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Effect of crossbreeding and rearing system on sensory characteristics of Iberian ham

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Abstract

The aim of this work was to study the influence of crossbreeding (Iberian and Iberian×Duroc 50% pigs) and rearing system (outdoors and indoors) on the sensory characteristics of Iberian ham [using descriptive analysis], and to investigate the relationships among sensory data and subcutaneous fat composition. Crossbreeding had a slight effect on sensory and fatty acid profile (only the bitter taste and some low-content fatty acids were significantly affected), but rearing system had a marked effect on subcutaneous fat composition (most fatty acids were affected) and sensory characteristics (texture characteristics being the most affected together with lean appearance and aroma). Palmitic, stearic and oleic acids were closely correlated to some sensory traits, not only lipid-related characteristics (brightness, fat oiliness) but also to aroma.

Keywords: Iberian ham; Sensory analysis; Dry-cured ham; Crossbreeding; Rearing system

1. Introduction

Iberian ham is an expensive Spanish dry-cured product produced from Iberian pigs, and characterized by a prolonged dry-curing process and excellent consumer acceptance. Crossbred Iberian with Duroc pigs are usually used to improve some productive characteristics, and up to Iberian×Duroc 50% pigs are currently allowed to produce Iberian hams (Boletín Oficial del Estado, 2001). A slight effect of crossbreeding on some Iberian ham physico-chemical parameters has been reported (Antequera et al., 1994), but there is a lack of information about its influence on Iberian ham sensory characteristics. Therefore, the general belief of a lower juiciness, aroma and quality of hams from Iberian×Duroc 50% pigs than from Iberian pigs has not been supported experimentally. Conversely, the effect of rearing system has been extensively researched (cf. review by Cava, Ventanas, Ruiz, Andrés, & Antequera, 2000). Because of its large influence on ham characteristics, commercial grades have been traditionally determined by this factor. Currently Iberian hams are classified into different commercial types (Flores, Biron, Izquierdo, & Nieto, 1988) with very different prices according to the fatty acid composition of the raw subcutaneous fat and the rearing system used during the fattening period. The more expensive hams are made using pigs reared outdoors (usually known as "montanera" system, with feeding based on acorns and pasture) and the less expensive ones from pigs reared indoors (feeding based on concentrate feeds). The sensory differences between dry-cured Iberian hams from pigs reared outdoors and indoors have been researched using the Rasch model (García et al., 1996) and a descriptive analysis (Cava et al., 2000).

There are some factors that influence Iberian ham characteristics within each commercial category, such as the outdoors fattening period length (Flores et al., 1988) or the concentrate feeding composition (Cava, Ruiz, Ventanas, & Antequera, 1999), that can confuse sensory characterization. Performing sensory analysis on hams produced from well-characterised raw hams could simplify the comparison between different commercial categories. Previous studies performed on raw Iberian hams have researched the influence of crossbreeding and rearing system on intramuscular fat and myoglobin

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content, muscle fibre type, fatty acid composition of phospholipids (Andrés et al., 2001; Andrés, Ruiz, Mayoral, Tejeda, & Cava, 2000) and triacylglycerols (Tejeda, Gandemer, Antequera, Viau, & García, 2002). Now attention focuses on how those differences in raw hams influence the sensory characteristics of the hams after dry-curing. In addition, the relationships between sensory and fatty acid data could clarify how changes in fatty acid profiles (currently used to classify hams) are related to sensory characteristics. The purpose of this work was to investigate the influence of crossbreeding and rearing system on the sensory characteristics of dry-cured Iberian hams produced using raw meat previously characterised.

2. Materials and methods

2.1. Samples

Thirty-four dry-cured Iberian hams grouped following a factorial treatment structure were used. Eighteen hams were obtained from pigs (11 Iberian pigs and seven Iberian×Duroc 50% pigs) reared on 30 ha of land during the fattening period (about 50 days), acorns and pasture being available. The other 16 hams (10 Iberian pigs and six Iberian×Duroc 50% pigs) were reared on 6 ha of land with concentrate feeding. One leg of each animal was processed into dry-cured ham following the traditional method (García et al, 1996). The other leg was analysed after slaughter and the results have been published by Andrés et al. (2000, 2001) and Tejeda et al. (2002).

