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The duration of the outdoor rearing period of pigs influences Iberian ham characteristics

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The effect of outdoor rearing duration (75 v 50 days) and rearing system (outdoor v indoor based systems) of Iberian pigs on the chemical composition (fatty acid composition of fat and intramuscular fat, moisture, salt, pigment concentrations and water activity of lean meat), the instrumental colour (CIE*L*a*b system) and the sensory characteristics (descriptive analysis) of dry-cured hams were investigated. The fatty acid composition of subcutaneous fat was weakly affected by outdoor rearing duration, but greatly affected by rearing system with the indoor hams showing larger proportion of saturated fatty acids than outdoor rearing. Rearing system also affected *L** of subcutaneous fat (the indoor hams were lighter than the outdoor ones). The instrumental colour of lean was only affected by outdoor rearing duration (scores for *a** and its derived variables were larger in the long-outdoor group than in the short-outdoor one). The effect of outdoor rearing duration on the sensory characteristics of Iberian hams was marked, 13 sensory characteristics being affected. Among them, odour intensity, flavour intensity, and flavour persistence were greater in the long-outdoor hams than in the short-outdoor ones, whereas these characteristics were not affected by rearing system. However, rearing system also had a large effect influencing 12 sensory characteristics.**

Keywords: Iberian dry-cured ham; outdoor rearing duration; rearing system

Introduction

In recent years concerns about animal welfare and environmental impact of pig production have increased interest in sustainable production systems. Apart from these considerations, the conditions in which pigs are fattened and reared have a marked influence on meat qual-

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ity (Gandemer, 2002; Gentry *et al*., 2002; Jonsall *et al*., 2002; Olsson *et al.,* 2003*)*.

The importance of the fattening conditions of pigs is reflected in the current grading system of Iberian ham, a high value dry-cured product with three different commercial categories: Montanera (from pigs fattened in outdoor-based systems with grass and acorns available), Pienso (from pigs fattened in indoor-based systems with concentrate feeding available) and Recebo (from pigs fattened using combined systems). Differences between Iberian hams derived from outdoor and indoor reared pigs have been widely reported (Cava *et al*., 2000a; Carrapiso, Bonilla and Garcia, 2003a). However, there are a number of factors within both systems that could influence, to a great extent, the characteristics of Iberian ham. With regard to the characteristics of Iberian ham derived from indoor-based systems, a number of factors have attracted attention such as composition of the concentrate diet and supplementation with vitamin E (Cava *et al*., 2000b; Ruiz *et al.,* 2005). However, less attention has been given to the effect of outdoor rearing conditions for Iberian ham and other dry-cured meats. Currently, no information is available about the effect of outdoor rearing duration on dry-cured meat characteristics. The general belief about the relationship between Iberian ham quality and the duration of the outdoor rearing period is partly supported by the current commercial grading of Iberian ham, which for the best grade (Montanera) requires at least 46 kg of weight increase during the outdoor fattening period (BOE, 2001). Apart from this requirement, along with the availability of acorns and grass and the lack of concentrated feeding, no more requirements about the outdoor period exist. After slaughter, the fatty acids of subcutaneous fat are checked to confirm the grading of pork and derived products. However, it would be interesting to know whether a potentially variable factor such as the duration of outdoor rearing period affects Iberian ham characteristics.

The purpose of this study was to investigate the effect of increasing the duration of the outdoor rearing period of Iberian pigs above the minimum acceptable for the best grade and compare it with the effect of rearing system (outdoor v indoor) on the main chemical composition variables, the instrumental colour and the sensory characteristics of the dry-cured hams.

Materials and Methods

Ham samples

Fifty-three Iberian pigs were reared indoors in similar conditions up to the fattening period. Then, 16 pigs were kept indoors and offered a concentrate diet (for details, see Tejeda *et al*., 2002) until slaughter at a mean weight of 153.9 kg. After reaching the mean weight of 100.7 kg (about 11 months), the remaining pigs were fattened outdoors, where they received a diet of acorns and pasture but were not offered a concentrate diet. The outdoor rearing period lasted for 50 days for the short-duration group (18 pigs). The mean weight gain of these pigs was 48.7 kg, and the mean slaughter weight was 138.3 kg. The outdoor rearing period lasted for 75 days for the long-duration group (19 pigs). The mean weight gain of these pigs was 73.9 kg, and the mean slaughter weight was 185.0 kg.

