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Fatty acid composition and eating quality of lamb types derived from four diverse breed × production systems

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Abstract

Carcass composition, muscle fatty acids and eating quality of loin chops were examined in ram lambs from four diverse breed × production system groups: pure Welsh Mountain off upland flora, pure Soays off lowland grass, Suffolk crosses off lowland grass and Suffolk crosses off concentrates. The two Suffolk groups had heavier and better muscled carcasses than the others and Soays were particularly lean. Fatty acid composition was different between the groups. The forage-fed lambs all had high concentrations of n-3 polyunsaturated fatty acids (PUFA) including 18:3 (α-linolenic acid) and 20:5 (eicosapentaenoic acid) compared with Suffolks-concentrates which had high concentrations of the n-6 PUFA 18:2 (linoleic acid) and 20:4 (arachidonic acid). Soays were high in both n-3 and n-6 PUFA. Flavour characteristics in grilled chops were similar in Welsh Mountain and Suffolks-grass which differed from Soays and Suffolks-concentrates. The latter two groups had low scores for lamb flavour and overall liking and high scores for abnormal lamb flavour, metallic, bitter, stale, and rancid. Soays had the highest score for livery. These results extend previous findings of the association between feed, PUFA composition and lamb flavour profile and confirm that forage-fed lamb is preferred by UK taste panellists. They also identify a specific breed effect on the quality of meat from lambs raised on forage. These findings suggest that possibilities exist for the production of meat with specific quality characteristics.

1. Introduction

Several factors affect consumers' decisions to purchase meat but an important one is the perception of quality. The perceived 'healthiness' of a food is becoming a key quality issue for consumers and, in the case of meat, this is largely related to its fat content and its fatty acid composition. Previous studies suggest that the fatty acid composition of ruminant meats can be influenced by diet, with consequences for other important quality attributes, most notably flavour which is a major determinant in eating satisfaction (Wood, Enser, Fisher, Nute, Richardson & Sheard, 1999). For example, grain diets which result in raised concentrations of n-6 polyunsaturated fatty acids (PUFA) in muscle produce a different flavour profile to grass diets which increase muscle concentrations of n-3 PUFA (Kemp, Mahyuddin, Ely, Fox & Moody, 1981; Larick & Turner, 1990). The preference of taste panellists for meat from grain-fed or grass-fed lambs seems to depend on previous experience: although Spanish taste panellists identified British grass-fed lamb as having more intense/pronounced lamb flavour, they preferred the flavour of younger, Spanish, grain-fed lamb. British panellists, assessing the same lambs, were in agreement on the flavour intensity ratings but preferred the flavour of the British lamb (Sanudo et al., 1998).

In addition to diet, the effect of breed may be important. There is anecdotal, but little scientific, evidence that the meat from lambs of certain breeds reared on particular diets (i.e. 'systems') has unique or characteristic flavours. Such meat could qualify for premium quality status if it were shown that it was genuinely different. One hypothesis to support differences in taste is that they are, in large part, a result of variation in fatty acid composition which, in turn, varies according to the breed and feed used. Ruminants preferentially deposit

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PUFA in phospholipids (Enser, Hallett, Hewett, Fursey, Wood & Harrington, 1998) so very lean breeds could have relatively high proportions of PUFA compared with fatter lambs in which the phospholipid effect is diluted by higher levels of neutral storage lipid (marbling fat). Variations in the absolute concentration and the relative proportions of different fatty acids would affect the flavour profile. In order to investigate these ideas further, fat content, muscle fatty acid composition and flavour profile have been studied in four lamb types. Three of these represent diverse breed × production systems found in the UK, whilst the fourth type was genetically similar to one of the others but was fed a different diet to provide information on the effect of diet per se. The aim in selecting animals from different breed × feed combinations was to determine the extent of natural variation in fatty acid composition and flavour characteristics.

2. Material and methods

Four groups of 20 entire ram lambs of usual commercial slaughter weight were studied: pure Soay, finished on lowland grass; pure Welsh Mountain, finished on upland flora; Suffolk × 'Mule', finished on lowland grass; and Suffolk × 'Mule', finished on concentrates. Both groups of Suffolk lambs were from the Harper Adams University College flock and were the same genetic type. The 'Mule' used here was a cross between the Scottish Blackface and Bluefaced Leicester breeds. It was intended that all the lambs would be slaughtered in their first year, but the Soays were about 12 months of age or slightly older. The typical concentrate feed used at Harper Adams contained 11.7 MJ ME and 219g total protein/kg dry matter.

