Sensory profile of green Spanish-style table olives according to cultivar and origin

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Abstract

This work studies the influence of cultivar and farming area on the sensory profile of green Spanish-style table olives, using Quantitative Descriptive Analysis. The lexicon developed was subsequently applied to samples of Gordal (G), Manzanilla (M), and Hojiblanca (H) from different origins: Arahal (A), Utrera (U), Alameda (Al), Estepa (E), Casariche (C), Alcalá de Guadaira (AG), Posadas (P), and Almendralejo (Am). The analysis of the data by ANOVA, considering the effect of the sample as fixed and those of the panelists and the sessions as random, showed good repeatability (no significant effect of the session). Bitter, salty, astringent, acid, alcohol and lupin descriptors had significant discriminating power. The samples were characterised by the following sensory attributes: HC, pungent and winery/wine; MP, salty and lupin; GA, acid and lactic acid; HAl, astringent and acetic/vinegar; and MAm, bitter and musty. The multivariate analysis combined with bootstrapping techniques offered a multidimensional view of repeatability, relationships among descriptors, and characterisation and segregation of products. The results then pointed to sensible differences among the sensory profiles of the samples due to cultivar and origin.

Keywords: Green table olives, Sensory descriptors, Sensory profile, Panel performance, Product characterisation

1. Introduction

Green Spanish-style table olives are the major fermented product in the world. Its production during the 2014/2015 season was estimated at 1.500.000 tonnes (60% of the total) according to statistics from the International Olive Council (IOC, 2016). Processing includes a previous lye treatment followed by washing with tap water and brining in a NaCl solution. The product follows a spontaneous lactic fermentation with a variable population of yeasts, which leads to the formation of numerous volatile compounds (Garrido Fernández, Fernández Díez, & Adams, 1997). Traditional preservation of these olives in high salt solutions and their utilisation in cocktails or as appetisers made a detailed study of their sensory characteristics irrelevant for decades. The Trade Standards Applying to Table Olives (IOC, 2004) simply mentions that olives should have sensory and texture characteristics in agreement with their processing system. Furthermore, the “Method for the sensory analysis of table olives” (IOC, 2011) is mainly focused on the commercial classification of the products since only the descriptors related to the perception of negative sensations (abnormal fermentation and other defects) play a crucial role. On the contrary, the gustatory attributes (salty, acid and bitter), and kinesthetic sensations (hardness, fibrousness, and crunchiness), although mentioned, are relegated to a secondary position. Despite this, most sensory studies on table olives are still associated with the official methods (Lanza, & Amoruso, 2016; Yilmaz, & Aydeniz, 2012). However, specific descriptors (terms, definitions, and references) for describing the particular sensory profiles of the Protected Denomination of Origin (PDO) *Aloreña de Málaga* presentations (Galán Soldevilla, Ruíz Pérez-Cacho, & Hernández Campuzano, 2013) or ripe olives (Lee, Kitsawad, Sigal, Flynn, & Guinard, 2012) have been developed.

The sensory profile of green Spanish-style table olives should be related to the non-volatile (Garrido Fernández et al., 1997) and volatile compounds present in them. Cortés-Delgado, Sánchez, de Castro, López-López, Beato, and Montañó (2016) identified *p*-cresol,

phenylethyl alcohol, acetic acid, ethanol, ethyl acetate, and (Z)-3-hexen-1-ol, among other components in the headspaces. Therefore, a great diversity of sensory notes would be expected in green Spanish-style table olives. Volatile compounds present in other styles and presentations have also been extensively studied recently (Dabbou et al., 2012; Malheiro, Guedes de Pinho, Casal, Bento, & Pereira, 2011).

The Quantitative Descriptive Analysis (QDA) has a wide application in many foods. Alasalvar, Pelvan, Bahar, Korel, and Ölmez (2012) used it to investigate the flavour of natural and roasted Turkish hazelnut varieties, relating the notes to the signals from the electronic nose by chemometric tools. Qin, Pang, Chen, Cheng, Hu, and Wu (2013) applied QDA to study the flavour profiles of high, middle and low-grade Chinese green and black teas. Minerality was correlated positively with reduce, chalky, and grassy aromas and bitter taste and negatively with barrel, caramel, honey, juicy fruit, musty, and cat pee aromas (Heyman, Hopfer, & Bershaw, 2014). The QDA includes the identification and development of a lexicon for the product to be studied, and the use of reference material for panel training (Pujchakran, Suwonsichon, & Suwonsichon, 2016).