The right leg from each animal was taken and hams (53) were processed into dry-cured hams in a local company following a traditional method (Carrapiso, Jurado and Garcia, 2003b). Hams were kept in piles of salt for a period, depending on weight (one day per 1 kg raw ham). The salting and post-salting stages (at 0

to 3 °C and 80 to 90% relative humidity) lasted for 4 to 6 months (depending on ham weight); the hams were then ripened for 15 months in a cellar at 10 to 27 °C and at 58 to 80% relative humidity. After colour measurements, the moisture concentration and water activity of the *biceps femoris* muscle were determined and a sensory analysis was performed. A sample of the centre of the *biceps femoris* and another taken from the subcutaneous fat were vacuum-packaged and kept at −80 °C for further analyses.

Chemical analyses

Fatty acid analysis: The fatty acids of subcutaneous fat were determined by gas chromatography of the fatty acid methyl esters synthesized by using methanolic hydrogen chloride, as described by Carrapiso *et al*. (2000). A 0.1 µL aliquot of solution was injected into a HP 5890 II chromatograph (Hewlett-Packard, Palo Alto, CA, USA) equipped with an on-column injector, a flame ionisation detector (FID) and a 30 m × 0.53 mm capillary column coated with FFAP-TPA stationary phase (1 µm thickness) (Hewlett-Packard, USA). Conditions were as follows: oven temperature 220 °C isothermal for 30 min, injector and detector temperature 230 °C, flow rate of the carrier gas (N_2) 2.6 mL/min. Total fatty acid concentration of the subcutaneous fat was calculated by means of an internal standard (tridecanoic acid methyl ester) and FID response factors calculated with standards (Sigma, St. Louis, USA). The fatty acids analysed were those currently included in the official grading system (BOE, 2004) and were expressed according to that regulation as a percentage of the sum of the fatty acids shown in Table 1.

Intramuscular fat concentration: Lipids from the *biceps femoris* muscle were extracted with chloroform:methanol (Bligh and Dyer, 1959). Solvent (chloroform) was removed by using a rotary vacuum evaporator, and residual chloroform by evaporation under a stream of N_2.

Moisture and sodium chloride: Moisture and sodium chloride (NaCl) concentrations were determined in the *biceps femoris* muscle according to AOAC methods (AOAC, 1984). Two replicates of each sample were analysed and the mean value was used in data analyses.

Water activity (a_w): Water activity of the *biceps femoris* muscle was determined with a GBS Scientific Instruments FA-st/1 system (Romans, France). Two replicates of each sample were analysed and the mean value was used in the data analyses.

Pigment concentration: Pigment in the *biceps femoris* muscle was determined as described by Hornsey (1956).

Instrumental colour measurement

Colour measurements were taken in triplicate across the surface of the subcutaneous fat of each ham just after removing the external layer (as it is usually done before slicing the hams) and across the surface of the *biceps femoris* muscle just after cutting it longitudinally.

Reflectance spectra data were obtained using a Minolta Chromameter CR-300 (Aquatecnica S.A., Valencia, Spain), with a 0° observer angle and a D65 illuminant. The colour system was CIE$L^*a^*b^*$ (CIE, 1976). Chroma (C^*) was calculated as $(a^{*2} + b^{*2})^{0.5}$ and Hue angle ($h°$) as arctangent(b^*/a^*) (Wyszecki and Stiles, 1982). The mean value of the replicates from each ham was used in data analyses.

