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Fatty acid composition and sensory characteristics of lamb carcasses from Britain and Spain

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Abstract

Fatty acid composition of intramuscular fat in *M. Longissimus* was measured in four groups of lambs representing two Spanish breeds: Rasa Aragonesa (RA) and Merino (ME) and two British lamb types: the Welsh Mountain breed (WM), whose carcasses were purchased in Spain and typical early lambs (EL) purchased in Britain. The lambs grown in Spain were concentrate fed and slaughtered at a lighter weight and lower age than those grown in Britain. The British lamb carcasses purchased in Spain were of a similar weight to the Spanish lambs but were lighter than the lamb carcasses purchased in Britain. The British lambs were grass fed. Relationships between fatty acid (FA) composition and sensory attributes were examined following sensory testing of all lambs by both British and Spanish taste panels. The production system was shown to be more important than breed in determining FA composition. British lambs had higher percentages, within total fatty acids, of 18:0, 18:3 (*n*-3) and long chain polyunsaturated *n*-3 FA and lower percentages of 18:2 (*n*-6) and long chain polyunsaturated *n*-6 FA than Spanish lambs. These differences were due to the different feeding systems used. The amounts of these FA in muscle (mg/100 g) were also different between the British and Spanish groups, not only because the British lambs had more total fat. For both taste panels, odour and flavour intensity were positively correlated with the amounts and percentages of 18:0 and 18:3 and negatively correlated with those of 18:2. This was explained by the fact that both panels gave higher odour and flavour intensity scores to the grass-fed British lamb with high 18:3 levels and lower scores to the concentrate-fed Spanish lamb with high 18:2 levels. However, 18:0 and 18:3 were positively correlated with flavour quality and overall appraisal for the British panel and negatively for the Spanish panel. Conversely, 18:2 was a positive contributor to flavour and overall preference for the Spanish panel and was negative for the British panel. The results show that the production system affects muscle fatty acid composition and the flavour of lamb. However, people's preference is determined to a large extent by their past experience.

Keywords: Fat quality; Taste panel; Lamb

1. Introduction

As far as most consumers are concerned, meat should contain only a small amount of fat. Too much fat discourages the purchase of meat and is commonly removed either before cooking or during the meal, especially by young people. However, some fat is always present in meat and indeed is required to impart flavour and juiciness (Melton, 1990). Many reports also show positive effects of fat level on tenderness (Wood, 1990).

The amount of fat in the diet, and especially its content of saturated fatty acids, are considered major risk factors for coronary heart disease (Department of Health, 1994). The balance between polyunsaturated fatty acids and saturated fatty acids (P:S) is considered to be too low in the UK diet with meat implicated in this imbalance. More recently it has become clear than Western diets also have an imbalance between the n-6 PUFA and the *n*-3 PUFA, with *n*-6:*n*-3 averaging around 10 instead of the preferred, below 5. Ruminant meats have a low P:S ratio because of the hydrogenating action of the rumen microorganisms on dietary fatty acids but the *n*-6:*n*-3 ratio is beneficially low, especially on grass diets (Enser, Hallett, Hewett, Fursey & Wood,

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1996; Enser, Hallett, Hewett, Fursey, Wood & Harrington, 1998).

Many factors in production such as diet, age of weaning, breed, sex, and body weight have effects on adipose tissue and muscle fatty acid composition (Boylan, Berger & Allen, 1976; Kemp, Mahyuddin, Ely, Fox & Moody, 1981; Sañudo et al., 1998b), despite the action of the rumen. Also, relationships between fat composition and meat characteristics, especially flavour, have been observed (Kemp et al., 1981; Larick & Turner, 1990; ; Melton, 1990) although the results are not always consistent.

In recent work we have shown large effects of grain-based or grass-based diets on muscle fatty acid composition in cattle (Enser et al., 1998). Cattle fed grass had much higher concentrations of α-linolenic acid (18:3) and other *n*-3 PUFA in muscle than those fed a 'barley beef' diet which had higher concentrations of linoleic acid (18:2) and the *n*-6 PUFA. In the present study with lambs, the importance of grain or grass-based production systems as represented by those employed for sheep production in Spain and Britain respectively, have been studied with respect to fatty acid composition and sensory characteristics. The sensory results were presented by Sañudo et al. (1998a).