This work aimed to introduce a novel approach to the sensory characterisation of green Spanish-style table olives by QDA. It includes the development of a lexicon and its application by a trained panel to study the sensory profiles of samples from diverse cultivars and farming areas. The results allowed for evaluating panel performance, the sensory characterisation of samples (product profiles), and the discrimination power of the descriptors. Also, a multivariate analysis of data using bootstrapping techniques is presented.

2. Materials and Methods

2.1. Olives and their processing

The olives, harvested from the second half of September to the last week of October 2014, were of the Manzanilla, Gordal, and Hojiblanca cultivars grown in different areas of Andalusia and Extremadura (Spain): *Manzanilla*, Alcalá de Guadaira (Sevilla), Posadas (Córdoba), and Almendralejo (Badajoz); *Gordal*, Utrera (Sevilla) and Arahál (Sevilla); *Hojiblanca*, Alameda (Málaga), Estepa (Sevilla), and Casariche (Sevilla). By combining cultivar and origin, the samples were coded as MAG, MP, MAm, GU, GA, HAl, HE, and HC, respectively.

The olive samples were elaborated in duplicate batches as green Spanish-style, using polyethylene containers (5.2 kg olives and 3.4 L brine), and they received similar processing treatments. The debittering treatment was carried out with a lye solution (1.90-2.10 g/L) which penetrated 2/3 of the flesh, followed by one washing with tap water for 11-17 h (depending on the lye concentration). After washing, brining was carried out by adding a 11% NaCl solution into the containers.

The evolution of the spontaneous fermentation was monitored by controlling the pH, titratable acidity, combined acidity, NaCl, and sugar in the brine (Garrido Fernández et al., 1997). After 5 months, there was no residual sugar left, and the process was considered finished. By then, the physicochemical characteristics (López-López, Sánchez-Gómez, Montaño, Cortés-Delgado, & Garrido-Fernández, 2018, Table 1) were considered typical for the style and appropriate for the subsequent sensory analysis.

2.2. Sensory analysis

A total of 15 panelists (9 men and 6 women) participated in the study. They were recruited because of their major role in the implementation of the Sensory Analysis Method for Table Olives (IOC, 2011) and their high level of training due to participation in the habitual sensory analysis of table olives for decades (e.g. Sánchez-Gómez, García García, & Garrido Fernández, 2013). The panelists were familiarised with the QDA techniques by training them for 1 h twice a week for two months. A shorter time frame was necessary for this training

because of their existing expertise in sensory testing. The initial draft of the descriptors was generated by selecting fermented samples from different cultivars and origins, based on their correct physicochemical conditions and ample sensory characteristics. The samples were always presented to the panelists in a randomised order, contained in standard glasses (IOC, 1987), and coded with three randomly chosen digits. Tap water was used for mouth rinsing between each sample evaluation. Initially, the panelists were asked to familiarise themselves with the product and detect as many sensory notes as possible in the olives, regardless of their inclusion or not in the “Method for the sensory analysis for table olives” (IOC, 2011) while excluding the kinesthetic sensations, which were outside the objectives of this work. After two weeks, the panelists were also asked to register their perceived sensory notes in the evaluation sheets, thus generating one list of sensory descriptors according to panelist and session. Finally, the panelists were allowed to familiarise themselves with them and practice with the unstructured scale (1, complete absence; 11, strongest perception) for another month.

When the training with the references ended and the panelists agreed that they were familiar with the new set of descriptors, the panel was used for the QDA. The green Spanish-style table olive samples were taken directly from the fermentation vessels and presented to panelists, who were asked to mark the intensity of the different descriptors in their corresponding scales using the methodology above-mentioned. Between tests, the panelists were provided with tap water to cleanse the palate. The scores of the attributes were measured with the exactitude of one decimal point and the results tabulated. The matrix of data consisted of 240 rows (8 samples x 15 panelists x 2 sessions) and 19 columns (sample, panelist, session and the 16 descriptors).

2.3. Data analysis

The data were analysed using the SensoMineR v.1.07 software (Husson, & Lê, 2007). The program was designed and programmed in R language (R Development Core Team, 2011) and collects classical methods usually applied when analysing sensory data as well as others directly conceived in the developers' laboratory. SensoMineR provides not only a synthesis of the results of the analyses of variance (ANOVA) models but also numerous easy to interpret graphical outputs. Particular interest was paid to the generation of virtual panels, by bootstrapping techniques, for the multivariate analysis and construction of product confidence ellipses. The Spider graphs were produced using Panel Check V1.4.2 software (2015).