Sensory analysis

A trained panel of 18 members evaluated the samples by applying a descriptive analysis method (Carrapiso *et al*., 2003a) to each of 24 traits, grouped in fat and lean appearance, odour, fat and lean texture,

Table 1. Values (mean ± s.d.) for the chemical composition of the subcutaneous fat and the biceps femoris of Iberian hams from pigs reared outdoors (for a long or short period) or indoors

Variable	Rearing system			*Significance level*
	Long-outdoor	Short-outdoor	Indoor	
Chemical composition of subcutaneous fat				
Total fatty acids[1]	839.0 ± 94.89	813.3 ± 96.38	802.3 ± 90.13	0.49
Fatty acid proportions[2]				
12:0	0.2 ± 0.06	0.2 ± 0.05	0.2 ± 0.05	0.70
14:0	1.3 ± 0.18^{b}	1.1 ± 0.46^{b}	1.6 ± 0.14^{a}	***
16:0	19.7 ± 1.63^{c}	21.4 ± 2.25^{b}	24.4 ± 1.14^{a}	***
16:1	2.2 ± 0.36^{c}	2.5 ± 0.40^{b}	3.1 ± 0.36^{a}	***
17:0	0.3 ± 0.03^{b}	0.3 ± 0.03^{b}	0.3 ± 0.06^{a}	***
17:1	0.3 ± 0.04^{b}	0.3 ± 0.05^{b}	0.4 ± 0.08^{a}	***
18:0	9.0 ± 0.93^{b}	9.2 ± 0.82^{b}	11.1 ± 1.12^{a}	***
18:1	56.4 ± 2.14^{a}	55.3 ± 2.43^{a}	49.6 ± 1.26^{b}	***
18:2	8.8 ± 0.65^{a}	8.0 ± 0.62^{b}	7.8 ± 0.83^{b}	***
18:3	0.2 ± 0.04^{b}	0.2 ± 0.03^{b}	0.2 ± 0.04^{a}	***
20:0	0.1 ± 0.04	0.1 ± 0.02	0.1 ± 0.02	0.64
20:1	1.6 ± 0.24^{a}	1.4 ± 0.23^{b}	1.2 ± 0.13^{b}	***
Chemical composition of biceps femoris				
Intramuscular fat (g/kg)	62.1 ± 16.03^{a}	57.5 ± 17.57^{ab}	46.8 ± 16.68^{b}	*
Moisture (g/kg)	484.6 ± 31.56^{a}	435.3 ± 30.15^{b}	425.1 ± 46.53^{b}	***
NaCl[3]	110.4 ± 22.52	125.0 ± 15.02	123.4 ± 25.85	0.09
Myoglobin (g/kg)	3.2 ± 1.1	3.0 ± 1.0	2.7 ± 0.7	0.26
Water activity (a_w)	0.87 ± 0.012^{a}	0.83 ± 0.018^{b}	0.82 ± 0.014^{c}	***

^{abc} Values in the same row, without a common superscript are significantly different ($P < 0.05$).
[1] g/kg subcutaneous fat.
[2] g/100 g total fatty acids.
[3] g/kg ham dry matter.

taste and flavour (listed in Table 3), using a 10 cm unstructured scale, the extremes being "very low" and "very high". The FIZZ (version 1.01, Biosystemes, France) program was used.

Three extremely thin slices from the front of each ham were obtained using a knife (traditional manner of cutting ham slices) and were immediately presented on a glass plate to the panellists. Sensory evaluations were undertaken at 20 to 22 °C in a 6-booth sensory panel room equipped with white fluorescent lighting. The whole panel participated in each session, the panellist order being randomised. Three hams were successively evaluated in each session (except for the last session), and the sample order was randomised. The mean value from the panel responses for each sensory trait and each ham was used in data analyses (Meilgaard Civille and Carr, 1999).

Data analyses

A one-way analysis of variance using a general linear model procedure was used and, when the F-test was significant, the Tukey test was used to evaluate differences for each variable among the three groups. Pearson correlation and factor analysis (using principal component analysis as the method for factor extraction) were applied to evaluate the relationships among variables (Hair *et al*., 1998). Statistical analyses were performed by means of SPSS version 11.0 (SPSS Inc., USA).