The lambs were slaughtered at the Bristol University abattoir, Langford and were electrically stunned and conventionally dressed. In order to prevent cold-shortening of the muscles, the carcasses were hung at ambient temperature for about 5 h prior to chilling at 1°C. Twenty-four hours after slaughter, carcasses were classified for fat cover and conformation using 1–15 scales similar to those for beef carcasses described by De Boer, Dumont, Pomeroy and Weniger (1974).

An anatomically defined forelimb joint was removed and stored in vacuum pack at −20°C before being dissected into lean, subcutaneous fat, intermuscular fat and bone (Fisher & De Boer, 1994). The *semimembranosus* muscle was dissected from the right hindlimb in order to determine the content and composition of fatty acids in the total muscle tissue lipids, and was stored frozen at −20°C. After thawing, the muscle, minus the epimysial connective tissue, was homogenised in a small food processor. Samples were saponified and the fatty acids extracted, methylated and analysed by gas–liquid chromatography as described by Whittington, Prescott, Wood and Enser (1986) and Enser, Hallett, Hewett, Fursey and Wood (1996). Fatty acids were quantified using heneicosaenoic acid methyl ester, added prior to saponification, as an internal standard.

Leg steaks, 10 mm thick, in the form of transverse cross-sections, were cut from the mid-thigh of the left hindlimb, 24 h after slaughter. These contained sections of the *semimembranosus* and the other major pelvic limb muscles *semitendinosus* and *gluteobiceps*. The steaks were conditioned at 1°C in vacuum packs for either 6 or 10 days then put into plastic containers with a modified atmosphere of 0.75 O_2:0.25 CO_2 and displayed in a cold room at 4°C under 1000 lux light (16 h on, 8 h off) for 7 days to simulate retail conditions. Lipid oxidation was assessed using the procedure of Vyncke (1975) which measures oxidation in terms of thiobarbituric acid reacting substances (TBARS). Colour of the individual muscles in cross-section was recorded as the CIELAB coordinates L^*, a^* and b^* using a Minolta chromameter. There was an electrical fault in the cold room while the steaks from the Welsh Mountain lambs were being displayed. This caused abnormally high lipid oxidation so the results for these animals were excluded from the analysis.

A section of *longissimus thoracis et lumborum*, approximately 25 cm long, was removed 24h after slaughter from the left side of the carcass, was packaged under vacuum and conditioned at 1°C for a further 10 days when it was frozen at −20°C prior to taste panel assessment. Samples were thawed at 4°C overnight and cut into 2.5 cm chops which were grilled to an internal temperature of 80°C. A panel of 10 trained assessors rated the intensities of toughness, juiciness, lamb flavour, abnormal flavour and several previously agreed flavour descriptive terms on line scales in which 0 = nil and 100 = extreme. Assessors were also asked to rate 'overall liking' on the same scale.

3. Results

Carcass weights, classification scores and composition of the forelimb joints are presented in Table 1. Welsh Mountain and Soay carcasses were about half the weight of the Suffolk, reflecting their smaller mature size. Carcass conformation and fatness scores were lower in Welsh Mountain and Soay lambs, indicating thinner muscles and less fat cover than in the Suffolk. The Soay had particularly lean forelimb joints, with lower percentages of subcutaneous and intermuscular fat than the other types in agreement with the findings of McClelland, Bonaiti and Taylor (1976). Welsh Mountain lambs had a higher lean percentage than the Suffolks and a lower bone percentage, their percentages of subcutaneous and intermuscular fat being similar. The concentrate-fed Suffolks had a higher subcutaneous

fat percentage than the grass-fed Suffolks (which were leaner), although the intermuscular fat proportion was not different.

Data on the fatty acid content of muscle (mg/100 g) are shown in Table 2. Welsh Mountain lambs had the highest concentration of intramuscular fat (total fatty acids), there being no significant differences between the other three types. Soays had the lowest, and the Welsh Mountain the highest, concentrations of the major fatty acids 16:0 (palmitic) and 18:1 (oleic). Soays had significantly more of three of the six PUFA quantified, including 18:2 (linoleic acid) and 18:3 (α-linolenic acid). The three forage-fed groups (Welsh Mountain, Soays and Suffolks-grass) had higher concentrations of most n-3 PUFA than Suffolks-concentrates; conversely, the latter were higher in n-6 PUFA than the Welsh Mountain and Suffolks-grass (but not the Soays).