3. Results and discussion

3.1. Development of the lexicon

Once the month of training was completed, the sheets with the descriptors were collected and studied (relevance and frequency) by the panel leader. A total of 40 descriptors were found in the table olive samples used for the suggestion of descriptors. The highest frequencies were found for salty (87 nominations), sour (68), bitter (56), piquant (49), astringent (42), pungent (38), lactic acid (32), acetic acid/vinegar (30), lupin (25), green fruit (14), grass (14), winery/wine (13), musty (13), ripe fruit (12), hay (11), and alcohol (10). Many others like beer, glue, mint, pickled, or rancid were mentioned only once. After discussion, under the supervision of the leader, the panel agreed to retain 16 descriptors for evaluation (Table 1). The list is different from that proposed for *Aloreña de Málaga* since many of the notes found in *Aloreña de Málaga* are related to the seasoning material (garlic, fennel, thyme or red pepper) (Galán Soldevilla et al., 2013). It also differs from that used by Lee et al. (2012) for ripe olives (darkened by oxidation), except for some aroma, flavour or taste descriptors. However, the selection of the descriptors to characterise the sensory profiles of directly brined olives from diverse Sicilian and Spanish olive cultivars followed a similar procedure to that applied in this work (Aponte et al., 2010).

3.2. Evaluation of samples

To analyse the scores assigned by the panel to the samples, the matrix of data (López-López et al., 2018, Table 2) was subjected to unidimensional and multivariate analysis to evaluate panel performance, sensory profile and product characterisation.

3.2.1. Overview of results

The scores given to the descriptors according to samples (López-López et al., 2018, Figure 1) were studied and considered appropriate for analysis. Boxplots (López-López et al., 2018, Figure 2) demonstrated that the greatest differences in the average scores of samples were observed for salty, bitter, sour, astringent and piquant. Therefore, they could be the main contributors to the sensory profiles of the samples. However, their boxes always overlapped (López-López et al., 2018, Figure 2), a circumstance that made the use of ANOVA or multivariate techniques necessary for proper data evaluation.

3.2.2. Panel performance

The study of the sensory panel performance is important to produce reliable results. Latreille et al. (2006) proposed a methodology for measuring the global performance. It is based on a mixed linear model describing the sensory score as a function of various effects: samples, panelists, sessions and the interactions panelists·samples, panelists·sessions, and samples·sessions. In this work the panel performance was achieved by the *panelperf* function of SensoMineR which performed an ANOVA, using the following model:

$$\text{Score} = \text{sample} + \text{panelist} + \text{session} + \text{sample} \cdot \text{panelist} + \text{sample} \cdot \text{session} + \text{panelist} \cdot \text{session}$$

where response stands for the expected score and sample, panelist, and session for the predictive variables. The panelist and the session were both considered random effects.

a) Sample effect (power of discrimination) and panelist effect

An overall panel performance on all descriptors is summarised by the p-values of the effects of sample, panelist, session, and their interactions deduced from the ANOVA analysis. In Table 2, the results are presented and sorted in ascending order by sample p-values and according to descriptors. When the sample effect was significant at $p \leq 0.05$ for a descriptor, it was considered efficient for discriminating among samples; therefore, bitter, salty, astringent, sour, alcohol and lupin (Table 2) can segregate among samples. The most discriminant power was found for bitter and salty, due to their marked low p-values, while green fruit (at the bottom) would not contribute at all (close to 1 p-value) to discrimination (Table 2). These results can be comparable to discriminant assays on table olives previously reported. Hurtado, Reguant, Bordons, and Rozés (2009) studied the influence of fruit ripeness and salt concentrations on Arbequina cultivar. The panelists were not able to tell the laboratory-scale processed olives from commercial samples, nor could distinguish between green olives from different brines.

The panelists always had significant effects on the descriptors' scores at $p \leq 0.05$ (Table 2); however, they are usually significant in the sensory analysis because, despite the training received, they normally do not use the scale in the same way. In any case, this fact does not affect the ANOVA interpretation much because of its removal in the analysis.

b) Panel reproducibility

Session effect. The effect of the session was not significant (except for astringent, grass, and pungent) (Table 2), indicating an overall good panelist performance over time (the samples were assessed in the same way from one session to another), which is a situation that is appropriate and desired.

Sample.panelist interaction. It is related to another aspect of the panel reproducibility. When it is significant, there is no total consensus among the members of the panel to evaluate some descriptors in all samples. In this study, the interaction was significant only for salty and sour

(discriminant descriptors), and lactic acid. However, there was consensus for the rest of the descriptors (Table 2). The meaning of such interaction is illustrated by its coefficients (defined as the difference between the expected mean score by all panelists and that given by a specific one) for salty and sour (Figure 1). In it, two situations are observed: a) panelists do not rank samples in the same order; e.g. panelist A11 assigned the highest score for salty perception to HAI while panelist A8 gave the lowest t-values to the same sample; for sour, diverse trends among panelists are similarly observed, and b) panelists do not use the scale in the same way (for salty, panelists A3 and A11 or, for sour, panelists A1 and A14 do not use the same amplitude of scale).