Table 2. Values (mean ± s.d.) for instrumental colour, using the CIE*L*a*b variables, measured in the subcutaneous fat and the biceps femoris of Iberian hams from pigs reared outdoors (for a long or short period) or indoors**

Variable[1]	Rearing system			*Significance level*
	Long-outdoor	Short-outdoor	Indoor	
		Subcutaneous fat		
L^*	61.9 ± 2.68[b]	64.4 ± 4.76[b]	68.2 ± 3.06[a]	***
a^*	9.9 ± 1.58[a]	7.7 ± 1.95[b]	9.6 ± 1.59[a]	***
b^*	8.2 ± 0.91	8.19 ± 1.39	8.7 ± 0.98	0.26
C^*	12.9 ± 1.35[a]	11.4 ± 1.39[b]	13.0 ± 1.37[a]	**
$h°$	39.8 ± 5.40[b]	46.9 ± 9.31[a]	42.6 ± 5.75[ab]	*
		Biceps femoris		
L^*	38.4 ± 1.81	38.5 ± 1.79	38.0 ± 1.51	0.59
a^*	19.1 ± 1.19[a]	17.5 ± 1.26[b]	17.3 ± 1.65[b]	***
b^*	7.4 ± 0.67	7.6 ± 0.67	7.6 ± 1.09	0.72
C^*	20.5 ± 1.26[a]	19.0 ± 1.36[b]	18.9 ± 1.74[b]	**
$h°$	21.2 ± 1.50[a]	23.5 ± 1.28[b]	23.6 ± 2.86[b]	***

[ab] Values in the same row, without a common superscript are significantly different ($P < 0.05$).
[1] L^*, a^* and b^* using Minolta Chronometer CR-300; $C^* = (a^{*2} \times b^{*2})^{0.5}$ and $h° = \text{arctangent}(b^* \times a^*)$.

Results and Discussion

Chemical composition

The total fatty acid concentration of subcutaneous fat was not affected either by outdoor rearing duration or rearing system (Table 1). Conversely, the fatty acid composition of subcutaneous fat was affected by both factors. Outdoor rearing duration (long v short) significantly influenced 4 fatty acid percentages (16:0, 16:1, 18:2 and 20:1; Table 1), but rearing system (short-outdoor v indoor) had a larger effect altering the percentages of 8 fatty acids (14:0, 16:0, 16:1, 17:0, 17:1, 18:0, 18:1 and 18:3, Table 1). Therefore, results indicate that during the first 50 days of fattening on the outdoor-based system the fatty acid percentages become clearly different from those of indoor-reared pigs, which is in line with previous studies (Ordóñez *et al*., 1996; Flores *et al*., 1988; Ruiz *et al*., 1998; Carrapiso *et al*., 2002; Carrapiso *et al*., 2003a), and differences increase, to a lesser extent but significantly, when the duration of the outdoor rearing lasts for a further 25 days.

With regard to the chemical composition of lean, differences in the fattening period caused significant differences in the intramuscular fat concentration, moisture and a_w (Table 1). The significant differences in the intramuscular fat concentration between the long-outdoor and the indoor group could not be attributed to differences in age because the intramuscular fat concentration of Iberian pigs does not increase with time during the fattening period (Mayoral *et al*., 1999). In addition, the group with the lowest weight (the short-outdoor group) did not have the lowest value for intramuscular fat concentration, so it could be accepted that live weight was not responsible for differences observed. Up to now, no effect (Carrapiso and Garcia, 2005) or only a weak effect (Cava *et al*., 2000a) of rearing system on intramuscular fat concentration of Iberian ham has been reported, and the effect of outdoor rearing duration has not been investigated, but there is a tendency of local breeds to have a higher intramuscular fat concentration when they

Table 3. Values (mean ± s.d.) for the sensory characteristics of Iberian hams from pigs reared outdoors (for a long or short period) or indoors