2. Materials and methods

2.1. Animals

Thirty two male lamb carcasses were studied, 24 purchased in Spain and 8 in Britain. Lambs purchased in Spain had light carcasses (10.0–11.5 kg cold weight) as is characteristic in Spanish markets. Eight were Spanish Merino (ME), 8 Rasa Aragonesa (RA) and 8 Welsh Mountain (WM). ME were produced in an intensive system in the south-west of Spain and after weaning were fed concentrates ad libitum in a feedlot. The slaughter age was 80–90 days. RA is a rustic-type breed from the north-east of Spain with the traditional commercial name 'Ternasco de Aragón'. Animals are produced intensively, weaned and kept on cereal straw and concentrate fed ad libitum until slaughter at 80–90 days. WM is a rustic breed from Wales in Great Britain. Animals were reared extensively (i.e. on pasture) and slaughtered at 5–6 months of age in Britain. Their carcasses were sent refrigerated to Spain.

The 8 lambs purchased in Britain were obtained at Easter time in the South West (Somerset area) from a commercial abattoir. These carcasses were typical early lambs (EL), which are suckled, provided with some creep feed concentrate to help early growth after which they are reared entirely on grass pasture. Early lambs were slaughtered at about 4–5 months of age with carcass weights of 16.5–18.5 kg.

2.2. Sampling

After 3 days post slaughter for ME and RA and post purchase for WM, all at 3°C, loin joints were blast frozen in plastic vacuum bags and stored at −20°C. Left side loins remained in Spain and right ones were delivered frozen to Britain. British purchased loins (EL) were blast frozen, vacuum packaged and stored on the purchased day. Only right sides were tested, in Britain. A slice of *Longissimus lumborum* (first lumbar vertebra) was removed for intramuscular fatty acid analysis from all lambs.

2.3. Spanish panel

Samples were thawed for 24 h before cooking and the *Longissimus lumborum* muscle (LD) was removed and completely trimmed of fat. The epimysium was not removed. The entire LD was grilled, until the internal temperature reached 70°C, and cut into 2 cm thick slices. An eleven-member, trained taste panel assessed lamb odour intensity, flavour intensity, flavour quality and overall appreciation using a non-structured line scale measuring 100 mm (100 points). Hot samples were randomly evaluated in trios and each trio (ME, RA, WM) was evaluated in separate sessions. More details are in Sañudo et al. (1998a).

2.4. British panel

Entire loin joints were thawed for 24 h before cooking and were tested by a 10 member trained taste panel. The same attributes were evaluated as in Spain, using 8 point category scales. Joints were cut into 2 cm steaks and then cooked in an infrared grill to an internal temperature of 80°C. The four lamb types (ME, RA, WM, EL) were randomised and assessed in the same session. More information about this procedure and the results were reported previously (Sañudo et al., 1998a).

2.5. Fatty acid composition

The muscle tissue was blended using a small food processor. Duplicate 1 g samples were hydrolysed in 6 ml of 5 M KOH in methanol:water (1:1, v/v) at 60°C. After acidification the fatty acids and aldehydes were extracted in petroleum spirit (BP 40–60°C), methylated with a solution of diazomethane in diethyl ether and analysed on a 50 m×0.25 mm ID CP Sil 88 FAME column (Chrompack, UK) (Whittington, Prescott, Wood & Enser, 1986). Fatty acids were quantified using heneicosanoic acid methyl ester as internal standard added prior to saponification. Peaks were identified using standards where available (Sigma Chemical Co., Ltd, Poole, UK). Linearity of response was confirmed using GLC-50 monoenoic reference mixture (Superlco, Poole, UK) and on-column injection of test samples.

2.6. Data analysis

Data were analysed using the GLM procedures of the SAS package (SAS, 1985) according to the following model

$$y = xb + e$$

where b denotes the fixed effects in the model (lamb type), and e denotes the vector of residual effects. Significant differences between main effects were tested using the Bonferroni t-test.

Linear correlations were calculated between sensory attributes and fatty acid composition in the whole lamb population for British and Spanish panels and in lambs from both origins (Britain or Spain) for the British panel.