The focus of the interaction sample-panelist can also be fixed on the contributions of their factors to the ANOVA model. As examples, the most relevant sample contributors (as assessed by the t-values) were MP to salty, GA to bitter, MAm to alcohol, GA to sour or MAG to astringent (López-López et al., 2018, Figure 3) while the major panelist contributors (as assessed by the ANOVA coefficients) were A9 and A10 to musty, A7, A9, and A10 to alcohol, A15 and A12 to salty, or A8 and A15 to bitter (López-López et al., 2018, Figure 4).

C) Panel repeatability

Sample-session interaction. The meaning of this interaction should not be confused with the session effect, which refers to the mean of all samples between sessions. In this study, the sample-session was significant in the case of a few descriptors (Table 2), indicating that some samples were not assessed in the same way from one session to another (the mean of each product changed from one session to another) but, overall, the panel was repeatable.

Panelist-session interaction. It was found significant in only a reduced number of assessors and, subsequently, most panelists had the same score from one session to another (Table 2). As an example, only panelists A7 and A10 gave different scores for astringent in sessions 1 and 2 (Figure 2).

d) Panelist performance

A panelist can be considered efficient if she/he can discriminate, is repeatable and agrees with the rest of the panel. Rossi (2001) defined repeatability as the ability to score the same product consistently for a given attribute and reproducibility as the ability to score products the same, on average, as the other panel members. Latreille et al. (2006) also proposed several methods for the individual performance of each panelist, regarding discriminability and agreement or disagreement with the panel. In this work, the panel performance study was considered as an essential step for the reliability of results.

Panelist agreement. This characteristic was estimated as the correlation, by descriptors, between the panelists' scores and those of the adjusted means of the panel (estimated by the ANOVA model). In it, both panelists in line and descriptors in columns are sorted from the strongest to the weakest by their marginal median (López-López et al., 2018, Table 3). The strongest agreement, highest significant correlation (in blue) among panelists and the whole panel was observed for A1 for hay and the lowest (in brown) for A14 for sour (panelist scored the sample in the opposed direction of the whole panel). Some panelists strongly agree with the panel in one descriptor but disagree in another (e.g. A6 for piquant and hay, respectively). Most panelists showed moderate correlations, but several panelists correlated negatively in the case of specific descriptor/s (e.g. A14 in sour, or A15 and A2 in musty); the descriptor with the most negative panelist correlations was green fruit, in agreement with its low discriminant power (Table 2).

Discrimination power of each panelist. The individual efficiency of panelists was evaluated with the model: score=sample+session. The ANOVA produced the matrix of the p-values (López-López et al., 2018, Table 4) associated with the F-test of the sample effect on each panelist, sorting rows and columns by the median estimated over them. In this study, there was no systematically excellent or bad panelist, but many of them were good at some descriptors

(significant p-value, in brown) and, overall, panelist discrimination was reasonable (López-López et al., 2018, Table 4).

Panelist repeatability. The panelists' repeatability (ability to always give the same score to each product) was evaluated by the standard deviation (SD) of the model residual for each panelist and descriptor (López-López et al., 2018, Table 5). It was considered that $SD \geq 1.96$ was produced when the panelist did not score samples in a narrow range through the different sessions. There were a few panelists who graded the samples differently from one session to another ($SD \geq 1.96$, in blue) but most of them showed reasonable dispersion for the majority of the descriptors. Therefore, in general, the panelists showed acceptable repeatability.

3.2.3. Product characterisation

Once the quality of the data provided by the panelists has been checked, it makes sense to finally adopt a product perspective since the data were collected, ultimately, for the sensory characterisation of the samples and, based on it, their possible segregation. QDA methods aim at obtaining an accurate description of the products regarding a list of descriptors (their so-called sensory profiles) that define their sensory spaces and reveal their relationships. In line with this objective, a full image of the sensory profiles of the diverse samples is provided by the spider graph (López-López et al., 2018, Figure 5). The most similar values were observed for pungent, ripe fruit, or musty. GA is characterised by its high score for sour and low for bitter. MP had the highest score for salty. MAm is high for bitter while HC has average values for all descriptors. However, in this work, the bitter taste scores were usually around the average or below it. This residual bitterness may be due to an insufficient lye treatment (Garrido-Fernández et al., 1997) or caused by the presence of other elements in the brine as reported by Marsilio, Campestre, Lanza, De Angelis, and Russi (2002) who observed that fermentation in a mixture of NaCl and KCl (1:1) was acceptable for consumers but slightly bitter. In green Spanish-style Turkish olive cultivars, significant differences between descriptors

were only found for vinegar and oily, strongly related to the oil content (Yilmaz, & Aydeniz, 2012). The spider graph (López-López et al., 2018, Figure 5) also points to the difficulties in establishing specific sensory profiles due to the observation of different scores for only a few attributes.