2.2. Fatty acid analysis

Samples of subcutaneous fat were vacuum-packaged and kept at −80 °C. Fatty acid composition was determined by gas chromatography of the fatty acid methyl esters synthesized by using methanolic hydrogen chloride, as described by Carrapiso, Timón, Petrón, Tejeda, and García (2000). The solution (0.1 μl) was injected into an HP 5890 II chromatograph (Hewlett-Packard) equipped with a cold on-column injector, a flame ionisation detector and a 30 m–0.53 mm capillary column coated with a FFAP-TPA stationary phase (1 μm thickness). Conditions were as follows: oven temperature 220 °C isothermal for 30 min, injector and detector temperature 230 °C, flow rate of the carrier gas (nitrogen) 2.6 ml/min.

2.3. Sensory analysis

The samples were assessed by a trained panel of 18 members using a descriptive analysis method previously developed by García et al. (1996). Twenty-four traits about sensory characteristics of Iberian ham (Table 2), grouped in fat and lean appearance, odour, fat and lean texture, taste and aroma were studied using the FIZZ (version 1.01) program. A 10-cm unstructured scale was used, the extremes being ‘‘very low’’ and ‘‘very high’’. Three extremely thin slices from the front of each ham were obtained using a knife and were immediately presented on a glass plate to the assessors. All sessions were done at 20–22 °C in a six-booth sensory panel room equipped with white fluorescent lighting. The whole panel participated in each session, the panellist order being randomised. Three hams from three different groups were successively evaluated in each session (except for the last session), assessing simultaneously only one treatment per session. The sample order was randomised.

2.4. Data analysis

Statistical analyses were performed on the mean responses of the panel for each ham sensory trait (Meilgaard, Civille, & Carr, 1999). A two-way analysis of variance (ANOVA) with interaction by the GLM (General Linear Models) procedure was performed to compare means for each characteristic. A two-way multivariate analysis of variance (MANOVA) with interaction by the GLM procedure was used to compare the groups of hams. Pearson correlation and factor analysis [using principal components analysis (PCA) as the method for factor extraction] and the Varimax rotation were applied to evaluate the relations between variables (Hair, Anderson, Tatham, & Black, 1998). Statistic analyses were performed by means of the SPSS version 10.0.

3. Results and discussion

The fatty acid composition of subcutaneous fat and scores from the descriptive analysis of hams are shown in Tables 1 and 2, respectively.

3.1. Effect of crossbreeding

According to the ANOVA data (Table 1), crossbreeding influenced the fatty acid composition of the subcutaneous fat. All the fatty acids significantly affected (16:1, 17:0, 17:1, 20:0) appeared at low percentages (less than 3.25%) and showed larger values in the fat from Iberian pigs than from Iberian×Duroc pigs (Table 1). None of the fatty acid percentages currently taken into account to classify hams (16:0, 18:0, 18:1 and 18:2, Boletín Oficial del Estado, 2000) was affected by crossbreeding. Therefore, crossbreeding only slightly influences fatty acid composition and its effect on analytical classification is negligible.

Table 1
Effect of crossbreeding and rearing system on the fatty acid composition (%) of the subcutaneous fat (data are presented as mean ± standard deviation and significance levels from a two-ways analysis of variance)[a]

