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VARIATION IN MUSCLE COMPOSITION BETWEEN DIFFERENT COMMERCIAL LAMB TYPES AND ITS RELATIONSHIP WITH MEAT TEXTURE

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Background and Objectives

Lamb is produced in most regions of the world using an extremely large variety of inputs which include mainly the type of animal (breed age, sex status) and the rearing practices (weaning, feeding strategy, housing). The combinations of these conditions result in a large numbe of different production systems and lamb types, and consequently in a highly variable quality of the meat available to the consumers (Sañudo et al., 1998a). However, there is still little information published to date allowing an objective comparison of the meat quality traits of commercial lamb types from different geographical origins. Jeremiah (1988), Dufey and Wirz (1995) and Sañudo et al. (1998b) found significant differences in texture and flavour scores when comparing commercial lambs from different countries (Spain, Great-Britain Switzerland, Canada, New Zealand and Australia). These differences could not be explained in the absence of information about the composition of the meats and the post-mortem conditions applied to the carcasses. Thus, collaborative research (FAIR 3CT96-1768 project funded by the EC was undertaken to collect meats from contrasting european lamb types, and to analyze them (composition, texture) in the same laboratories, thus ensuring the most favourable conditions of slaughter, carcass post-mortem handling and meat conditioning for comparison of meat quality traits and the interpretation of differences between lamb types. The present paper integrates the results of the two phases of the project already presented by Berge et al. (1998 and 1999).

Materials and Methods

Twenty-two groups of approximately 20 lambs (n = 18 to 26) from six different European countries were studied (Table 1). Each group was representative of a local commercial lamb type. Within each lamb type, the animals had the same sex status (except for one lamb type which combined equal numbers of males and females) and feeding background, and similar age, breed type and carcass weight. A more detailed description of the lamb types is given by Sañudo et al. (2000). Each lamb type was slaughtered in its country of origin. The carcass was kept for 6 h post-mortem at room temperature (> 10°C) prior to chilling for 24 h at 2 (± 2)°C. The pH was measured at 24 h post-mortem (ultimate value, pHu) in the *Longissimus thoracis* muscle and a sample of this muscle was frozen at –20°C until determination of its chemical composition (moisture, total collagen, soluble collagen after a 90°C, 2-h heat treatment, total lipids, haem iron). A sample of the *Longissimus lumborum* muscle was vacuum packed, aged for 6 days at 2°C and frozen at –20°C. After thawing, this sample was used to determine sarcomere length (10 lambs/type) and instrumental texture characteristics according to the methods presented by Sañudo et al. (2000). Two textural traits were selected for the purpose of this study, the stress value during the linear compression of raw meat samples at a strain of 20% of initial thickness (S20) and the maximum stress value during a Warner-Bratzler shear test performed on meat cooked at 70°C internal temperature (WBMS). The S20 value is a measurement of the residual toughness of the myofibrillar component related to the extent of ageing before cooking (Lepetit, 1989) while WBMS is a measurement of the overall meat toughness after cooking. Data were subjected to one-way analysis of variance and Scheffe's test was used to assess the significance of the differences between treatment (lamb type) means.

Results and Discussion

The chemical composition and textural traits of the *Longissimus* muscle of the 22 lamb types are presented in Table 1 in the order of increasing age. The effect of lamb type was generally highly significant ($P < 0.001$). The large differences between lamb types for each of the quality traits studied reflected the wide ranges of age at slaughter and carcass weight achieved in this study. With the exception of one lamb type which exhibited high pH (pHu 5.8), the pHu value was always within the range of normal values (5.4-5.7). The pigment content, an index of animal maturity, varied from 15 to 48 µg haem iron/g dry matter and showed a high positive correlation with lamb age ($r = .66$; $P < 0.001$). A comparable age-related increase in pigment concentration was previously reported by Contreras-Villanueva (1972) in lambs of 3 to 17 months. Total lipids ranged from 5.3 to 13.0 %, dry matter basis. The total collagen content varied by almost 2-fold between extreme lamb types (from 1.6 to 2.9 mg HyPro/g dry matter, equivalent to 1.2 to 2.2% collagen). This variation could be attributed, at least partly, to breed. The Icelandic breed (types 9, 10, 19 and 20) consistently exhibited low values while in contrast the Karagouniko (types 7, 8 17 and 18) and Bergamasca (types 11, 21 and 22) breeds showed high values (means 1.4, 2.0 and 2.0% collagen, respectively). The proportion of heat soluble collagen ranged from 21 to 50% of total collagen according to lamb type. This trait showed an inverse relationship with lamb age ($r = -.67$; $P < 0.001$), which confirms the works of Boccard et al. (1970) and Young et al. (1993). The youngest lamb types with light carcasses (types 3, 4, 7 and 12) had the most soluble collagen, and the least soluble collagen was that of the pasture-fed lambs with heavier carcasses (types 2, 5, 11, 13, 17, 20 and 21).

