MUSCLE STRUCTURE AND MEAT QUALITY AS AFFECTED BY CARCASS MUSCLE YIELD IN TWO BEEF BREEDS

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Background and objectives

The rearing of domestic animals for meat production has long aimed at both increasing the proportion/weight of lean cuts and limiting the extent of adipose tissues deposition in the carcass. These two objectives are achieved by genetic selection and the use of adequate nutrition strategies adapted to the pattern of body tissues development specific to each animal type and each animal species. However, the impact of the improvement of the quantity of saleable meat on the quality of this product has received little attention in the past. Recent studies showed a negative effect of selection for higher lean growth or carcass lean proportion on meat quality in pigs (Cameron and Enser, 1991; Pringle and Williams, 2000) and poultry (Dransfield and Sosnicki, 1999; Berri, 2000). There is no comparable work published for beef. Comparing two lines of Charolais young bulls obtained by divergent selection on growth rate and feed efficiency, Renand et al. (1994) found that an increased lean to fat ratio was associated with lower intramuscular lipid content and greater glycolytic enzyme activity, but they did not evaluate the texture or the sensory quality of the meat. The aim of the present work was to investigate in two beef breeds the relationship between the carcass muscle yield and the meat quality traits.

Materials and methods

Animal management and carcass handling. Two groups of Salers (n = 12) and Holstein (n = 12) cull cows (non pregnant and non lactating) of similar age were used. They were fattened on the same beet pulp silage based diet supplemented with soybean meal and urea and slaughtered at the same body fatness condition of 3.5 scored subjectively by palpation in the rib and tail regions according to Agabriel et al. (1986). The measurements of empty body weight, hot carcass weight (HCW) and weight of offal fat tissues (kidney, heart, digestive tract), together with the results of the dissection of the 6th rib cut were used to estimate the carcass anatomical composition (muscle, fat, bone) according to Robelin and Geay (1975). The animals were slaughtered at the INRA abattoir in compliance with the current ethical guidelines for animal welfare. Carcasses were chilled at 4°C.
Meat sampling and analyses. The semimembranosus (SM) muscle was excised from the right carcass side immediately after slaughter. A sample of muscle was taken, vacuum packed, then allowed to age at 4°C for 14 days and kept frozen at –20°C prior to sensory analysis. Another sample (approx. 4 cm^3) was taken 24 h postmortem (pm), frozen in isopentane cooled by liquid nitrogen, and stored at –80°C prior to histological examination. The SM muscle from the left side was excised 24 h pm and a sample was allowed to age at 4°C for 14 days and further kept frozen at –20°C prior to chemical analysis. Transverse sections of the muscle (10 µm thick) were cut on a cryostat and stained using red sirius. Images of the whole muscle section (approximately 1.5 × 1.5 cm) placed on a light box were taken with a black and white video camera (JAI M300). Digital images were recorded using a macro lens attached to the video camera. Images were analysed for perimysium total area and perimysium network length using Visilog-5 software package (Noesis, France). Muscle collagen content was determined from the hydroxyproline concentration (conversion factor 7.5) according to the method of Bergman and Loxley (1963) adapted by Bonnet and Kopp (1984). Collagen solubility was determined after heating meat homogenates at 70°C for 1 h in an isotonic buffer solution according to Bonnet and Kopp (1992). Muscle total lipid content was determined by refractometry as described by Arneth (1972). Enzyme activities were measured as described by Jurie et al. (1995). The activities of lactate dehydrogenase (LDH, EC 1.1.1.27) and isocitrate dehydrogenase (ICDH, EC 1.1.1.42) were used to assess the metabolism of glycolytic (anaerobic) and oxydative (aerobic) muscle fibres, respectively. A panel of 12 trained persons was used to evaluate during 5 sessions the tenderness, juiciness and flavour of steaks grilled in a double contact grill to an internal temperature of 65°C on a non-structured intensity scale (subsequently scored from 0 to 10). In each session, each panelist was asked to rate successively 2 pairs of meat samples, each pair consisting of samples from the 2 breeds. Data were subjected to a one-way analysis of variance (SAS, 1989-96) with breed as the source of variation. The residuals of the model were used for the calculation of the correlation between variables of carcass and meat quality.