Variable	Rearing system			*Significance level*
	Long-outdoor	Short-outdoor	Indoor	
Fat appearance				
Yellowness	2.0 ± 0.35	2.0 ± 0.65	1.9 ± 0.39	0.53
Pinkness	3.5 ± 0.59	4.0 ± 0.84	3.6 ± 0.64	0.07
Lean appearance				
Redness	5.2 ± 0.73[a]	4.9 ± 0.93[a]	4.2 ± 0.60[b]	**
Brightness	5.5 ± 0.43[a]	4.4 ± 0.83[b]	3.1 ± 0.63[c]	***
Marbling	3.0 ± 0.51	2.8 ± 0.73	2.6 ± 0.43	0.10
Odour				
Intensity	5.4 ± 0.50[a]	4.9 ± 0.70[b]	4.8 ± 0.48[b]	*
Montanera-ham typical odour	5.2 ± 0.38[a]	4.6 ± 0.65[b]	4.2 ± 0.48[c]	***
Fat texture				
Oiliness	6.3 ± 0.43[a]	5.2 ± 0.86[b]	4.0 ± 0.44[c]	***
Hardness	2.5 ± 0.41[c]	3.4 ± 0.62[b]	4.4 ± 0.38[a]	***
Lean texture				
Hardness	2.7 ± 0.64[c]	4.9 ± 0.80[b]	5.4 ± 0.56[a]	***
Dryness	2.8 ± 0.54[c]	4.7 ± 0.62[b]	5.2 ± 0.60[a]	***
Fibrousness	2.9 ± 0.46[b]	4.2 ± 0.67[a]	4.2 ± 0.50[a]	***
Juiciness	5.8 ± 0.50[a]	5.2 ± 0.52[b]	4.5 ± 0.54[c]	***
Taste				
Saltiness	4.9 ± 0.35[b]	5.6 ± 0.40[a]	5.5 ± 0.47[a]	***
Sweetness	2.1 ± 0.38[a]	2.2 ± 0.53[a]	1.5 ± 0.41[b]	***
Bitterness	2.3 ± 0.24	2.4 ± 0.29	2.3 ± 0.17	0.48
Flavour				
Intensity	5.5 ± 0.31[a]	4.9 ± 0.36[b]	4.7 ± 0.25[b]	***
Persistence	4.9 ± 0.32[a]	4.5 ± 0.35[b]	4.3 ± 0.38[b]	***
Cured	4.7 ± 0.36[a]	4.8 ± 0.46[a]	4.3 ± 0.38[b]	**
Rancid	1.6 ± 0.30[b]	2.1 ± 0.49[a]	1.8 ± 0.44[b]	**
Other flavour descriptors				
Toasted	1.7 ± 0.26[a]	1.5 ± 0.35[ab]	1.4 ± 0.33[b]	*
Mouldy	0.6 ± 0.23[a]	0.5 ± 0.19[a]	0.4 ± 0.11[b]	**
Pungent	1.2 ± 0.31	1.3 ± 0.27	1.3 ± 0.27	0.15
Ketone-like	0.5 ± 0.19	0.6 ± 0.27	0.4 ± 0.27	0.07

[abc] Values in the same row, without a common superscript are significantly different ($P < 0.05$).

are reared outdoors compared to when they are reared indoors (Pugliese *et al*., 2004). According to the results in Table 1, the increase in the duration of outdoor rearing could cause an enhanced effect of rearing system on intramuscular fat content.

Significant differences also appeared in lean moisture concentration due to outdoor rearing duration (moisture increased as outdoor rearing duration increased) and in water activity (the largest values were found for the long-outdoor group and the lowest for the indoor group), which could be related to a decrease in water transfer as intramuscular fat concentration increases (Ruiz-Cabrera *et al*., 2004). Cava *et al.* (2000a) also reported a higher moisture concentration in hams from outdoor-reared pigs than from indoor-reared pigs. No significant differences appeared in NaCl or pigment concentration.

Instrumental colour and sensory appearance

The instrumental colour and the sensory appearance of subcutaneous fat and lean were affected by outdoor rearing duration and rearing system (Tables 2 and 3). The L^* of fat which is the CIE$L^*a^*b^*$ variable most related to the sensory appearance of sliced ham (Carrapiso and Garcia, 2005) was not affected by outdoor rearing duration. However, it was affected by rearing condition: L^* was larger in hams from the indoor group than those from the outdoor groups (Table 2). These results agree with fatty acid analysis data, which showed a marked effect of rearing system but a weaker effect of outdoor rearing duration (Table 1). In any case, differences in L^* of lean were not reflected in the sensory perception of fat colour: fat yellowness and pinkness were not affected by outdoor rearing duration or rearing system, and no significant correlations were found between L^* (or other instrumental colour variables) and the sensory colour variables of fat.