Fatty acids expressed as a percentage of total fatty acids are shown in Table 3. Soays had significantly ($p < 0.05$) the highest percentages of four of the six PUFA, including both in the n-6 series and 18:3 n-3 and 20:5 n-3. Generally, the three forage-fed groups had higher n-3 PUFA than the Suffolks-concentrates.

Results for eating quality are presented in Table 4. Suffolks-concentrates produced the most tender meat, Soays the toughest. The Welsh Mountain produced the most juicy meat, Soays the least juicy. Soays had high scores for abnormal lamb flavour, metallic, bitter, stale, rancid, livery, fishy and ammonia. The pattern of these responses to flavour attributes was generally similar in Suffolks-concentrates, but there were subtle differences: compared with the Suffolks-concentrates the Soays were less sweet, more fishy and, perhaps most importantly, more livery. However, both these groups had low overall liking scores. Welsh Mountain and Suffolks-grass, i.e. two of the three forage-fed groups, had high scores for lamb flavour, low scores for abnormal flavour, low scores for metallic, bitter, stale, rancid and ammonia and high overall liking scores. These different flavour profiles are illustrated in Fig. 1.

The overall results for lipid oxidation are shown in Table 5. Soays and Suffolks-grass had higher TBARS than Suffolks-concentrates and the *semimembranosus* and *gluteobiceps* muscles had higher TBARS than the *semitendinosus* which contains a higher proportion of glycolytic white muscle fibres. Soays had particularly high TBARS in the redder muscles (containing higher proportions of the more oxidative muscle fibres). For example, values in *semimembranosus* were 2.93, 2.70 and 1.90 in Soays, Suffolk-grass and Suffolks-concentrates,

Table 1
Carcass classification and composition of the forelimb joint from ram lambs in four breed×production system groups[a]

	Welsh Mountain	Soay	Suffolk grass	Suffolk concentrates	s.e.d	Significance
Hot carcass wt (kg)	10.4a	10.9a	18.3b	20.0c	0.55	***
Conformation (1–15)	3.0b	1.4a	7.8c	8.0c	0.39	***
Fatness (1–15)	3.8b	1.4a	6.7c	7.9c	0.51	***
Forelimb joint (%)						
Subcutaneous fat	4.8c	1.4a	3.3b	5.3c	0.37	***
Intermuscular fat	8.0b	5.4a	9.2c	8.6bc	0.40	***
Lean	61.8c	66.3d	59.7b	58.0a	0.52	***
Bone	25.3a	26.8b	27.8c	28.1c	0.46	***

[a] Means with different letters are significantly different ($P < 0.05$). ***$P < 0.001$.

Table 2
Fatty acid content of *semimembranosus* (mg/100g) in four breed×production system groups[a]

	Welsh Mountain	Soay	Suffolk grass	Suffolk concentrates	s.e.d	Significance
12:0	12c	2.2a	2.8a	6.3b	1.15	***
14:0	104c	33a	62b	45ab	8.96	***
16:0	492c	274a	349b	382b	36.50	***
18:0	431b	224a	264a	239a	26.49	***
18:1	851d	472a	593b	725c	58.80	***
18:1 trans	73	61	82	87	9.70	ns
18:2 n-6	106a	207d	119b	188c	6.09	***
18:3 n-3	40b	54c	41b	14a	2.99	***
20:4 n-6	44a	63b	45a	62b	1.69	***
20:5 n-3	23b	29c	24b	8.4a	0.86	***
22:5 n-3	22b	26c	27c	16a	0.85	***
22:6 n-3	6.2a	11b	10b	5.5a	0.50	***
Total fatty acids	2509b	1668a	1853a	1963a	157.4	***

[a] Means with different letters are significantly different ($P < 0.05$). *** $P < 0.001$; ns, not significant.

Table 3
Fatty acid composition of semimembranosus (% by weight of total fatty acids) in four breed×production system groups[a]

	Welsh Mountain	Soay	Suffolk grass	Suffolk concentrates	s.e.d	Significance
12:0	0.5d	0.1a	0.4c	0.3b	0.03	***
14:0	4.1c	1.9a	3.2b	2.3a	0.20	***
16:0	19.4b	16.0a	18.6b	19.4b	0.44	***
18:0	17.0c	13.5b	14.3b	12.3a	0.37	***
18:1	33.8c	28.0a	31.7b	36.7d	0.77	***
18:1 trans	2.9a	3.6ab	4.3b	4.3b	0.32	***
18:2 n-6	4.4a	12.9d	6.8b	9.7c	0.58	***
18:3 n-3	1.6b	3.3d	2.3c	0.7a	0.14	***
20:4 n-6	1.9a	4.0d	2.6b	3.3c	0.25	***
20:5 n-3	1.0b	1.8c	1.3b	0.4a	0.10	***
22:5 n-3	0.9a	1.6b	1.5b	0.8a	0.09	***
22:6 n-3	0.3a	0.7b	0.6b	0.3a	0.05	***

[a] Means with different letters are significantly different ($P < 0.05$). *** $P < 0.001$; ns, not significant.