The textural traits of the meat have been presented in greater detail and for a larger population of animals from the same lamb types by Sañudo et al. (2000). From the limited number of lambs used in the present study, it is also clear that considerable differences existed in meat toughness between lamb types. The shear value of cooked meat (WBMS) varied from 1.6 to 4.1 kg/cm² according to lamb type. Meat toughness was generally not related to the feeding background or the type of the lamb (age, breed) but two exceptions are noteworthy. The first is the Icelandic breed (types 9, 10, 19 and 20) that produced four among the six most tender lamb types. The second is the lambs fed milk, either alone or with concentrate (types 4, 7 and 12), that exhibited high shear values. These three lamb types were among the four youngest of the 22 studied in this work (less than 2.5 months of age) and their collagen was practically the most soluble of all types. Their meat was as tough as that of the oldest lamb type (type 11; 12 months of age). The corresponding S20 values were also the highest of all lamb types. There was generally little variation of this parameter between the other lamb types. This demonstrates that the post-mortem tenderization in the meat of very young lambs is slower, or its extent is smaller, than in older lambs and that it may have been the primary factor responsible for the relatively higher toughness level of their meat.

Although not evidence of cause and effect, the correlation coefficients between variables indicate patterns of change. The WBMS value was best correlated with S20, pHu, total collagen content and sarcomere length ($r = .39, .37, .34$ and $-.30$, respectively; $P < 0.001$), but poor correlations were found with collagen heat solubility ($r = .17$; $P < 0.001$), intramuscular lipids ($r = .11$; $P < 0.05$) and age ($r = -.04$; $P = 0.38$). Overall, these correlations indicate that the combined effects of myofibrillar strength, pHu, total collagen and sarcomere length were linked to meat texture. The data in Table 1 show that the five toughest lamb types actually presented at least two of the favourable conditions for the occurrence of tough meat: high myofibrillar strength (types 4, 7 and 12), high pHu (types 7, 12, 21), high collagen content (types 4, 7, 11 and 21) and short sarcomere (types 4, 11 and 12). The low collagen solubility due to the advanced age (1 year) of type 11 lambs probably also contributed to enhance the toughening effects of the other mentioned factors. Conversely, the five most tender lamb types presented at least two of the following features: low myofibrillar strength (type 19), low pHu (types 6, 10, 15 and 19), low collagen content (types 9, 10 and 19) and long sarcomere (types 6, 9 and 15).

Conclusions

The large variations observed in the texture of the meat from 22 different commercial lamb types from 6 european countries (see also Sañudo et al., 2000) reflect the complex influence that animal characteristics and rearing conditions exert on muscle structure and composition. The results showed that the main factors linked to meat toughness were myofibrillar strength, pHu, total collagen and sarcomere length, but not collagen heat stability or amount of intramuscular lipids.

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Table 1. Composition and texture characteristics of the *Longissimus thoracis* and *lumborum* muscle in the 22 different lamb types.