3. Results and discussion

3.1. Sensory assessments

In the previous report (Sañudo et al., 1998a), summarised in Table 1, significant differences were found between British and Spanish carcasses for several sensory characteristics. Both British and Spanish panels found that odour and flavour intensity were scored higher in the British carcasses but the panels differed in their ratings of flavour quality and overall appraisal. Whereas the British panel preferred the flavour and overall liking of British lamb, the Spanish panel preferred the flavour and overall appreciation of Spanish lamb.

3.2. Fatty acid composition

Average values and standard errors for intramuscular fatty acid composition (mg/100 g and %) are given in Tables 2 and 3. In general, the fatty acid composition results were similar to others published in Spain or Britain (Enser et al., 1996, 1998; Horcada et al., 1994).

The concentrations of total fatty acids were lower in the Spanish lambs (ME and RA) than in the older British lambs (WM and EL). Total fatty acids (mg/100 g muscle) were 2220, 1994, 3694 and 3157 in ME, RA, WM and EL respectively, i.e. about 60% greater in the British groups. Fatty acids C12:0, C18:1 trans, C18:3 (n-3), EPA, C22:4 (n-6) and DHA showed the greatest variation as indicated by their SE whereas C16:1, C18:0 and C18:1 n-9 were the least variables. The weights of the major fatty acids 16:0 (palmitic), 18:0 (stearic) and 18:1 (oleic) were greater in the British groups with no differences between breeds (groups) within country. Total saturated fatty acids were also higher in WM and EL. However, despite having much less intramuscular fat, both Spanish groups had significantly more polyunsaturated fatty acids than the British groups. The P:S ratio was higher in the Spanish lambs, being 0.33, 0.33, 0.14 and 0.15 in ME, RA, WM and EL, respectively. The British ratios are similar to those reported previously (Enser et al., 1996) but the Spanish ratios are much higher, approaching those in pork and indicating a ‘healthier’ balance of fatty acids.

Within PUFA, the weight of 18:2 was greater in ME and RA and that of 18:3 was greater in WM and EL (Table 2). The percentage of 18:2 was, therefore, much greater in the Spanish groups, above 9 compared with 2–3 and the percentage of 18:3 was much greater in the

Table 1
Sensory scores given by the British panel (BP) and the Spanish panel (SP) to the different groups of lambs (from Sañudo et al., 1998a)[b]

	Spanish Merino		Rasa Aragonesa		Welsh Mountain		Early lamb	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Odour intensity								
BP[a,c]	2.83b	0.20	2.69b	0.16	4.03a	0.21	3.58a	0.21
SP	57.95b	2.14	58.47b	1.34	67.34a	1.99	–	–
Flavour intensity								
BP	3.03b	0.17	3.17b	0.16	4.45a	0.19	3.91a	0.18
SP	63.55b	1.94	58.20c	1.23	73.72a	1.82	–	–
Flavour quality								
BP	3.34b	0.17	3.35b	0.15	4.52a	0.20	4.03a	0.20
SP	57.79a	1.72	59.42a	1.13	33.14b	1.85	–	–
Overall appraisal								
BP	3.49bc	0.16	3.43c	0.15	4.74a	0.20	4.09b	0.19
SP	54.48a	1.92	57.82a	1.34	32.01b	2.01	–	–

[a] $n = 88$ for SP and $n = 80$ for BP.
[b] Values in the same row with different letters are significantly different ($P < 0.05$).
[c] The BP used 1–8 category scales, SP used 0–100 mm line scales.