Results and discussion

The treatments mean values are presented in Table 1. The mean age of animals at slaughter was 6.6 (± 0.7) years. There was no significant difference between the 2 breeds in HCW, but carcass dressing percentage (DP) and muscle content, expressed either as weight of tissue or proportion of HCW, were significantly greater in the Salers cows in comparison with their Holstein counterparts. Carcass fat content, expressed as a proportion of HCW, was not only quite variable within breed but also significantly greater in the Holstein cows. This shows that the subjective assessment of the body fatness condition on the live animal was a poor predictor of the actual carcass fat content. The composition of weight gain of cull cows during fattening depends upon several factors including breed and initial fatness condition (Malterre and Jones, 1992). The present data are consistent with earlier observations that the weight gain of mature female cattle of dairy (or early maturing) breeds such as Holstein cull cows during fattening contain a lower proportion of lean tissue than that of continental beef breeds such as Charolais (Robelin et al., 1990; Dumont et al., 1991; Roux et al., 1993).
The total collagen content of SM muscle was significantly affected by breed and was higher in the Holstein cows compared with Salers cows. The other compositional traits (dry matter and lipid contents, collagen heat solubility), the metabolic type of muscle fibres, the perimysial relative area and length, and the sensory scores were not significantly different between the two breeds.
The differences found in carcass fat content were not reflected by the muscle lipid content (r = –.26). This contradicts the high correlation coefficients reported by Hoving-Bolink et al. (1999) in Piemontese and Limousin bulls and heifers (r = .77) and by Renand et al. (1994) in Charolais young bulls (r = .66) for the *longissimus* muscle. However, there is evidence that the changes in lipid content during fattening is muscle dependent (Johnson, 1987; Langlois, 1990): it increases in some muscles (e.g. *longissimus*, *diaphragma*) while it remains stable in

others (e.g. *semitendinosus, triceps brachii*). It is also possible that the fattening period in this study was too short to allow a significant development of intramuscular fat in the SM muscle. The content of this constituant practically did not exceed 2.0%, which is lower than the values previously reported in the *longissimus* muscle of Charolais cull cows after a 2.5 to 3.0-month fattening period (Dumont et al., 1991; Roux et al., 1993).

The correlation analysis (Table 2) showed a significant relationship between carcass DP and carcass composition. The lean proportion and weight increased and the fat proportion decreased in the carcass as DP increased, independently of breed. An increase in HCW was accompanied by a significant decrease in the intramuscular lipid content ($r = -.62$) and a significant increase in muscle LDH activity ($r = .44$), indicating a shift towards a greater glycolytic metabolism of muscle fibres in the larger animals. This contrasts with the lack of a significant relationship between carcass weight and muscle characteristics reported by Renand et al. (1994) in Charolais bulls. The low but significant correlation of lipid content and tenderness agrees with the findings of McKeith et al. (1985) and Tatum et al. (1980), indicating that intramuscular lipids contribute to sensory tenderness.

In general, the meat quality traits measured in this trial were poorly related to the carcass muscle yield. Unfortunately, the carcass muscle yield has seldom been measured objectively in previous studies which make difficult the comparison with the present results. In a recent trial on 103 Charolais young bulls, Renand (unpublished results) also found weak relationships between meat tenderness, juiciness or flavour and carcass muscle weight ($r = .22, .12, -.10$, respectively) or carcass muscle proportion ($r = .00, -.05, -.30$, respectively). The perimysial relative area and length were negatively correlated with carcass muscle weight ($r = -.39$, $P = .06$ and $r = -.27$, $P = .19$). Although these relationships do not reach significance, they indicate that as carcass meat yield increased less primysial connective tissue could be detected histologically. No relationship, however, was found between perimysial relative area and muscle collagen content. Thus, in the present experimental conditions, the muscle collagen content could not be estimated accuretely by image analysis of histological preparations.