Descriptors that differentiate the samples were identified through the ANOVA, described in section 3.2.2, performed descriptor by descriptor on the original data which computes the adjusted means of samples vs descriptors (López-López et al., 2018, Table 6). The information may contribute to some comparisons between samples and to roughly grouping them. GU and HE are characterised by high (in blue) average scores (over the general mean) for hay. Several samples show simultaneously high (blue) and low (brown) scores for different descriptors like MAm (high for bitter and alcohol but low for ripe fruit and sour) or HC (high for winery/wine and astringent but low for hay). HAI stands out because of its low (pink) lupin score. The contribution of each descriptor to the sensory profile of samples may also be visualised by the coefficients (effects) of samples in the ANOVA model, e.g. bitter and sour in GA (López-López et al., 2018, Figure 6). Also, those with significant p-value associated with the F-test of the product effect on each descriptor may be easily identified (López-López et al., 2018, Figure 7). In a study on natural olives, Lanza and Amoruso (2016) found high scores for salty and bitter but low for sour since the limited lactic acid fermentation. In *Aloreña de Málaga* olives packaged in diverse salt mixtures, high concentrations of calcium were related to bitterness and hardness, but potassium was not related to any descriptor (Moreno-Baquero, Bautista-Gallego, Garrido-Fernández, & López-López, 2013). Apparently, the nutrient salts require a threshold to be detected by sensory analysis. The sensory characteristics of green Spanish-style and ripe olives were reported to remain stable during the commercial shelf life, with only non-significant changes in most of the attributes (Sánchez-Gómez et al. 2013; García-García, Sánchez-Gómez, & Garrido-Fernández, 2014).

3.3. Multivariate data assessment

The multivariate sensory data analysis is widely used. The descriptive analysis of a complex product space for drug-beverage mixtures was studied by applying Principal Component and Hierarchical Clustering Analysis (Pense-Lheritier, Vallet, Aubert, Courne, & Lavarde, 2016). The exploration of the perception of minerality in white wines was analysed by Heymann et al. (2014), evaluating the data by canonical analysis, which allow determining the sample separations in two-dimensional space.

In this work, PCA analysis, in combination with bootstrapping, was used to visualise panel performance, characterisation of samples and their segregation. The studies were made by considering the results of a virtual panel obtained by taking successive samples (500 simulations) from the real data, selecting those variables with contributions higher than 0.20, and fixing a $p=0.05$ for confidence limits when appropriate. The analysis was made using the function `panelist-session` and `panelist` for repeatability and product characterisation, respectively. The results are interpreted by projecting the variables or cases onto the plane of the first two PCs.

Repeatability. In this case, the first two components (Figure 3) explained 33.36% and 17.92% of the variance, respectively and the PCA projections were focused on the results according to sessions. The results showed good repeatability of descriptor scores between sessions (closeness of vectors from each descriptor but different sessions) for hay, alcohol, bitter or sour. However, others exhibited appreciable displacements from one session to another (lupin, salty, musty or winery/wine) (Figure 3), indicating certain differences in the way these descriptors were evaluated between sessions. Also, a considerable dispersion among the data of each descriptor around their respective vectors is observed (Figure 3, which reproduces only part of points and discriminating descriptors with $p \leq 0.20$) when, ideally, they should be grouped around the end of the vectors. Overall, the projection of the samples on the plane of

the same PCs, according to sessions (Figure 4), shows acceptable repeatability as the successive centres of samples were some what close, and the confidence ellipses had a marked overlapping.

Product characterisation. The multivariate analysis for product characterization is frequently used. In a recent study, it was used to segregate between sliced ripe table olives from different countries and relate them with the corresponding descriptors (e.g. olives from Egypt were characterized by mouth coat, moist, or thick) (Le et al., 2012). Also, PCA and Partial Least Square related the mineral contents (Na, Ca, K) with the scores given to *Aloreña de Málaga* olives packaged in diverse salt mixtures (Moreno-Baquero et al., 2013).

In this work, only three eigenvalues higher than 1 were found in the PCA (López-López et al., 2018, Figure 8), but the first two explained a sensible proportion of the variance (67.52%) and, consequently, the projections of the variables and cases on them could be very informative, as observed in the following sub-sections.