The principal component (PC) analysis of subcutaneous fat variables showed a homogeneous grouping of samples according to rearing system in the PC 1 axis (Figure 1a), mainly composed of fatty acid variables (Figure 1b). The PC 2 axis (mainly defined by instrumental colour variables) showed differences between hams from the long and short outdoor groups (Figure 1a). According to Figure 1b, the sensory colour of Iberian ham fat is only weakly related to fatty acid and instrumental colour data. In fact, the only significant correlation involving the sensory variables appeared between yellowness and 16:0 proportion (–0.31, $P = 0.026$), and 20:1 proportion (0.28, $P = 0.043$). Conversely, the instrumental colour was strongly related to fatty acid composition, the largest correlations appearing between L^* and 18:0 proportion (0.66, $P < 0.001$) and 18:1 proportion (–0.67, $P < 0.001$).

With regard to the instrumental colour of lean, outdoor rearing duration,

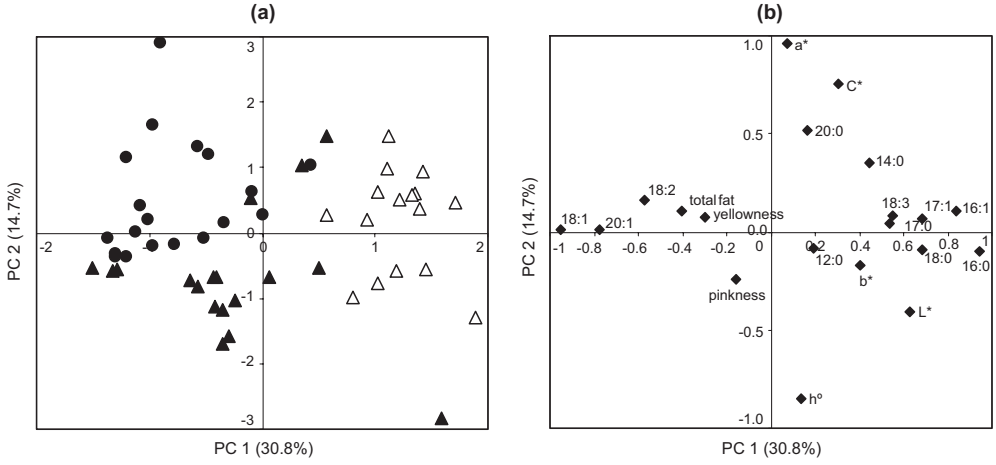

Figure 1. Subcutaneous fat colour and appearance of Iberian ham: projection of the samples (a) and the variables (fatty acid composition, instrumental colour and sensory appearance) (b) onto the space defined by the first two principal components (PC 1/PC 2). Sample groups: (●) long-outdoor group; (▲) short-outdoor group; (△) indoor group.

but not rearing system, influenced the CIE*L*a*b** variables (Table 2). A significant effect of outdoor rearing duration on *a** (and the derived variables *C** and *h*°) was evident; the long-outdoor group had higher values than the short-outdoor group. The effect on *a** was in line with that found in pigment, a_w, moisture and intramuscular fat levels (Table 1) and sensory redness, brightness and marbling (Table 3). In fact, these variables were closely related in the principal component analysis (i.e. large absolute values in the PC 1) (Figure 2b), and some of them were significantly correlated: *a** and moisture (0.41, $P < 0.01$), *a** and brightness (0.37, $P < 0.01$), redness and intramuscular fat concentration (0.33, $P < 0.02$), marbling and intramuscular fat concentration (0.32, $P = 0.02$).

With regard to the lean appearance perceived by panellists, outdoor rearing duration only had a significant effect on lean brightness but rearing system (indoor v outdoor) affected not only brightness but also redness (Table 3).