Table 2
Fatty acid composition (mg per 100 g muscle) of intramuscular fat from four types of sheep

Trait	Spanish Merino		Rasa Aragonesa		Welsh Mountain		Early lamb	
	Mean[a,b]	SE[a]	Mean	SE	Mean	SE	Mean	SE
C10:0	4.02b	0.45	5.08ab	0.89	6.48a	0.43	4.80ab	0.35
C12:0 (lauric)	7.58ab	1.23	12.25a	2.88	5.85b	0.88	5.99b	0.98
C14:0 (myristic)	77.88	10.81	100.73	18.91	89.74	7.70	71.38	4.62
C15:0	14.73	1.78	15.20	2.10	17.83	1.53	14.36	1.62
C16:0 (palmitic)	489.44b	47.39	473.64b	55.72	848.11a	59.82	746.47a	68.57
C16-ald	30.50a	1.15	26.34a	1.36	27.66a	1.69	19.54b	1.33
C16:1 (palmitoleic)	59.80	7.84	53.06	6.42	78.39	5.01	64.88	91.37
C17:0	35.70	4.90	27.55	2.55	46.49	7.54	35.70	3.82
C18:0 (stearic)	285.73b	24.14	272.88b	28.85	780.06a	75.09	711.72a	81.57
C18-ald	14.11bc	0.92	10.65c	0.46	23.39a	1.55	17.01b	0.78
C18:1 trans	4.59	0.66	4.49	0.69	3.56	0.21	4.78	0.24
C18:1 *n*-9 (oleic)	816.63b	96.80	630.87b	64.73	1457.50a	134.00	1165.00a	155.80
C18:1 *n*-11	40.48	4.52	33.31	3.60	29.39	1.47	31.64	2.14
C18:1-ald	11.65b	0.77	9.99b	0.66	18.17a	1.94	14.06ab	1.56
C18:2 *n*-6 (linoleic)	202.17a	11.22	185.87a	9.39	89.00b	4.19	107.54b	6.81
C18:3 *n*-3 (α-linolenic)	13.43b	0.66	20.73b	3.15	67.08a	4.49	50.24a	8.27
C20:1	3.32	0.41	2.39	0.31	2.62	0.38	2.67	0.26
C20:3 *n*-6	5.89a	0.23	5.24a	0.30	3.25b	0.15	3.50b	0.24
C20:4 *n*-6 (arachidonic)	67.56a	4.40	57.12a	3.57	35.42b	3.31	29.63b	1.65
C20:5 *n*-3 EPA	8.38c	0.97	14.59bc	2.46	26.86a	0.95	21.35ab	2.35
22:4 *n*-6	5.05a	0.42	3.37ab	0.44	1.35c	0.10	2.04bc	0.91
C22:5 *n*-3 DPA	15.42c	0.90	19.17bc	1.52	26.84a	0.83	22.81ab	2.16
C22:6 *n*-3 DHA	6.46	0.89	9.75	1.58	8.97	0.73	9.68	1.37
Saturated	959.68b	83.58	944.34b	102.35	1845.61a	147.53	1626.98a	165.85
Polyunsaturated	324.36a	14.51	315.84	13.37	258.77b	8.38	246.79b	14.23
n-6	280.67a	9.67	251.60a	9.14	129.02b	8.55	142.71b	7.14
n-3	43.60b	2.71	64.24b	7.37	129.75a	5.02	104.08a	12.67
P:S	0.33a	0.03	0.33a	0.004	0.14b	0.01	0.15b	0.01
n-6/*n*-3	6.44a	0.53	3.92b	0.68	0.99c	0.07	1.37c	0.33

[a] Means and standard errors.
[b] Values in columns with different letters are significantly different (within trait) ($P<0.05$).

British groups, 1.6–1.8 compared with 0.6–1 in the Spanish groups (Table 3). The percentages of the other *n*-6 and *n*-3 PUFA tended to follow this pattern, the *n*-6 PUFA being higher in ME and RA and the *n*-3 PUFA in WM and EL. The ratio of *n*-6:*n*-3 PUFA was much higher in the two Spanish groups than in the British lambs. Values below 4–5 are preferred on health grounds (Department of Health, 1994). Of the major fatty acids, 18:0 was most different between the Spanish and British lambs, being 12.9, 13.7, 21.1 and 22.2% in ME, RA, WM and EL, respectively.