	Outdoors		Indoors		P values		
	Iberian	Iberian×Duroc	Iberian	Iberian×Duroc	Breed	Rearing	Interaction
14:0	0.99±0.550	1.35±0.100	1.65±0.135	1.50±0.094	0.381	0.002	0.039
16:0	21.64±2.797	20.90±1.007	24.28±1.424	24.34±0.581	0.614	<0.001	0.551
16:1	2.59±0.478	2.47±0.262	3.24±0.269	2.77±0.302	0.026	0.001	0.189
17:0	0.27±0.029	0.26±0.023	0.36±0.053	0.29±0.039	0.019	<0.001	0.027
17:1	0.33±0.052	0.32±0.039	0.46±0.056	0.36±0.057	0.004	<0.001	0.021
18:0	9.24±0.796	8.98±0.883	10.51±0.827	11.99±0.923	0.051	<0.001	0.007
18:1	55.10±2.989	55.29±1.193	49.78±1.437	48.87±0.547	0.611	<0.001	0.438
18:2	7.77±0.546	8.34±0.579	7.72±0.925	7.89±0.697	0.154	0.329	0.429
18:3	0.17±0.028	0.17±0.027	0.22±0.038	0.20±0.036	0.212	0.001	0.208
20:0	0.10±0.022	0.09±0.011	0.11±0.020	0.09±0.012	0.009	0.375	0.163
20:1	1.35±0.265	1.36±0.163	1.18±0.131	1.21±0.144	0.818	0.028	0.895
20:4	0.46±0.085	0.48±0.057	0.48±0.075	0.50±0.046	0.470	0.345	0.953

[a] Effects were considered significant at a level of 5%.

With regard to sensory characteristics, only bitterness was significantly affected, hams from Iberian pigs showing larger scores than from Iberian×Duroc pigs (Table 2). Bitter taste is related to peptide (Ruiz et al., 1999) and nonprotein nitrogen (Virgili, Schivazappa, Parolari, Soresi Bordini, & Degni, 1998) content. Crossbreeding is the first known factor that can modify this characteristic in Iberian ham. No influence of other factors such as processing time, rearing system or muscle location has been found (Ruiz, Ventanas, Cava, Timón & García, 1998; Cava et al., 2000). Bitterness was not correlated to subcutaneous fatty acid composition and was only significantly correlated to aroma traits (greater than 0.4 for all traits except for aroma intensity and toasted aroma) and sweetness (0.562, $P = 0.001$).

There was a slight effect ($P < 0.1$) of crossbreeding on other characteristics (bright, marbling and some aroma traits). Hams from Iberian pigs showed larger scores for marbling than hams from Iberian×Duroc pigs, in both outdoor and indoor reared pigs. No influence of processing conditions and rearing system on Iberian ham marbling was found in previous works (Ruiz, Ventanas et al., 1998; Cava et al., 2000) although muscle location (Ruiz, Ventanas et al., 1998; Cava et al., 2000) and age (Mayoral et al., 1999) have a marked effect. Marbling has been related to the intramuscular fat content of Iberian ham (Ruiz-Carrascal, Ventanas, Cava, Andrés, & García, 2000). However, the intramuscular fat content of the raw hams used to produce the dry-cured hams was previously studied and was not significantly influenced by crossbreeding (Andrés et al., 2001; Tejeda et al., 2002), as also found in dry-cured hams from Iberian and Iberian×Duroc 50% pigs by Antequera et al. (1994). Therefore, the effect of intramuscular fat content on sensory characteristics such as marbling is not clear. Some studies have reported close relations (Devol et al., 1988; Ruiz-Carrascal et al., 2000) but others report a lack of correlation between fatness measurements (intramuscular fat content and marbling) and other sensory characteristics in meat (Blanchard, Willis, Warkup, & Ellis, 2000).

The aroma traits slightly influenced by crossbreeding (cured, rancid, mouldy and pungent aroma) showed larger scores in hams from Iberian than from Iberian×Duroc pigs. However, aroma intensity and persistence were not affected. Previous research reported a clear influence of crossbreeding on the volatile aldehydes of Iberian hams and discussed its effects on ham aroma (Antequera Rojas, Córdoba Ramos, Ruiz Carrascal, Martín Cáceres, & Ventanas Barroso, 1993), but our results on the influence on volatile compounds showed only a slight effect (unpublished data), which could explain the slight effect in aroma.

