LAMB MEAT TEXTURE AS INFLUENCED BY ANIMAL AGE AND COLLAGEN CHARACTERISTICS

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BACKGROUND AND OBJECTIVE

The specific flavour (or "mutton flavour") of sheep meat is certainly a major factor of reduced acceptability by consumers for this type of meat (Young et al., 1994). For this reason, sheep meat is generally obtained from lambs. However, there is a large variability in age, sex, slaughter weight and carcass fatness among the lambs produced, depending on the different production systems used and on the regional patterns of consumer (Sañudo et al., 1998a). Thus, one may expect noticeable variations in lamb quality attributable to the geographical origin of the animal. These differences have little been documented. Most works undertaken in the past took into account one or more controlled factors, but seldom geographical origin which combines most of the other ante-mortem factors. Jeremiah (1988) reported significant differences in texture and flavour scores between commercial lamb leg roasts from Canada, New Zealand and Australia. Also, Sañudo et al. (1998b) found significant differences in the texture and flavour scores of the loin between Spanish and British lambs of similar carcass weights. This shows that, even with young animals, consumers are sensitive to the variations of texture, which may also influence lamb acceptability when flavour is not objectionable. Lamb tenderness decreases with increasing animal age (Bray, 1988), this effect being already perceptible soon after birth (Jeremiah et al., 1971; Young et al., 1993). At a given stage of maturity, the variations in lamb texture can be accounted for by the variations in muscle collagen content and in collagen heat stability (Bruwer et al., 1987; Young and Braggins, 1993) if muscle cold-shortening or pre-slaughter stress of animals are prevented. The collagen heat stability in turn is closely dependent upon the age of the animal (Boccard et al., 1970; Heinze et al., 1986; Young et al., 1993). The objective of this work was to determine the variations in the meat texture of contrasted types of lamb from different geographical origins, and to relate these variations to the age of the animals and to the characteristics of their muscle collagen. It is part of a collaborative research project under course (FAIR 3CT96-1768) which is supported by the European Union, and includes the six European countries who supplied the animals (see footnote for contact persons). This paper reports preliminary results from only a part of the experimental material.

MATERIALS AND METHODS

Six commercial lambs types, each including 20 to 26 animals, from different European countries were studied. Within each type, lambs had the same sex status and feeding background, and similar age, breed type and carcass weight. The breed types differed between countries, and included dairy, dual purpose and meat breeds. Lambs were either milk fed (1 type), or suckling at pasture (1 type), or weaned and subsequently fed concentrate (1 type) or reared at pasture (3 types). Three types consisted in ram lambs, two in wether lambs and one in female lambs. 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. A sample of the Longissimus thoracis muscle was taken and frozen at –20°C until determination of its chemical composition (moisture, total collagen, soluble collagen after a 90°C, 2-h heat treatment, lipids, pigment). Another sample of the Longissimus lumborum muscle was vacuum packed and aged for 6 days at 2°C before being frozen at –20°C. After thawing, the texture of this sample was determined using an Instron universal testing machine. A raw sample was submitted to a compression test across the main muscle fibre axis, and stress at strains of 20 and 80 % of initial sample thickness were recorded. Another sample was cooked at 75°C until a 70°C internal temperature was reached. Then, a Warner-Bratzler (WB) shear test was performed, and the maximum stress and average stress were determined.

RESULTS AND DISCUSSION

The age of the lambs ranged from approximately 1.5 to 12 months. It was on average 1.7 (± 0.2), around 2.8, 4.1 (± 0.5), 4.3 (± 0.4), 7.0 (± 0.6) and around 12.0 months in the different lamb types. The respective average cold carcass weights were 8.4 (± 0.8), 10.1 (± 0.6), 17.5 (± 1.2), 16.8 (± 1.8), 16.3 (± 2.6) and 30.4 (± 2.3) kg. The age differences between lamb types were reflected in the muscle pigment concentration, an index of animal maturity, which was on average 5.0 (± 0.9), 6.1 (± 0.8), 9.0 (± 1.0), 8.8 (± 1.0), 8.3 (± 1.3) and 12.6 (± 1.4) µg haem iron/mg respectively (significant lamb type effect; $P < 0.001$). Contreras (1972) reported a similar increase in the pigment concentration from 6.6 to 15.0 µg/mg when lamb age increased from 3 to 17 months. The intramuscular lipid content ranged from 0.3 to 6.3 %. With the exception of the oldest lambs which showed a significantly higher lipid content (3.5 %; $P<0.001$), this content did not vary much between lamb types (mean values 1.4 to 2.1 %). But large individual variations were noted within lamb type (24 to 43 % c.v.). The muscle total collagen content (HyPro × 7.5) also varied considerably between animals, ranging from 2.8 to 8.3 mg/g (average 4.5 ± 1.0). Within lamb type, the coefficient of variation for this variate was 10 to 20 %. There were significant differences in collagen contents between lamb types ($P < 0.001$). The highest contents were found both in the youngest and in the oldest lamb groups (5.3 and 5.2 mg/g respectively). The second youngest lamb group also showed a relatively high collagen content (4.7 mg/g) while the other groups showed contents ranging from 3.7 to 4.2 mg/g. All these contents are of the same order than those reported by Valin et al. (1982), Koomahrie and Shackelford (1991) and Koomahrie et al. (1991) in 3.5- to 7-month old lambs. Young et al. (1993) stated that the muscle collagen content in lambs did not vary as the animal age increased from 1.5 to 12 months; but, in newborn lambs, the collagen content was twice that of the older lambs. In a comparative study of different lamb breeds, Heinze et al. (1986) found that meat breeds had a lower collagen content than wool breeds. Therefore, the variations in muscle collagen content found between lamb types in this experiment could be due to a combination of breed and age effects. The collagen heat solubility showed a marked decrease with increasing age from 43 % at 1.7 months to 21 % at 12 months of age ($r = -0.73$; $P < 0.001$). A similar decrease of perimysial collagen solubility has been described by Boccard et al. (1970) in sheep which age ranged from 2.5 months to 8 years, and also by Young et al. (1993) between birth and 1 year of age.