Table 4
Toughness, jiuciness, overall liking and flavour descriptive tems in grilled chops from four breed×production system groups (0–100 scales)[a]

Attributes	Welsh Mountain	Soay	Suffolk grass	Suffolk concentrates	s.e.d	Significance
Toughness	30.0b	53.5c	28.3b	24.4a	1.70	**
Juiciness	41.0c	30.6a	33.8b	34.3b	1.34	***
Lamb flavour	20.5b	13.5a	27.2c	14.9a	1.43	***
Abnormal lamb flavour	28.8a	41.8b	28.2a	45.0b	2.04	***
Fatty/greasy	21.6b	19.0a	18.2a	19.5a	1.03	**
Sweet	12.1c	7.2a	11.2bc	9.1b	1.24	***
Acidic	5.4	6.9	5.9	6.4	0.79	ns
Metallic	10.6a	14.3b	9.2a	11.6ab	1.34	**
Bitter	10.9a	15.9b	10.5a	14.0b	1.45	***
Stale	8.9a	12.3b	8.1a	11.9b	1.13	***
Rancid	6.9a	11.0b	6.8a	10.3b	1.26	***
Livery	16.2a	20.5b	14.9a	16.7a	1.67	**
Vegetable	11.0	11.5	9.9	9.7	1.14	ns
Grassy	4.2	3.1	2.9	3.1	0.87	ns
Fishy	2.6a	4.8b	1.4a	2.0a	0.66	***
Ammonia	3.1a	5.9b	2.5a	5.4b	0.98	***
Overall liking	18.5b	11.1a	23.3c	12.9a	1.26	***

[a] Means with different superscripts are significantly different ($P < 0.05$). **$P < 0.01$; ***$P < 0.001$; ns, not significant.

respectively, whilst the corresponding values in *gluteobiceps* were 2.70, 2.40 and 1.49. There was no significant difference between 6 and 10 days conditioning time and at each time Soays had the highest values in the two red muscles.

Results for the colour of *semitendinosus* are shown in Fig. 2. The results were similar for the other muscles. Soays had darker muscle as determined by L^* values but had similar saturation (intensity of colour) as Suffolks-grass or Suffolks-concentrates during retail display.

4. Discussion

The results for carcass quality, because they determine price, are currently more important to farmers than those for meat quality. For conventional UK markets, the Suffolk-cross lambs approached the norm, both in terms of carcass weight and classification scores (conformation and fatness). The UK national average carcass weight of new season lambs in 1998 was 17.8 kg and mean conformation and fatness scores were R and 3L (Meat and Livestock Commission, 1999) corresponding to scores of approximately 7 and 8, respectively, on the 15-point scales used here. The Welsh Mountain carcasses were smaller and were representative of carcasses selected for UK exports to some southern Mediterranean countries, especially Spain, where smaller carcasses are preferred. The Soay carcasses were very different from the other types in that they were very thinly fleshed and had very little subcutaneous or intermuscular fat. Despite their poor conformation, the Soay carcasses had the highest lean to bone ratio in the forelimb joint.

The amount of intramuscular fat, of direct relevance to eating quality, was related to overall carcass fatness

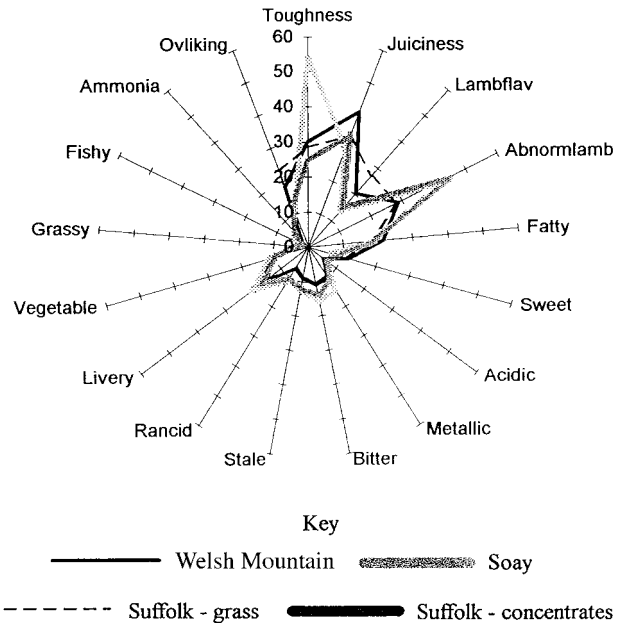

Fig. 1. Plot of flavour descriptive terms in four breed×production system groups.