These results, showing smaller differences in fatty acid composition between genetic groups than between diets and production system, are consistent with other reports in the literature (Boylan et al., 1976; Kemp et al., 1981). On the other hand, Merino lambs had a higher unsaturated fat percentage ($P<0.05$) than the coarse wool breeds, as showed by Cramer, Pruet and Schwartz (1970) in Merino vs Romney breeds. Grass-fed animals often have high muscle concentrations of 18:0, reflecting high levels of rumen biohydrogenation (Casey & Webb, 1995; Enser et al., 1998) and conversely, grain or concentrate-fed animals have higher concentrations of 18:2 (Enser et al., 1998; Miller, Varnell & Rice, 1967). This is due both to the presence of 18:2 as the major fatty acid in the cereal based concentrates consumed by the Spanish lambs and to the lower level of biohydrogenation, resulting in less breakdown of 18:2 to 18:0. The higher percentages of odd chain fatty acids in the Spanish lambs has also been observed before in sheep fed concentrate diets (L'Estrange & Mulvihill, 1975), or when the period of time between weaning and slaughter is not too long (Horcada et al., 1994; Sañudo et al., 1998b).

The higher concentration of 18:3 found in the British groups has previously been found by others in animals fed grass diets (Enser et al., 1998; Marmer, Maxwell & Williams, 1984; Mitchell, Reed & Rogers, 1991) and is probably due to the fact that 18:3 is the major fatty acid in grass. A high proportion of this is hydrogenerated in the rumen, leading to the higher concentration of 18:0 in grass-fed animals, but a significant amount escapes the rumen to be absorbed intact in the small intestine.

Table 3
Fatty acid composition (percentage of total fatty acids) of intramuscular fat from four types of sheep

Trait	Spanish Merino		Rasa Aragonesa		Welsh Mountain		Early lamb	
	Mean[a,b]	SE[a]	Mean	SE	Mean	SE	Mean	SE
C10:0	0.18ab	0.01	0.25a	0.03	0.18ab	0.01	0.15b	0.01
C12:0 (lauric)	0.34ab	0.04	0.62a	0.11	0.16b	0.02	0.19b	0.04
C14:0 (myristic)	3.51ab	0.28	5.05a	0.65	2.43b	0.34	2.26b	0.18
C15:0	0.66ab	0.04	0.76a	0.16	0.48b	0.02	0.46b	0.11
C16:0 (palmitic)	22.04	0.43	23.75	1.08	22.96	0.38	23.65	0.76
C16-ald	1.37a	0.16	1.32a	0.13	0.75b	0.04	0.62b	0.08
C16:1 (palmitoleic)	2.69a	0.14	2.66a	0.12	2.12ab	0.06	2.05b	0.07
C17:0	1.61a	0.12	1.38ab	0.10	1.26ab	0.10	1.13b	0.02
C18:0 (stearic)	12.87b	0.39	13.69b	0.61	21.12a	0.61	22.25a	0.60
C18-ald	0.64	0.08	0.53	0.05	0.63	0.04	0.54	0.06
C18:1 trans	0.21	0.02	0.22	0.03	0.10	0.02	0.15	0.01
C18:1 *n*-9 (oleic)	36.78ab	1.20	31.64b	1.01	39.46a	0.86	36.90ab	1.06
C18:1 *n*-11	1.82a	0.14	1.67a	0.19	0.80b	0.02	1.00b	0.09
C18:1-ald	0.52	0.03	0.50	0.03	0.49	0.03	0.44	0.02
C18:2 *n*-6 (linoleic)	9.10a	0.75	9.32a	0.92	2.41b	0.16	3.41b	0.39
C18:3 *n*-3 (α-linolenic)	0.60c	0.07	1.04bc	0.18	1.81a	0.14	1.59ab	0.14
C20:1	0.15a	0.01	0.12ab	0.01	0.07c	0.01	0.09bc	0.01
C20:3 *n*-6	0.27a	0.03	0.26a	0.02	0.07b	0.01	0.11b	0.04
C20:4 *n*-6 (arachidonic)	3.05a	0.35	2.87a	0.29	0.96b	0.09	0.94b	0.10
C20:5 *n*-3 EPA	0.38	0.08	0.73	0.17	0.73	0.04	0.68	0.07
C22:4 *n*-6	0.23a	0.02	0.17ab	0.03	0.04c	0.00	0.06bc	0.03
C22:5 *n*-3 DPA	0.69	0.11	0.96	0.11	0.73	0.05	0.72	0.04
C22:6 *n*-3 DHA	0.29	0.06	0.49	0.10	0.24	0.01	0.31	0.07
Saturated	43.22b	0.59	47.35ab	1.86	49.97a	0.49	51.55a	0.99
Polyunsaturated	14.61a	1.40	15.84a	1.51	6.99b	0.38	7.82b	0.58
n-6	12.65a	1.12	12.62a	1.21	3.48b	0.24	4.52b	0.51
n-3	1.96	0.31	3.22	0.52	3.51	0.20	3.30	0.25

[a] Means and standard errors.
[b] Values in columns with different letters are significantly different (within trait) ($P < 0.05$).