Otherwise, the differences in colour measurements and the myoglobin content reported by Andrés et al. (2000) in the same hams but before dry-curing were not reflected in the dry-cured hams redness. Andrés et al. (2001) also reported a slight influence of crossbreeding on the muscle fibre type and fatty acid profiles of the intramuscular phospholipids of the raw hams. However, a marked influence on the fatty acid composition of the intramuscular triacylglycerols was found by Tejeda et al. (2002) in the same raw hams but these differences were not reflected in the textural traits of the dry-cured Iberian hams (none of the characteristics related to odour or texture was affected by crossbreeding), in spite of the relationship between oleic and palmitoleic acid content to Iberian ham texture (Ruiz-Carrascal et al., 2000).

Therefore, the effect of crossbreeding was slight. These results were confirmed by performing a MANOVA

Table 2
Effect of rearing system and crossbreeding on the sensory characteristics of Iberian hams (data are presented as mean±standard deviation and significance levels from a two-ways analysis of variance)[a]

	Outdoors		Indoors		*P* values		
	Iberian	Iberian×Duroc	Iberian	Iberian×Duroc	breed	rearing	interaction
Fat appearance							
Yellowness	2.00±0.570	2.10±0.799	1.85±0.459	1.89±0.296	0.742	0.359	0.899
Pinkness	3.93±0.879	4.10±0.824	3.68±0.761	3.41±0.367	0.854	0.093	0.431
Lean appearanc							
Redness	4.89±1.017	4.84±0.853	4.30±0.563	4.08±0.698	0.635	0.026	0.764
Bright	4.39±1.002	4.50±0.517	3.46±0.349	2.42±0.411	0.061	<0.001	0.022
Marbling	3.09±0.813	2.44±0.335	2.64±0.503	2.51±0.276	0.064	0.357	0.211
Odour							
Intensity	5.08±0.544	4.69±0.889	4.78±0.516	4.79±0.447	0.381	0.638	0.370
Montanera-ham typical odour	4.71±0.604	4.45±0.729	4.26±0.548	4.15±0.380	0.365	0.079	0.728
Fat texture							
Oiliness	5.12±0.965	5.43±0.672	4.19±0.388	3.69±0.358	0.687	<0.001	0.100
Hardness	3.52±0.679	3.22±0.498	4.31±0.437	4.63±0.151	0.960	<0.001	0.100
Lean texture							
Hardness	5.12±0.681	4.47±0.871	5.37±0.594	5.54±0.521	0.327	0.010	0.099
Dryness	4.85±0.473	4.49±0.794	4.99±0.636	5.47±0.421	0.758	0.012	0.056
Fibrousness	4.38±0.598	3.93±0.730	4.25±0.559	4.06±0.415	0.143	0.997	0.542
Juiciness	5.12±0.607	5.21±0.380	4.75±0.564	4.23±0.296	0.240	0.001	0.104
Taste							
Saltiness	5.64±0.402	5.44±0.389	5.53±0.504	5.51±0.457	0.492	0.911	0.571
Sweetness	2.21±0.606	2.11±0.409	1.67±0.442	1.29±0.234	0.167	<0.001	0.397
Bitterness	2.47±0.267	2.20±0.265	2.32±0.190	2.18±0.105	0.016	0.303	0.465
Aroma							
Intensity	4.89±0.286	4.94±0.487	4.74±0.270	4.74±0.238	0.836	0.128	0.855
Persistence	4.56±0.401	4.40±0.251	4.36±0.443	4.32±0.263	0.453	0.294	0.659
Cured	4.85±0.512	4.65±0.370	4.44±0.393	4.11±0.254	0.077	0.003	0.651
Rancid	2.21±0.464	2.00±0.527	1.95±0.501	1.57±0.137	0.081	0.041	0.592
Other aroma descriptors							
Toasted	1.57±0.289	1.52±0.454	1.37±0.365	1.51±0.264	0.735	0.391	0.445
Mouldy	0.57±0.166	0.46±0.220	0.38±0.108	0.31±0.100	0.092	0.004	0.689
Pungent	1.39±0.217	1.28±0.342	1.34±0.251	1.13±0.267	0.097	0.302	0.632
Ketone-like	0.62±0.328	0.59±0.148	0.49±0.314	0.29±0.089	0.219	0.028	0.358

[a] Effects were considered significant at a level of 5%.