in a general way but was also influenced by breed. Thus, there was a tendency for Suffolks-concentrates to have more intramuscular lipid than Suffolks-grass, and for Soays to have the lowest level, although these differences were not significant. Welsh Mountain, however, had significantly more intramuscular fat than the other groups despite being intermediate in separable fat between Soays and the two Suffolk groups. Welsh Mountain lambs had the highest juiciness rating and the intensity of this attribute is correlated with the amount of intramuscular fat (Wood et al., 1999). They also had the highest rating for fatty/greasy flavour.

The results show important effects of breed, in combination with feeding regime, on the sensory characteristics and fatty acid composition of lamb. The three groups fed grass or natural flora had high concentrations of 18:3 (α-linolenic acid) and long chain n-3 PUFA and two of them (Welsh Mountain and Suffolks-grass) had high taste panel scores for lamb flavour, low scores for abnormal flavour and high scores for overall liking. In contrast, the Suffolks fed concentrates had a high concentration of 18:2 (linoleic acid) and its major product 20:4 (arachidonic acid) and had a low score for lamb flavour and overall liking and a high score for abnormal lamb flavour. The results from the two Suffolk groups show that the effects of feed were marked. In fact, this effect of feed was more important than the effect of breed (similar feed) in the comparison of Suffolks-grass and Welsh Mountain which had similar flavour ratings. Overall, these results, which appear to link production system, muscle fatty acid composition and flavour profile, are similar to those of Sanudo et al. (1998, in press). Lamb produced in Spain fed grain (concentrates) had a lower flavour intensity than that produced in Britain on grass as identified by taste panels in both Britain and Spain. The Spanish lamb was high in n-6 PUFA and the British lamb high in n-3 PUFA. There were high correlations between flavour intensity and 18:3 (positive) and 18:2 (negative), identified by both taste panels. However, relationships between fatty acids and liking (preference) scores were different for the two panels: the Spanish panel preferred the grain-fed lamb they were used to and the British panel the grass-fed lamb. The importance of the n-3 and n-6 PUFA in determining flavour has also been shown by Larick and Turner (1990) in beef and by Purchas, O'Brien and Pendleton (1979) and Kemp et al. (1981) in sheep. In the US study of Larick and Turner (1990), taste panellists preferred the flavour of the grain-fed beef with which they were familiar and in the New Zealand study of Purchas et al. (1979) panellists preferred grass-fed lamb which is the norm in that country.

Although the Soay lambs in this study had also consumed grass, their flavour profile was different from Welsh Mountain and Suffolks-grass and was closer to Suffolks-concentrates. Even so, the meat from the Soays had some unique characteristics in the context of this trial, the high score for livery being of interest. This particular flavour may be related to the overall composition of the muscle tissue which, in the Soays, was high in PUFA and was much darker than that from the other breeds, probably due to a higher myoglobin content. This combination will increase the development of flavour volatiles during cooking, through lipid oxidation. The high n-6 and n-3 PUFA in the Soay would be particularly susceptible to peroxidation and could be responsible for

Table 5
Lipid oxidation after 6 days retail display as shown by TBARS (mg malonaldehyde kg muscle)[a]

				s.e.d.	Significance
Breed	Soay	Suffolks-grass	Suffolks-concentrates		
	2.43b	2.37b	1.52a	0.173	***
Muscle	*semimembranosus*	*semitendinosus*	*gluteobiceps*		
	2.51b	1.60a	2.20b	0.173	***
Cond. time	6d	10d			
	1.95	2.26		0.141	ns

[a] Means with different letters are significantly different ($P < 0.05$). ***$P = 0.001$; ns, not significant.