Agreement among panelists and the whole panel. By projecting the samples as seen by the whole panel (squares, each sample represented by one colour)) and the panelists (linked to samples by the same colour), it may be appreciated how close their answers were (Figure 5). There were marked discrepancies in some cases (see A9 for at least 5 samples), but most of the panelists were placed close the samples and around their respective centres. The graph is then useful for identifying panelists in the farthest positions and to facilitate the appropriate correcting measures (e.g., for A9, A7, or A6).

The relationship among variables. The projection of the most discriminant descriptors ($p \leq 0.20$), regardless of session, on the plane of the first two PCs can be used to interpret their relationships (Figure 6, which reproduces only part of points to facilitate readability). Alcohol, winery/wine, bitter, and musty are positively related to PC1 while lupin, and sour are negatively associated with it. Lupin, salty, and astringent present short vectors and may not be

well explained in the graph. Among descriptors, winery/wine, bitter, and musty are strongly related but opposed to lupin and, possibly, to hay and salty; but the two groups are quite different. Also, it is observed that sour was opposed to musty and bitter; lupin was not at all related to musty or bitter (both groups form an angle of approx. 90°). These associations could be used for investigating their possible metabolic origins when crossed with the corresponding microbial populations. Galán Soldevilla et al. (2013) also found an opposed relationship between sour and lactic acid with bitter. In ripe olives, alcohol was opposed to sour (or lactic acid) (Lee et al., 2012), possibly due to the predominance of yeasts during the storage period before processing (Garrido Fernández et al., 1997).

Discrimination power. The gravity centres of the virtual panel perception of products (the same of the real panel) were also projected onto the plane of the two first PCs. Also, 95% of the closest points of the generated cloud of points were used to draw their confidence ellipses (Figure 7). PC1 discriminated MAm, HAl, and HC from MP, GU, MAG, and GA fairly well. Apparently, PC2 segregated MAm from HAl and HC or MP and GU from MAG and GA, although in some cases the segregation was not efficient since their confidence ellipses overlapped. Combining the directions of descriptors on the correlation circle (Figure 6) with the sample positions (Figure 7), an overview of the sample sensory profiles may be drawn. MAm, HAl, and HC had similar (and different from the other samples) sensory profiles characterised by their high scores for musty, bitter, winery/wine, alcohol and, possibly astringent. GA is also peculiar and characterised by its high score for sour (due to the ability of Gordal to ferment). MP and GU showed quite similar sensory profiles associated with lupin and, possibly, hay and salty. Finally, MAG has a profile half way between GA and MP, GU and HE. Galán Soldevilla et al. (2013) also reported good discrimination among *Green*, *Cured*, and *Traditional* presentations, associating them with bitter, sour, and wood, respectively. Aroma and flavour characteristics were the attributes that separated sliced ripe olives according to their countries of origin, based on the 2nd and 3rd PCs since the 1st was a textural dimension (Lee et al., 2012), not

considered in this work. They were also the attributes that determined consumer preferences (Lee et al., 2012). PCA separated defected and un-defected samples in different parts; however, the highest loading in both cases was related to kinesthetic sensations (Lanza et al., 2016).

The dissimilarities among the table olive samples under study were also studied by the Hotelling's T-tests (Table 3). MAG was different (p -values ≤ 0.05 , coloured in pink) from most of the samples, except for GA. GU was similar to HE and MP but distinct from the others. The significant differences between any other pair can be similarly deduced. Overall, most samples showed peculiar sensory profiles due to their significant distances.

4. Conclusion

A lexicon to characterise the sensory profile of green Spanish-style table olives was developed and applied to the description of samples from diverse cultivars and production areas, using a trained panel and Quantitative Descriptive Analysis. The panel and panelist performance checking showed acceptable reproducibility and repeatability. The study was completed with a multidimensional analysis, which, by applying resampling techniques, created a virtual panel. The generated data were used for performing PCA and to evaluate repeatability under a multidimensional overview. PCA analysis of the adjusted means (samples vs descriptors) was particularly useful for studying relationships among descriptors and segregation of samples. This work will then enable further developments in the field.

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Figure captions

Figure 1. ANOVA model. Coefficients for the interaction sample·panelist for salty and sour. Abbreviations for panelists are represented in this case only by their order number. GA, (cultivar, Gordal; origin, Arahál (Sevilla)); GU, (Gordal; Utrera (Sevilla)); HAI, (Hojiblanca; Alameda (Málaga)); HC, (Hojiblanca; Casariche (Sevilla)); HE, (Hojiblanca; Estepa (Sevilla)); MAG, (Manzanilla, Alcalá de Guadaira (Sevilla)); MAM, (Manzanilla; Almendralejo (Badajoz)); MP, (Manzanilla, Posadas (Córdoba)).