(criteria for data were reached), which showed a lack of differences in the sensory characteristics ($P=0.686$). The lack of large and significant differences could be attributed to the genetic similarity between Iberian and Iberian×Duroc pigs 50% (Andrés et al., 2001). Antequera et al. (1994) also reported slight differences in some physico-chemical parameters between hams from Iberian pigs and Iberian×Duroc 50% pigs and the results also agree with previous data that reported a slight influence of crossbreeding between a selected and a non-selected breed on some muscle characteristics (Coutron-Gambotti, Gandemer, & Casabianca, 1998).

3.2. Effect of rearing system

Most of the fatty acids were affected by rearing system (Table 1), as previously reported (Flores et al., 1988; Ruiz, Cava, Antequera, Martín, Ventanas, & López-Bote, 1998). According to the fatty acid data, hams from pigs reared outdoors and indoors are clearly different and belong to different commercial categories.

Twelve sensory characteristics were significantly affected, including those related to lean appearance (except for marbling), fat and lean texture (except for fibrousness), taste (only sweetness), and aroma (cured, rancid, mouldy and ketone-like). Fat pinkness and lean redness were greater in hams from free-range animals than from those reared indoors, with a slight ($P=0.093$) and a significant ($P=0.026$) effect, respectively. However, Andrés et al. (2001) reported no effect of rearing system on the myoglobin content of the hams studied in this work but before dry-curing. Both sensory variables (fat pinkness and lean redness) were significantly correlated (0.501, $P<0.001$), suggesting a common factor influences both colour characteristics.

The effect of rearing system on brightness was reported by Cava et al. (2000) and could be related to the larger intramuscular content of saturated fatty acids in the raw hams from pigs reared indoors compared with these reared outdoors (Andrés et al., 2001; Tejeda et al., 2002). The differences in the feed composition (Tejeda et al., 2002) seem to be responsible of these differences. Brightness was significantly correlated to lipid-related characteristics, mainly to fat oiliness (0.917, $P<0.001$) and fatty acid composition, mainly to stearic (18:0) and oleic (18:1) acids (−0.766 and 0.765 respectively, $P<0.001$ in both cases), which further suggests the feed source as the cause of the differences. No significant correlation with marbling was found.

Montanera-ham odour was greater for hams from pigs reared outdoors than for those reared indoors, although the differences were slight ($P=0.079$). This trait could be defined as a special and strong meaty note, although no alternative term has been found to describe it (García et al., 1996; Ruiz et al., 2000; Ruiz, Ventanas et al., 1998b). Montanera-ham odour is related to Maillard reaction compounds whose meaty odour is enhanced by lipid oxidation products (Carrapiso, Ventanas, & García, 2002) and has been traditionally related to hams from pigs reared outdoors. The influence of rearing system on this special trait and on odour intensity was not as large as reported by Cava et al. (2000), probably due to the short outdoor-fattening period (about 50 days instead of the minimum of at least 60 days for the better commercial category (Boletín Oficial del Estado, 2000). Otherwise, odour intensity and montanera-ham odour were correlated (0.89, $P<0.001$). Montanera-ham odour showed a remarkable correlation to juiciness (0.743, $P<0.001$) but only a weak but significant correlation to the fatty acid composition (−0.386, −0.373 and 0.39 to palmitic, stearic and oleic acids, respectively).