3.3. Correlations between fatty acid concentrations and sensory scores

The correlations between the scores given by the British and Spanish panels and fatty acid composition (mg/100 g muscle) for all the lambs are given in Table 4. There were consistent relationships between major fatty acids and the scores given by both panels for odour and flavour intensity. The correlations were positive for 18:0, 18:1 (oleic) and 18:3 and negative for 18:2 and 20:4 (arachidonic). These scores reflect the similar evaluations given by both taste panels to the various groups. Both gave higher scores for odour and flavour intensity to the British lambs and these lambs were relatively high in 18:0, 18:1 and 18:3 and low in 18:2. The high correlations suggest that fatty acid composition affects odour and flavour to an important extent.

There were different relationships between fatty acids and the scores for both flavour quality and overall appraisal given by the two panels. These reflected the fact that the British panel preferred the intense odours and flavours associated with 18:3 and grass feeding whereas the Spanish panel preferred the odours and flavours associated with 18:2 and grain feeding. Thus the correlations between 18:0, 18:2 and 18:3 and flavour quality were 0.65 and −0.74; −0.62 and 0.85; and 0.68 and −0.78 for the British and Spanish panels respectively. Correlations for overall appraisal followed a similar pattern.

Correlations between sensory scores and fatty acid composition (mg/100 g) were also examined within the British and Spanish lambs (Table 5). This was only possible for the British panel who assessed all the lambs. In these more restricted groups, having a more limited range of fatty acid composition, less consistent relationships were detected. However, some of the same trends were apparent. For example, negative correlations were found in British lambs for 18:2 and positive (but low) correlations were found for 18:3.

Correlations between sensory scores and fatty acid composition, when this was expressed as a percentage of total fatty acids, are shown for all the lambs in Table 6. The same pattern of results was found as for fatty acids expressed as mg/100 g muscle (Table 4). Thus, odour intensity and flavour intensity were positively correlated with 18:0, 18:1 and 18:3 for both panels and the correlations with 18:2 were negative. For flavour quality and overall appraisal these fatty acids were also important

Table 4
Correlations between meat sensory characteristics and fatty acid composition (mg per 100 g muscle) of intramuscular fat as determined by the British panel (BP) and the Spanish panel (SP)[a]