With regard to the principal component analysis of lean colour variables, Figure 2a shows a separated grouping of long-outdoor hams from the others on the PC 1 axis. This axis was mainly composed of *a** and its derivates *h*° and *C**, a_w, moisture and brightness (Figure 2b). In fact, all the correlations between these variables were significant, the largest (excluding those between *a** and its derivates *h*° and *C**) being between brightness and a_w (0.74, $P < 0.001$) and moisture and a_w (0.60, $P < 0.001$).

It should be noted that *L** of fat and brightness were significantly correlated (–0.70, $P < 0.001$), but *L** of lean and brightness were not. Therefore, fat colour measurement would be more useful than lean colour measurement to predict sensory lean characteristics such as brightness, as already reported by Carrapiso and Garcia (2005).

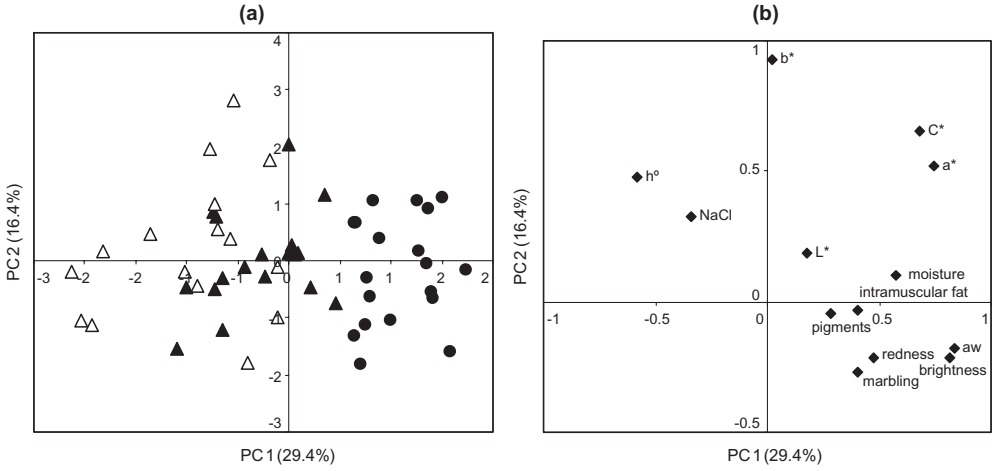

Figure 2. Lean (biceps femoris) colour and appearance of Iberian ham: projection of the samples (a) and the variables (chemical composition, instrumental colour, sensory appearance) (b) onto the space defined by the first two principal components (PC 1/PC 2). Sample groups: (●) long-outdoor group; (▲) short-outdoor group; (△) indoor group.

Sensory characteristics

Eighteen of the 24 sensory characteristics of hams were affected by the fattening conditions of pigs. Table 3 shows that outdoor rearing duration affected a similar number of characteristics (13 characteristics were different between the short and long groups) as did rearing system (12 characteristics were different between the short-outdoor and indoor groups). The sensory differences between the outdoor and the indoor groups (Table 3) coincided with the large effect on fatty acid composition of the subcutaneous fat (Table 1) and agree with results obtained from previous studies (Carrapiso *et al*., 2003a; Cava *et al*., 2000a). However, the marked effect of outdoor rearing duration on the sensory characteristics did not match the small differences found in the fatty acid data.

Some characteristics affected by outdoor rearing duration were also affected by rearing system, but this was not the case for odour, flavour intensity or flavour persistence, which are among the most important and appreciated sensory traits of Iberian ham (Ruiz *et al*., 2002). Odour intensity, Montanera-ham typical odour (a special and strong meaty note) and flavour intensity and persistence of ham increased significantly with outdoor rearing duration (Table 3). Rearing system affected Montanera-ham typical odour, cured and mouldy flavours but not the other odour and flavour characteristics (Table 3). Otherwise, strong relationships among odour and flavour variables and some fatty acids, texture traits and a_w and moisture concentration were found (Figure 3b). The largest correlations involving odour and flavour and chemical variables were between a_w and Montanera-ham typical odour and flavour intensity (0.60 and 0.63, respectively, $P < 0.001$).