Most texture characteristics were significantly affected by rearing system, differences being larger in fat than in lean tissues. Fat oiliness was closely correlated to lean brightness (0.917, $P<0.001$) and fat hardness (0.905, $P<0.001$). However, fat hardness correlated to a smaller extent to brightness (0.79, $P<0.001$). As expected, significant correlations were found between fat oiliness and such fatty acids as oleic (0.766, $P<0.001$) and stearic (−0.752, $P<0.001$). Except for fibrousness, all the lean texture characteristics were significantly affected by the rearing system. Some studies on cooked pork meat reported that outdoors rearing causes a decrease in juiciness (Enfält, Lundström, Hansson, Lundeheim, & Nyström, 1997; Jonsäll, Johansson, & Lundström, 2001). However, the effect on the dry-cured hams was the opposite (Table 2), in agreement to previous results on Iberian ham (Cava et al., 2000), probably because of the large differences in the feeding composition when Iberian pigs are reared outdoors or indoors. The influence of rearing system on the intramuscular lipid content and composition of the hams was studied by Andrés et al. (2001) and Tejeda et al. (2002) before dry-curing and could explain the differences in lean hardness and dryness, as reported by Ruiz et al. (2000). However, results from works on other dry-cured hams have been contradictory (Buscailhon et al., 1994; Parolari, Rivaldi, Leonelli, Bellati, & Bovis, 1988).

With regard to taste characteristics, only sweetness was significantly affected by the rearing system. A previous study showed no effect of rearing system on this trait (Cava et al., 2000).

Aroma descriptors were greatly affected by rearing system, as found by Cava et al. (2000). Scores for all the characteristics were larger in hams from pigs reared outdoors than indoors, and differences in cured, rancid, mouldy and ketone-like aroma were significant. These traits were also the only aroma characteristics significantly correlated to fatty acid composition. Most correlations appeared between cured, rancid and mouldy aroma and palmitic, stearic and oleic acids. However, mouldy and ketone-like aroma reached extremely low scores, and these notes were not identified in all the hams nor by all the assessors; therefore they make a little contribution to the overall sensory impression.

In conclusion, the rearing system had a marked effect on the sensory characteristics, as confirmed by MANOVA ($P=0.023$).

3.3. *Relationships among sensory characteristics and fatty acids*

In the principal component analysis, one variable (saltiness) was rejected because of its poor inclusion in the model (Kaiser–Meyer–Olkin measure of sampling adequancy: 0.322). Results are shown in Fig. 1 and were clearly grouped according to rearing system and to a lesser extent according crossbreeding in the first principal component axis.

To study the relationship between variables, a Varimax rotation was performed (Table 3). Variables included in the first principal component were significantly and closely correlated (Pearson correlation coefficients greater than 0.7). The good correlations between textural traits are in agreement with other results on dry-cured hams (Buscailhon et al., 1994; Ruiz et al., 2000).

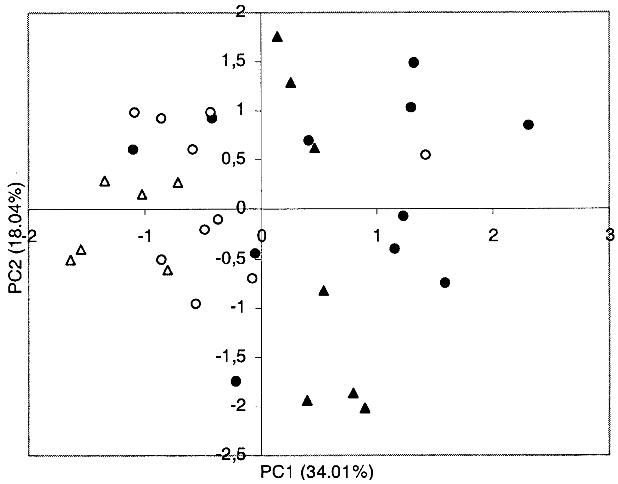

Fig. 1. Projection of the samples onto the space defined by the first two principal components (PC1/PC2). Sample groups: (●) hams from Iberian pigs reared outdoors; (▲) hams from Iberian×Duroc pigs reared outdoors; (○) hams from Iberian pigs reared indoors; (Δ) hams from Iberian×Duroc pigs reared indoors. Principal component analysis was performed on the panel means for each sample.