Country of origin (1)	Lamb type		Number of animals	Age at slaughter (months) (3)	Cold carcass wt. (kg) (3)	pHu	Lipids (%) (4)	Pigment (µg haem iron/g) (4)	Total collagen (mg HyPro/g) (4)	Collagen solubility (%)	Sarcomere length (µm)	S20 (N/cm²)	WBMS (kg/cm²)
	Code	Feed (2)											
ES	4	M	20	1.0 a	5.4 a	5.6 abcd	6.2 ab	15 a	2.6 defgh	49 f	1.5 ab	12.0 c	3.6 cdef
GR	7	M	26	1.7 b	8.1 b	5.8 e	8.5 abcd	20 abcd	2.9 h	43 ef	1.6 abc	10.9 bc	3.9 ef
GR	18	C	20	2.3 c	11.1 c	5.6 bcd	9.6 abcd	18 ab	2.5 cdefgh	37 bcde	1.6 ab	4.7 a	3.2 abcdef
IT	12	M+C	20	2.4 cd	11.2 cd	5.7 de	6.8 abc	28 efg	2.2 bcdef	40 def	1.5 a	7.7 abc	4.1 f
ES	3	C	20	2.8 cde	10.0 bc	5.6 abcd	5.8 a	25 bcde	2.6 defgh	40 def	1.6 abc	6.3 a	2.7 abcdef
IS	19	M+G	20	2.7 cde	13.9 ef	5.5 abc	6.8 abc	23 abcde	1.9 abc	38 bcde	1.7 abc	4.2 a	2.0 ab
ES	15	C	20	3.0 def	13.6 def	5.5 ab	6.4 ab	26 cdef	2.1 abcdef	37 bcde	1.7 bc	4.8 a	1.9 ab
ES	16	C	20	3.0 def	11.8 cde	5.6 abcd	5.4 a	20 abc	2.4 bcdefgh	39 cdef	1.6 abc	7.6 abc	3.1 abcdef
FR	6	C	20	3.3 ef	15.3 fgh	5.5 a	10.2 abcd	27 defg	2.0 abcde	35 bcde	1.6 ab	5.0 a	2.1 abc
GR	8	C+G	20	3.5 fg	15.4 fghi	5.6 bcd	9.7 abcd	27 cdef	2.7 fgh	36 bcde	1.5 ab	6.7 ab	2.7 abcdef
GB	1	M+G	22	4.0 gh	17.8 ijk	5.6 abcd	7.1 abc	36 hi	2.2 bcdef	35 bcde	1.5 ab	5.0 a	3.2 abcdef
IS	9	M+G	20	4.3 h	16.7 hij	5.6 abcd	7.5 abc	33 fghi	1.9 ab	34 bcde	1.7 bc	4.9 a	1.9 a
IS	10	M+G	20	4.3 h	15.9 fghi	5.5 abcd	9.7 abcd	34 ghi	1.6 a	30 abcd	1.6 abc	5.0 a	1.6 a
IT	22	C	18	5.0 i	19.7 kl	5.6 abcd	8.5 abcd	24 bcde	2.4 bcdefgh	36 bcde	1.5 ab	6.1 a	3.5 bcdef
GB	13	G	20	5.0 i	10.4 bc	5.6 bcd	9.2 abcd	30 efgh	2.3 bcdefg	28 ab	1.7 bc	5.2 a	2.2 abc
GR	17	G	20	5.1 i	14.0 efg	5.6 abcd	11.8 cd	26 bcde	2.6 defgh	29 abc	1.6 abc	5.0 a	2.4 abcde
IT	21	G	20	6.0 j	18.9 jkl	5.7 d	5.3 a	30 efgh	2.9 gh	29 ab	1.8 c	4.7 a	3.7 cdef
GB	2	G	20	7.4 k	15.3 fgh	5.7 cd	11.5 bcd	39 i	2.1 abcde	27 ab	1.6 ab	6.5 a	2.2 abcd
FR	5	G	20	7.0 k	16.6 hij	5.4 a	7.6 abcd	33 fghi	2.0 abcd	28 ab	1.6 abc	4.7 a	2.5 abcde
GB	14	C	20	7.4 k	20.5 l	5.6 abcd	9.5 abcd	25 bcde	1.9 abc	28 ab	1.7 bc	5.2 a	2.4 abcde
IS	20	G	20	7.0 k	16.5 ghi	5.6 abcd	7.4 abc	25 bcde	2.0 abcde	28 ab	1.6 abc	4.8 a	2.5 abcde
IT	11	G	20	12.0 l	30.5 m	5.6 bcd	13.0 d	48 j	2.6 efgh	21 a	1.5 a	4.7 a	3.8 def
SEM				*0.3*	*1.4*	*0.08*	*2.9*	*4*	*0.3*	*6*	*0.1*	*2.6*	*0.9*

(1) Spain (ES), France (FR), Great-Britain (GB), Greece (GR), Iceland (IS) or Italy (IT).
(2) feeding background (predominant type of feed): milk (M), concentrate (C), pasture or grass (G) and their combinations (M+C, M+G or C+G).
(3) mean values with common superscript(s) do not differ significantly ($P > 0.05$).
(4) on a dry matter basis.