Conclusions

The goal of this study was to determine if carcass muscle yield had an effect on palatability traits of beef semimembranosus muscle. The carcass quality of the two breeds examined differed in fat and muscle proportions, but only muscle collagen content varied, not histologic nor lipid traits. In addition only muscle lipid content was associated with tenderness, not collagen parameters nor lean carcass content.

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Table 1. Carcass and meat quality of cull cows according to breed.

	Variables (†)	Holstein	Salers	*RSE*
	Age of animals (years)	6.3	6.8	*0.6*
	Duration of fattening (days)	56	56	*21.8*
(1)	Hot carcass weight (HCW, kg)	359	363	*31.8*
(2)	Carcass dressing (%)	60.0x	63.7y	*1.0*
(3)	Carcass muscle weight (kg)	193u	222v	*18.8*
(4)	Carcass muscle content (% HCW)	54.1x	61.0y	*4.1*
(5)	Carcass fat content (% HCW)	29.3a	23.8b	*5.0*
	Muscle composition:			
	Dry matter (mg . g^{-1})	27	26	*0.9*
(6)	Total collagen (mg . g^{-1})	6.6a	5.8b	*0.9*
(7)	Collagen solubility (%)	9	9	*4.5*
(8)	Total lipids (mg . g^{-1})	14.7	14.5	*4.5*
(9)	ICDH activity (µmol . min^{-1} . g^{-1})	1.9	1.7	*0.4*
(10)	LDH activity (µmol . min^{-1} . g^{-1})	812	852	*73*
	Organization of perimysial tissue:			
(11)	Relative area (% total)	8.9	10.1	*2.5*
(12)	Length (10^3 pixels)	21.0	20.6	*3.6*
	Meat sensory quality:			
(13)	Tenderness	5.3	4.6	*0.9*
(14)	Juiciness	5.8	5.2	*0.8*
(15)	Flavour	5.9	5.6	*0.6*

(†) Means with different superscripts differ significantly at $P < 0.05$ (a, b), 0.01 (u, v) or 0.001 (x, y).

Table 2. Pearson's correlation coefficients between variables of carcass and meat quality (calculated on residuals; see Table 1 for the description of variable code numbers).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(2)	0.07													
(3)	**0.63**	**0.49**												
(4)	-0.35	**0.54**	**0.50**											
(5)	0.38	**-0.46**	**-0.46**	**-0.97**										
(6)	-0.02	-0.20	-0.09	-0.08	0.09									
(7)	0.18	-0.01	-0.10	-0.34	0.34	0.09								
(8)	**-0.62**	0.12	-0.36	0.26	-0.26	0.07	-0.27							
(9)	0.06	-0.31	-0.18	-0.29	0.29	-0.04	**0.49**	0.04						
(10)	**0.44**	0.10	0.22	-0.24	0.26	0.05	0.24	**-0.43**	-0.05					
(11)	-0.35	-0.18	-0.39	-0.07	0.10	0.02	-0.12	0.05	-0.20	0.03				
(12)	-0.39	-0.03	-0.27	0.12	-0.08	-0.08	-0.31	0.20	**-0.45**	-0.08	**0.85**			
(13)	-0.10	0.03	-0.21	-0.14	0.19	-0.18	-0.14	**0.42**	0.10	-0.12	-0.11	-0.06		
(14)	-0.32	0.04	-0.26	0.05	-0.11	0.08	-0.21	0.23	-0.30	0.09	0.31	0.30	0.22	
(15)	0.00	-0.18	-0.23	-0.27	0.26	0.25	0.12	-0.16	-0.04	**0.41**	0.06	0.02	0.08	**0.56**

(†) Correlation coefficients in bold characters differ significantly from zero ($P < 0.05$).