Figure 2. Panelist-session interaction (panel repeatability) for astringent according to panelists. Abbreviations for panelists are only represented by an A (assessor) followed by the order number.

Figure 3. Repeatability. Average scores for descriptors, according to sessions. Ast, Astringent; W/W, Winery/Wine; Alc, Alcohol.

Figure 4. Projection onto the first two PCs of the partial virtual centres of samples and their confidence ellipses, according to session. MAM, (cultivar, Manzanilla; origin, Almendralejo (Badajoz)); HAI, (Hojiblanca; Alameda (Málaga)); MP, (Manzanilla, Posadas (Córdoba)); GU, (Gordal; Utrera (Sevilla)); HC, (Hojiblanca; Casariche (Sevilla)); HE, (Hojiblanca; Estepa (Sevilla)); MAG, (Manzanilla, Alcalá de Guadaira (Sevilla)); GA, (Gordal; Arahál (Sevilla)).

Figure 5. Projection onto the first two PCs of the appreciation of samples by the whole panel and each panelist. Abbreviations for panelists are represented by only an A (assessor) followed by the order number. MAM, (cultivar, Manzanilla; origin, Almendralejo (Badajoz)); HAI, (Hojiblanca; Alameda (Málaga)); MP, (Manzanilla, Posadas (Córdoba)); GU, (Gordal; Utrera (Sevilla)); HC, (Hojiblanca; Casariche (Sevilla)); HE, (Hojiblanca; Estepa (Sevilla)); MAG, (Manzanilla, Alcalá de Guadaira (Sevilla)); GA, (Gordal; Arahál (Sevilla)).

Figure 6. Projection onto the first two PCs (variable factor map) of the major contributing descriptors (based on the virtual panel generated). The numbers of points were intentionally reduced to facilitate its interpretation. Ast, Astringent; W/W, Winery/Wine; Alc, Alcohol.

Figure 7. Projection of the samples and their 95% confidence ellipses as deduced from the virtual panel onto the first two PCs. Mam (cultivar Manzanilla; origin, Almendralejo (Badajoz)); HAI, (Hojiblanca; Alameda (Málaga)); MP, (Manzanilla, Posadas (Córdoba)); GU, (Gordal; Utrera

(Sevilla)); HC, (Hojiblanca; Casariche (Sevilla)); HE, (Hojiblanca; Estepa (Sevilla)); MAG, (Manzanilla, Alcalá de Guadaira (Sevilla)); GA, (Gordal; Arahál (Sevilla)).

Table 1

Descriptors and reference standards chosen for the evaluation of the green Spanish-style table olives sensory profile by Quantitative Descriptive Analysis.

<u>Category</u>	<u>Sensory attribute; Abbreviation</u>	<u>Definition</u>	<u>References</u>
Aroma	Green fruit; Green	Odour/aroma of fresh green olives and close to harvest in time.	Grinded flesh of fresh green olives.
	Ripe fruit; Ripe	Odour/aroma of ripe olives that have already reached the purple colour.	Grinded flesh of ripe olives that have already reached the purple colour.
	Grass; Grass	Odour characteristic of newly cut grass.	1 drop of cis-3-hexen-1-ol in 50 mL of water or newly cut grass.
	Hay; Hay	The odour of dried grass.	Dried grass wrapped in aluminium paper.
	Lupin; Lupin	Odour characteristic of boiled and salty lupin.	Grinded boiled and salty lupin.
	Lactic acid; Lac	Odour characteristic of lactic acid.	5% Lactic acid solution or yoghurt.
	Acetic acid/Vinegar; A/V	Odor characteristic of acetic acid.	5% Acetic acid solution or vinegar.
	Winery/Wine; W/W	Perceived wine odour.	50% v/v white wine in brine.
	Musty; Musty	Humus-like aromatics that may or may not include damp soil, decaying vegetation, or cell-like characteristics.	0.4 mg of 1-octen-3-ol in 1 L of water or wet garden soil.
	Alcohol; Alc	Characteristic odour of alcohol group compounds such ethanol.	10% v/v solution of ethanol in water.
Taste	Salty; Salty	The taste sensation perceived on the tongue as stimulated by sodium salts, such as chloride and in part other salts.	2 g/L NaCl in water.
	Bitter; Bit	Basic taste associated with caffeine and other bitter compounds.	0.3 g/L caffeine in water.
	Sour; Sour	The taste sensation perceived on the tongue as stimulated by acids such citric acid.	0.3 g/L citric acid in water.
Mouthfeel	Astringent; Ast	A sensation that lingers and coats, dries and numbs the mouth, palate and tongue.	0.5 g/L tannic acid in water or a piece of kaki.
	Piquant; Piq	Causing a sharp sensation of the buccal mucosa membranes.	Virgin olive oil from the Picual variety.
	Pungent; Pun	Causing a sharp sensation of the nasal mucosa membranes.	Vinegar of wine.