Trait	Odour intensity		Flavour intensity		Flavour quality		Overall appraisal	
	BP	SP	BP	SP	BP	SP	BP	SP
C10:0	0.26	0.21	0.31	0.05	0.24	−0.38	0.23	−0.44*
C12:0	−0.35	−0.14	−0.25	−0.49*	−0.32	0.28	−0.35	0.11
C14:0	−0.07	−0.01	0.03	−0.26	−0.04	0.02	−0.09	−0.11
C15:0	0.18	−0.01	0.27	0.01	0.15	−0.17	0.09	−0.23
C16:0	0.52*	0.26	0.59*	0.39	0.55*	−0.59*	0.51*	−0.55*
C16-ald	−0.31	−0.11	−0.26	−0.04	−0.27	0.04	−0.24	0.03
C16:1	0.39	0.12	0.40*	0.29	0.29	−0.38	0.23	−0.35
C17:0	0.42*	0.01	0.41*	0.20	0.40*	−0.22	0.33	−0.15
C18:0	0.55*	0.39	0.65*	0.56*	0.65*	−0.74*	0.62*	−0.68*
C18-ald	0.44*	0.48*	0.50*	0.61*	0.49*	−0.75*	0.54*	−0.69*
C18:1 trans	−0.13	−0.24	−0.35	−0.11	−0.31	0.20	−0.32	0.27
C18:1 *n*-9	0.59*	0.30	0.61*	0.48*	0.57*	−0.59*	0.53*	−0.52*
C18:1 *n*-11	−0.15	−0.46*	−0.32	−0.21	−0.33	0.37	−0.40*	0.43*
C18:1-ald	0.44*	0.40*	0.59*	0.49*	0.55*	−0.56*	0.52*	−0.52*
C18:2 *n*-6	−0.63*	−0.65*	−0.69*	−0.67*	−0.62*	0.85*	−0.64*	0.81*
C18:3 *n*-3	0.64*	0.43*	0.75*	0.57*	0.68*	−0.78*	0.72*	−0.77*
C20:1	0.04	−0.32	−0.18	−0.05	−0.19	0.24	−0.27	0.32
C20:3 *n*-6	−0.58*	−0.60*	−0.64*	−0.69*	−0.58*	0.82*	−0.61*	0.77*
C20:4 *n*-6	−0.54*	−0.49*	−0.55*	−0.54*	−0.51*	0.69*	−0.51*	0.64*
C20:5 *n*-3	0.58*	0.44*	0.76*	0.45*	0.68*	−0.73*	0.70*	−0.77*
C22:4 *n*-6	−0.48*	−0.64*	−0.73*	−0.46*	−0.70*	0.75*	−0.73*	0.77*
C22:5 *n*-3	0.58*	0.43*	0.72*	0.38	0.64*	−0.74*	0.64*	−0.77*
C22:6 *n*-3	0.01	0.05	0.33	−0.01	0.20	−0.19	0.19	−0.37

[a] * = $P<0.05$.

Table 5
Correlations between meat sensory characteristics and fatty acid composition (mg per 100 g muscle) for British lambs (BL) and Spanish lambs (SL) as determined by the British taste panel[a]

Trait	Odour intensity		Flavour intensity	
	BL	SL	BL	SL
C10:0	0.18	−0.03	0.49	−0.14
C12:0	−0.35	−0.06	−0.03	0.02
C14:0	−0.01	0.06	0.45	0.01
C15:0	0.05	0.28	0.52*	−0.04
C16:0	−0.01	0.32	0.50*	−0.21
C16 ald	−0.08	0.08	0.04	−0.01
C16:1	0.09	0.40	0.56*	−0.18
C17:0	0.23	0.48	0.58*	−0.29
C18:0	−0.02	0.23	0.44	−0.35
C18 ald	−0.09	−0.05	0.11	−0.11
C18:1 trans	−0.41	0.27	−0.49	−0.29
C18:1 *n*-9	0.22	0.44	0.60*	−0.30
C18:1 *n*-11	−0.36	0.52*	−0.13	−0.20
C18:1 ald	0.08	0.29	0.58*	−0.30
C18:2 *n*-6	−0.50*	0.32	−0.53*	−0.18
C18:3 *n*-3	0.28	0.07	0.56*	0.44
C20:1	−0.03	0.44	0.05	−0.36
C20:3 *n*-6	−0.29	0.23	−0.57*	0.10
C20:4 *n*-6	0.08	−0.03	−0.07	−0.04
C20:5 *n*-3	0.30	0.02	0.43	0.69*
C22:4 *n*-6	−0.25	0.09	−0.57*	−0.55*
C22:5 *n*-3	0.37	0.01	0.47	0.61*
C22:6 *n*-3	−0.29	0.04	−0.09	0.72*

[a] *$P<0.05$.

although the signs of the relationships were different for the 2 panels. As before, 18:0 and 18:3 were positive contributors to preferences for the British panel and negative for the Spanish panel. On the other hand 18:2 was positive for the Spanish panel and negative for the British panel.

