When we focused on the new varieties and took into account both their external and internal properties, we concluded that Omet had the potential for success if stored no longer than 15 days as its sensitiveness to manifest skin damage was a limiting factor for longer storage periods. Although the good external appearance of the new Matiz variety remained throughout the storage period, consumers did not appreciate its internal quality and its consumer acceptance was even low at harvest time. The Tri-703 was the most interesting variety of the new ones. It did not show any relevant skin problems during storage, and internal properties were appreciated by consumers throughout the storage period, with 60% of the participants willing to buy it even after 30 storage days. However, it is important to bear in mind that the semitrained panellists detected a slight off-flavour after 30 days. Although off-flavour intensity was low enough to not affect consumer acceptance, this fact must be taken into account, as storage should not be any longer than 30 days.

In view of our results, we can state that the combined approach herein followed, in which physico-chemical changes were analytically determined and the sensory changes described by the FCP during cold stored were related to consumer acceptance, was most appropriate to select new varieties comparatively to commercial varieties. To our knowledge, this is the first time that such an approach has been followed for selecting varieties and it has proven to have a very high potential to be implemented into the selection process of breeding programmes.

4. Conclusions

By combining the physico-chemical parameters of fruit, the sensory profiling obtained by semitrained assessors and consumer responses, this study was able to identify the limiting factors for consumer acceptance and to establish the maximum period that fruit from the studied varieties can be stored.

Among the new cultivars, Tri-703 had a considerable number of potential consumers because its appearance was attractive throughout storage and its internal properties were liked more than or equally to those of commercial varieties. The internal quality of Omet was also appreciated by most consumers. However, its fruit should not be stored for more than 15 days to ensure its good appearance, as this variety is susceptible to skin damage during cold storage. Finally, Matiz was the most attractive new variety externally, with no skin damage noted during storage. However, its internal properties may be a limiting factor when competing with commercial cultivars. Of the commercial cultivars, Orri is highlighted for its internal properties, while Ortanique displayed the most attractive appearance. In general, Nadorcott was the least appreciated commercial cultivar by consumers after storage.

Supplementary Materials: The following are available online at https://www.mdpi.com/2073-4395/11/1/116/s1, Figure S1: External appearance of mandarins at harvest time.

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Institutional Review Board Statement: The protocol and procedures used in this study were revised by the scientific directorate of Valencian Institute for Agricultural Research, which stated a waiver consent. All articles from the Declaration of Helsinki and the 2016/679 EU Regulation on the protection of natural persons regarding the processing of personal data and on the free movement of such data were met.

Informed Consent Statement: The experimental procedure was explained to, and written consent indicating voluntary participation was obtained from, each participant prior the beginning of the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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