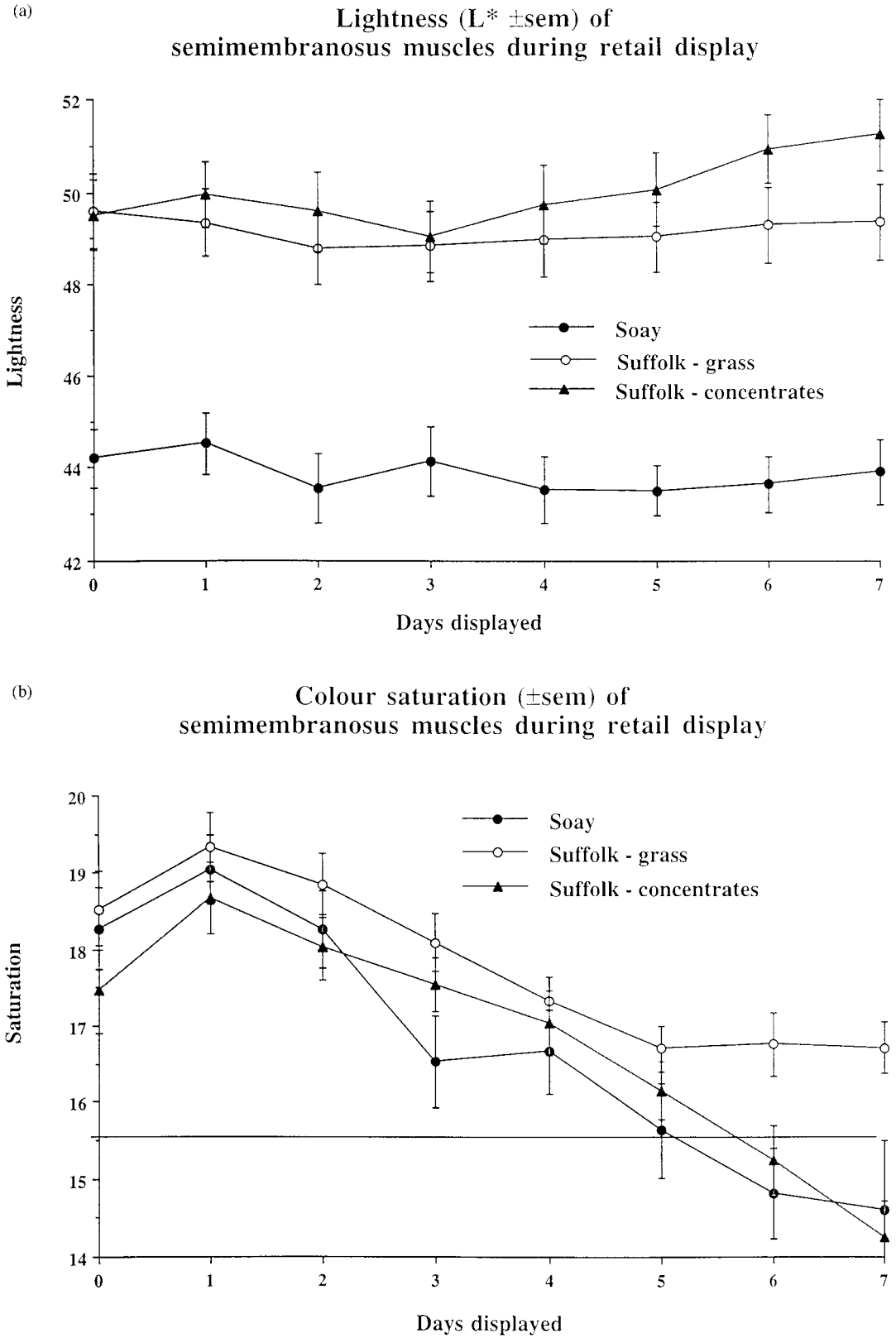

Fig. 2. (a) Lightness ($L^* \pm$ sem) of semimembranosus muscles during retail display; (b) colour saturation ($\pm$ sem) of semimembranosus muscles during retail display.

the strong livery flavour. Livery features as a descriptor of venison (Fisher, Nute & Davies, 1995), another meat high in myoglobin. Also, there was evidence that these Soay lambs were older than the others and it is known that flavour develops with age. Greater age may also have caused the greater toughness in the Soay lambs.

The fact that the Bristol taste panel gave a lower 'overall liking' score to the Soays and the lambs fed concentrates reflects their preferences and past experience but is not necessarily a guide to consumer responses in UK or elsewhere. Nevertheless, the results provide further evidence for real differences in flavour between lambs from different genetic and production backgrounds which could form the basis of premium quality marketing schemes.

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