Other reports in the literature have shown that the *n*-6 and *n*-3 polyunsaturated FA are important contributors to the odour and flavour of ruminant meats fed grain or forage respectively. Most of these are from the USA and the overall conclusion is that the odours and flavours associated with feedlot-fed (i.e., grain-fed) meat are less intense than those from forage (grass) and are more preferred (Kemp et al., 1981; Larick & Turner, 1990; Melton, 1990). One report from New Zealand, where grass feeding is universal, questioned these conclusions: Purchas, O'Brien and Pendleton (1979) found that the flavour of pasture-fed lamb was preferred to that of grain-fed by their taste panellists. Furthermore, the incorporation of a high level of 18:2 into meat fatty acids using a 'protected' fat supplement greatly reduced the flavour liking score. The present results confirm that feeding grass or grains changes the odour and flavour of lamb because of incorporation of *n*-3 or *n*-6 PUFA into muscle. We believe the results also provide the clearest indication so far that the previous experience of the tasters determines which kind of meat will be preferred. Thus, the Spanish panel was more sensitive to the flavour of lamb with a

Table 6
Correlations in all lambs between meat sensory characteristics and fatty acid composition (% of total fatty acids) of intramuscular fat as determined by the British panel (BP) and the Spanish panel (SP)[a]

Trait	Odour intensity		Flavour intensity		Flavour quality		Overall appraisal	
	BP	SP	BP	SP	BP	SP	BP	SP
C10:0	−0.30	−0.05	−0.24	−0.45*	−0.25	0.22	−0.25	0.06
C12:0 (lauric)	−0.49*	−0.22	−0.36	−0.59*	−0.41*	0.46*	−0.43*	0.29
C14:0 (myristic)	−0.46*	−0.22	−0.33	−0.58*	−0.37	0.45*	−0.39	0.27
C15:0	−0.44*	−0.36	−0.35	−0.56*	−0.46*	0.55*	−0.48*	0.40*
C16:0 (palmitic)	0.01	−0.04	0.06	−0.22	0.02	−0.02	0.01	0.39
C16−ald	−0.58*	−0.28	−0.46*	−0.32	−0.44*	0.46*	−0.39	0.43*
C16:1 (palmitoleic)	−0.33	−0.33	−0.42*	−0.34	−0.56*	0.49*	−0.61*	0.42*
C17:0	−0.15	−0.35	−0.25	−0.18	−0.28	0.43*	−0.32	0.45*
C18:0 (stearic)	0.52*	0.51*	0.56*	0.63*	0.62*	−0.83*	0.62*	−0.76*
C18-ald	−0.17	0.21	−0.08	0.23	−0.02	−0.18	0.08	−0.12
C18:1 trans	−0.13	−0.24	−0.35	−0.11	−0.33	0.20	−0.32	0.27
C18:1 *n*-9 (oleic)	0.61*	0.31	0.41*	0.47*	0.37	−0.41*	0.35	−0.31
C18:1 *n*-11	−0.53*	−0.46*	−0.60*	−0.40*	−0.59*	0.62*	−0.60*	0.62*
C18:1−ald	−0.27	0.23	−0.08	0.08	−0.08	0.10	−0.05	0.12
C18:2 *n*-6 (linoleic)	−0.67*	−0.45*	−0.60*	−0.51*	−0.55*	0.71*	−0.53*	0.66*
C18:3 *n*-3 (α−linolenic)	0.56*	0.38	0.68*	0.44*	0.61*	−0.67*	0.68*	−0.69*
C20:1	−0.48*	−0.37	−0.68*	−0.34	−0.67*	0.67*	−0.70*	0.71*
C20:3 *n*-6	−0.65*	−0.41*	−0.42*	−0.50*	−0.46*	0.66*	−0.36	0.62*
C20:4 *n*-6 (arachidonic)	−0.64*	−0.37	−0.56*	−0.44*	−0.51*	0.63*	−0.49*	0.58*
C20:5 *n*-3 EPA	0.12	0.17	0.35	0.07	0.30	−0.27	0.35	−0.37
C22:4 *n*-6	−0.60*	−0.44*	−0.69*	−0.42*	−0.67*	0.73*	−0.66*	0.73*
C22:5 *n*-3 DPA	−0.18	0.01	0.04	−0.15	0.01	0.06	0.06	−0.05
C22:6 *n*-3 DHA	−0.31	−0.14	−0.05	−0.24	−0.11	0.17	−0.08	0.04

[a] $*P<0.05$.

high content of *n*-6 PUFA derived from concentrates, whereas the British panel preferred the lamb with a stronger odour and flavour associated with *n*-3 PUFA from grass.

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