Characteristics included in the second component were correlated in a lesser extent (less than 0.6), but correlations were significant except for yellowness and rancid aroma, redness and bitterness and redness and rancid aroma. The third principal component was composed of variables significantly correlated, all correlations being greater than 0.49. Brightness, marbling, fibrousness, bitterness, rancid, mouldy and pungent aroma were grouped in the fourth component, although rancid aroma was barely correlated to the other characteristics. Traits included in the fifth principal component were significantly correlated, except for pinkness and mouldy aroma. Characteristics included in the sixth component were also correlated (greater than 0.49, $P<0.001$). With regard to the relationships between sensory and subcutaneous fatty acid data, palmitic and oleic acids were the fatty acids significantly correlated to the largest number of sensory traits. The largest correlations appeared between stearic and oleic acid and brightness and oiliness (greater than 0.75, $P<0.001$). Palmitic and stearic acids (Davenel, Riaublanc, Marchal, & Gandemer, 1999) and oleic acid (Flores et al., 1988) are closely related to solid fat content, and therefore their correlation to lipid-related traits was expected. The following most related sensory traits to fatty acid composition were juiciness, sweetness, fat hardness, and cured aroma. On the contrary, odour intensity, fibrousness, bitterness, aroma intensity and persistence and toasted aroma were not correlated to

Table 3
Factor loadings for each variable on the rotated components[a]

	Component (% variance explained)					
	1 (17.36)	2 (14.67)	3 (13.86)	4 (12.95)	5 (11.52)	6 (8.97)
Fat yellowness	0.001	**0.772**	−0.115	−0.091	0.199	−0.085
Fat pinkness	0.094	0.209	0.010	0.106	**0.807**	−0.137
Lean redness	−0.059	**0.444**	−0.049	0.193	**0.792**	0.059
Lean brightness	**0.575**	0.172	0.219	**0.437**	**0.515**	0.096
Marbling	0.210	0.064	0.042	**0.626**	0.038	−0.296
Odour intensity	0.103	0.048	**0.955**	−0.081	−0.121	0.055
Montanera-ham typical odour	0.166	0.044	**0.929**	0.104	0.057	0.033
Fat oiliness	**0.698**	−0.034	0.426	0.324	0.372	0.184
Fat hardess	**−0.765**	0.060	−0.287	−0.248	−0.126	−0.217
Lean hardness	**−0.885**	0.026	−0.020	0.235	−0.002	−0.178
Dryness	**−0.790**	−0.132	−0.038	−0.128	0.059	0.003
Fibrousness	**−0.603**	0.113	−0.140	**0.610**	0.160	−0.046
Juiciness	**0.582**	0.392	**0.513**	0.042	0.372	0.031
Sweetness	0.250	**0.717**	0.248	0.130	**0.447**	0.021
Bitterness	−0.079	**0.771**	0.186	**0.426**	−0.092	0.160
Aroma intensity	0.351	−0.029	**0.477**	−0.351	0.170	**0.591**
Aroma persistence	0.238	0.381	0.154	−0.013	0.156	**0.759**
Cured aroma	0.342	0.374	**0.592**	0.099	0.336	0.368
Rancid aroma	0.080	**0.549**	0.156	**0.594**	0.143	0.037
Toasted aroma	0.090	−0.131	0.003	0.145	−0.210	**0.760**
Mouldy aroma	0.017	0.080	0.158	**0.738**	**0.458**	0.227
Pungent aroma	0.075	0.317	−0.216	**0.637**	0.055	0.309
Ketone-like aroma	0.002	**0.700**	0.069	0.230	0.269	0.056

[a] Variables were considered to compose a factor when scores were greater than 0.4 (in bold).

the fatty acid composition of the subcutaneous fat. Correlations between some variables was of value because of their usefulness to control quality of the whole ham. Stearic and oleic acid of subcutaneous fat are closely related to textural traits and appearance (brightness), and their determination allows sampling the hams without destroying them. In the same way, fat oiliness and hardness are closely correlated to lean characteristics, and because of the easily access to subcutaneous fat, these traits could be used to predict other characteristics in ham quality control.

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