Table 2

Overall panel performance as assessed by ANOVA, sorted by sample p-values. It includes main effects (samples, panelists, and sessions) as well as interactions. Sample was considered fixed effect while panelist, session, and their interactions were analysed as random.

Descriptor	Sample	Panelist	Session	Sample.Panelist	Sample.Session	Panelist.Session	Median
Bitter	7.4e-6	1.0e-26	6.8e-1	9.8e-2	4.4e-2	1.9e-1	7.1e-2
Salty	4.4e-5	6.5e-20	1.1e-1	2.5e-2	2.4e-2	2.7e-2	1.3e-2
Astringent	1.5e-3	9.9e-22	2.4e-3	2.5e-1	4.1e-2	5.0e-4	1.9e-3
Sour	2.0e-3	1.0e-33	6.9e-1	4.0e-2	8.4e-1	7.8e-2	5.9e-2
Alcohol	1.7e-2	8.8e-21	8.1e-1	2.3e-1	9.9e-2	9.8e-1	1.7e-1
Lupin	3.9e-2	1.6e-17	3.03e-1	4.9e-1	1.6e-2	6.8e-2	5.3e-2
Hay	5.1e-2	1.5e-20	3.1e-1	4.3e-1	6.9e-1	2.8e-1	2.9e-1
Winery/Wine	6.8e-2	4.8e-15	5.2e-1	5.3e-1	3.4e-1	7.7e-1	4.3e-1
Musty	1.2e-1	9.6e-19	9.3e-1	1.2e-1	3.6e-1	5.8e-1	2.4e-1
Piquant	1.8e-1	5.6e-16	1.3e-1	1.5e-1	8.2e-1	5.7e-3	1.4e-1
Grass	3.8e-1	3.7e-15	4.6e-3	5.1e-1	1.5e-1	2.3e-1	1.9e-1
Acetic acid/Vinegar	4.5e-1	1.6e-19	6.5e-2	1.8e-1	3.2e-1	5.2e-1	1.2e-1
Ripe fruit	7.1e-1	2.9e-14	5.3e-1	9.1e-1	6.3e-1	4.4e-2	5.8e-1
Pungent	7.4e-1	5.2e-18	4.0e-2	6.1e-1	6.4e-1	7.0e-2	3.4e-1
Lactic acid	7.9e-1	1.1e-29	2.9e-1	4.3e-3	7.8e-2	1.7e-3	4.1e-2
Green fruit	9.4e-1	3.9e-14	6.9e-1	8.4e-1	7.1e-1	6.6e-1	6.8e-1

Note: Significant ($p \leq 0.05$) effects in bold.

Table 3

Distance between samples as evaluated by the P-values of the Hotelling tests. Significant distances when $p \leq 0.05$.

	GA	GU	HAI	HC	HE	MAG	MAm	MP
GA	1	0.001173	0.001431	0.005239	0.01849	0.1412	0.002337	0.001521
GU	0.001173	1	0.003296	0.0001744	0.6976	0.01517	0.01346	0.7351
HAI	0.001431	0.003296	1	0.4713	0.003017	0.00034	0.4618	0.0003886
HC	0.005239	0.0001744	0.4713	1	7.17e-05	5.84e-05	0.3086	1.027e-05
HE	0.01849	0.6976	0.003017	7.171e-05	1	0.08905	0.01113	0.3316
MAG	0.1412	0.01517	0.00034	5.84e-05	0.08905	1	0.00106	0.05697
MAm	0.002337	0.01346	0.4618	0.3086	0.01113	0.00106	1	0.003814
MP	0.001521	0.7351	0.0003886	1.027e-05	0.3316	0.05697	0.003814	1

Notes: GA, (cultivar, Gordal; origin, Arahal (Sevilla)); GU, (Gordal; Utrera (Sevilla)); HAI, (Hojiblanca; Alameda (Málaga)); HC, (Hojiblanca; Casariche (Sevilla)); HE, (Hojiblanca; Estepa (Sevilla)); MAG, (Manzanilla, Alcalá de Guadaira (Sevilla)); MAm, (Manzanilla; Almendralejo (Badajoz)); MP, (Manzanilla, Posadas (Córdoba)).

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7