The compression tests showed large and significant variations in the texture of raw meat between lamb types. The stress at 20 % strain (S-20) was 1.5 to 2.6-fold higher ($P < 0.001$) in the youngest group than in any other group, thus indicating a much greater mechanical resistance of the raw myofibrillar tissue in those animals (Lepetit, 1989). The stress at 80 % strain (S-80), an indicator of the mechanical resistance of the connective tissue, also varied significantly between lamb types ($P < 0.001$). Three lamb types had comparable S-80 values, while the other three groups showed 20 to 44 % higher values.

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Again, the highest S-80 value was observed in the youngest group, which also had the highest collagen content. Indeed, as shown in Figure 1, a high correlation coefficient ($r = 0.60$; $P < 0.001$) was found between S-80 and the muscle collagen content, which agrees with the findings of Abustam et al. (1987). The maximum WB shear stress (WB-MS) of cooked meat averaged 3.0 ± 1.1 kg/cm² (Figure 2) and differed significantly between lamb types ($P < 0.001$). The most tender lamb type (age 4.3 months) gave a WB-MS value of 1.9 kg/cm². The two types that had the highest contents in total or insoluble collagen produced the toughest meat with WB-MS values of around 3.9 kg/cm². The WB-MS was significantly correlated with the total collagen content ($r = 0.33$; $P < 0.01$; Fig 1), thus confirming the conclusions of Bruwer et al. (1987) and Young and Braggins (1993). But the correlation coefficient was lower than that found between S-80 and total collagen. The average shear stress (WB-AS; mean value 1.2 ± 0.4) followed similar trends and was significantly correlated with the insoluble collagen content ($r = 0.33$; $P < 0.01$; Fig 1). Correlation between collagen solubility and cooked meat texture was at the most, at the limit of significance ($r \leq -0.19$), which contradicts the results of Bruwer et al. (1987) and Young and Braggins (1993). The small size of the meat samples from the younger lambs led to a more rapid increase of internal temperature to 70°C during cooking. Consequently, cooking time was shorter in these animals, which could have limited the heat solubilization of the intramuscular connective tissue. Both WB-MS and WB-AS were surprisingly correlated positively with the intramuscular lipid content ($r = 0.23$; $P < 0.05$). Results from the litterature have generally shown that the correlation between lipid content and shear value in cooked meat was either very low (Reagan et al., 1976; Eikelenboom, 1996) or negative (Seideman, 1986; Bruwer et al., 1987). This shows that in the present experiment meat texture was little dependent upon the intramuscular lipids content.

Figure 1. Principle component analysis of composition and texture of meat in contrasted lamb types

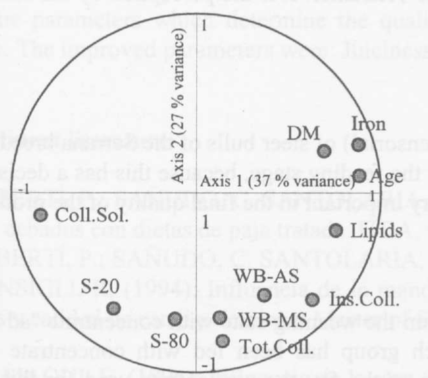
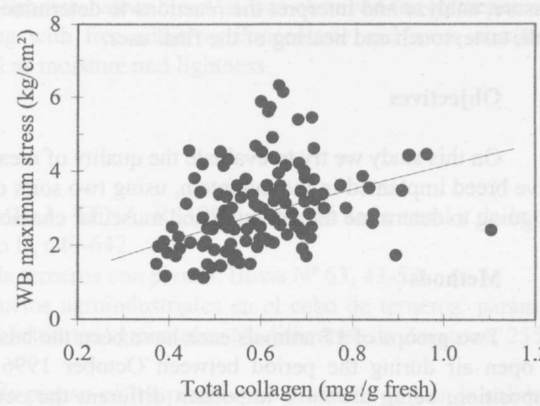


Figure 2. Variations of maximum stress of cooked lamb during a WB shear test according to total collagen content



CONCLUSION

The comparison of contrasted European lamb types showed that lamb meat quality varies to a considerable extent when animals are produced in different geographical areas and under different production systems, even when similar conditions are applied to the carcass and to the meat. Both the muscle pigmentation and the intramuscular collagen heat solubility increased with the age of the lambs. The large variations observed in the total collagen content of the meat were largely reflected in the texture profiles obtained by compression of the raw meat at high strain. However, the contribution of collagen content to the variations of cooked meat texture was less than in raw meat. Also, there was no evidence of an effect of collagen heat stability or intramuscular lipids on the toughness of cooked meat. The variations of stress at 20 % strain in raw meat are a clear indication of the strong influence of ante mortem factors on the composition and the structure of the muscle tissue. Further investigation is needed to evaluate how far these changes affect lamb texture.

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