All textural traits were affected by outdoor rearing duration and rearing system,

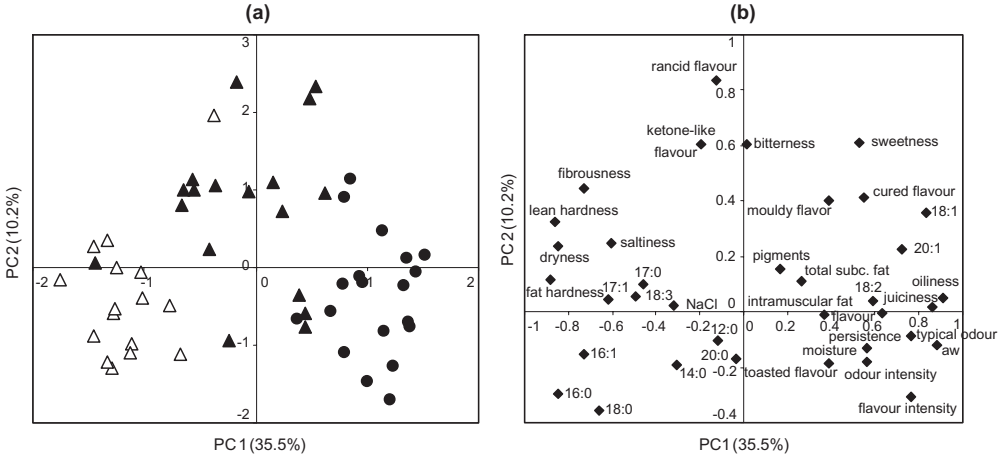

Figure 3. Characteristics (except for colour and appearance) of lean (biceps femoris) and fat of Iberian ham: projection of the samples (a) and the variables (chemical composition and sensory odour, flavour, texture and taste) (b) onto the space defined by the first two principal components (PC 1/PC 2). Sample groups: (●) long-outdoor group; (▲) short-outdoor group; (△) indoor group.

with the exception of fibrouness for rearing system (Table 3). Differences in fat characteristics could be expected, because fatty acids, the main contributors to fat consistency (Gandemer, 2002; Wood *et al*., 2004) were significantly affected by both factors (Table 1). In fact, Figure 3b shows strong relationships among fat hardness and oiliness and fatty acid composition, the largest correlations appearing, respectively, between hardness and 18:1 proportion (0.78, $P < 0.001$) and oiliness and 18:1 proportion (0.70, $P < 0.001$). Differences in lean texture could be related to the differences in moisture, a_w and intramuscular fat concentration (Table 1). In fact, all the textural variables were correlated with a_w (>0.70 and $P < 0.001$ in all cases), and also correlations between sensory texture and moisture were significant in all cases ($P < 0.01$) but were smaller (in the 0.42 to 0.57 absolute range). Correlations between texture and intramuscular fat concentration were significant except for fibrouness ($P < 0.05$) but even smaller (in the 0.29 to 0.34 absolute range).

With regard to taste, significant effects of outdoor rearing duration on saltiness, and of rearing system on sweetness were found (Table 3). Salting conditions were equivalent for all the hams (weight was taken into account) so differences could be related to the effect of intramuscular fat concentration on the ability to absorb salt (although differences in NaCl concentration were not significant, $P = 0.09$) (Table 1) but also to its effect on saltiness perception.

With regard to the principal component analysis, a clear grouping of samples according to the fattening conditions was found on the PC 1 axis (Figure 3a), mainly composed of odour, high-intensity flavour traits and texture traits, the most abundant fatty acids and a_w and moisture (Figure 3b). Hams from the short-outdoor group were also different from the other groups on the PC 2 axis (Figure 3a), mainly composed of low-intensity flavour and taste traits (Figure 3b).

It is concluded that the duration of the outdoor rearing period has a marked effect on dry-cured ham characteristics, especially on the sensory traits. Rearing system (outdoor v indoor) has not only a marked effect on the sensory traits but also on the chemical composition. Therefore, the main variations in fatty acid composition take place during the first 50 days after changing rearing system and diet, but the subsequent small changes in composition affect the chemical composition and colour of Iberian ham and cause a large impact on the sensory characteristics developed.

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