Animal Science Papers and Reports vol. 23 (2005) no. 3, 199-206
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Histological and physico-chemical traits of meat of Black-and-White bulls and F_1 Charolaise, Limousine and Simmental crossbreds, slaughtered at two levels of body weight

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(Received December 14, 2004, accepted September 28, 2005)

Used were Black-and-White (BW) and BW × Charolaise (BWC), BW × Limousine (BWL) and BW × Simmental (BWS) F_1 fattening bulls (n= 14, 12, 9 and 9, respectively). The final data on histological structure and physico-chemical traits of *Longissimus dorsi* muscle (LD) were related to bulls' weight at slaughter: ≤550 kg (group I) and >550 kg (group II).
The results generally indicate a significant effect of both weight at slaughter and genetic group on histological and physico-chemical traits of LD. Higher slaughter weight (group II) resulted, particularly in BW, BWC and BWL bulls, in greater mean diameter of muscle fibres (by 6.0 μm). Similar tendency occurred in meat colour, where the results ranged from 26.9 to 29.1%. Negative effect of increased slaughter weight was found for fat content of LD in BW bulls (3.77%) and pH_{48} (5.7), as well as for WHC in BW and BWL bulls (20.23 and 22.06% , respectively).

KEY WORDS: beef quality / cattle / commercial crossbreds / meat histological structure / meat quality / slaughter weight

Searching for production technologies of culinary beef and improving its quality, still remains an important research aim. Low quality of raw meat is caused mostly by unproper feeding, along with genetic traits of beef breeds and their crossbreds.

Numerous experiments performed on beef quality involve, first of all, the effect of commercial crossing, evaluation of feeding methods and systems of maintenance of animals during their production cycle. The corelation has been found between these factors and cattle slaughter value and beef quality indicators [Steen 1995, Seideman and Crouse 1986, Keane and Allen 1998, Groth *et al*. 1999; Vestergaard *et al*. 2000, Maltin *et al*. 2001, Trela *et al*. 2002]. A few domestic publications concern bilateral relations between the two factors and sex of animals or histological traits of meat and its quality [Kłosowska *et al*. 1992; Młynek and Litwińczuk 2003, Kołczak *et al*. 2003]. These traits determine culinary quality of beef and depend, among others, from sex and age of animals and their body weight at slaughter [Młynek and Litwińczuk 2001, Renand *et al*. 2001, Steen 1995].

In this paper a report is presented on selected histological and physico-chemical traits of beef obtained from fattening bulls of four genetic (breed) groups, slaughtered at two levels of body weight.

Material and methods

Material consisted of young bulls reared on individual farms and fattened with farm-made feeds. A total of 44 animals were considered of which 14 were pure Black-and-White (BW), 12 F_1 crosses of BW dams with Charolaise sires (BWC), 9 F_1 crosses of BW dams with Limousine sires (BWL) and 9 F_1 crosses of BW dams with Simmental sires (BWS). The animals were divided into two groups, according to their slaughter weight: group I – ≤550 kg and group II – >550 kg.

Analysed were samples of *Longissimus dorsi* (LD) muscle, obtained from best ribs section. LD fibres diameter and area were measured with Multi Scan programme on catalogued pictures obtained from microscopic set OLYMPUS (20×3, 3×1, 179/15) of samples taken approximately 30 min. *post mortem.* The other basic physico-chemical analyses of beef were performed on LD samples obtained approximately 48 hours *post mortem*. Meat pH_{48} was determined using the pH-meter with combined stiletto electrode, the colour in Hunte Lab system with MINOLTA apparatus type OR-310, and water holding capacity (WHC) according to Pohia and Niinivaara [1975]. Proximate LD composition (dry matter, fat and protein) was determined with conventional methods. Marbling was assessed with subjective scoring (depending on fat content, where 1 point stands for absence and 5 points for marked visible fat).

Statistical evaluation of results (MANOA programme) involved the effect of genetic (breed) group and slaughter weight on histological and physico-chemical LD traits. Significance of differences between groups was determined with Duncan test. Pearson correlation coefficients between weight at slaughter and histological and physico-chemical LD traits were calculated.

Results and discussion

Mean body weight at slaughter and histological parametres of LD across breed groups of bulls are shown in Table 1. Bulls from group I, slaughtered at mean body weight of 499.3 kg (BW) and 529.3 kg (crossbreds pooled), showed smaller fibre diameter and smaller muscle fibres area. Within group I the fibre diameter ranged from 11.7 μm in BW to 15.3 μm in BWS bulls. The LD muscle fibre area ranged in group I from 1764 μm^2 in BW to 2207 μm^2 in BWS bulls. Both BWC and BWL crossbreds showed intermediate fibre diameters and fibre area (the mean of 13.0 μm and 1860 μm^2, respectively. Generally, an increase in slaughter weight resulted in higher values of both histological traits.

Table 1. Means and their standard deviations (SD) for histological traits of *longissimus dorsi* muscle in bulls slaughtered at different body weight levels (≤550 kg vs >550 kg)

Genetic group		Slaughter weight (kg)		Muscle fibre diameter (μm)		Muscle fibre area (μm^2)	
		≤550 kg (n=19)	>550 kg (n=25)	≤550 kg (n=19)	>550 kg (n=25)	≤550 kg (n=19)	>550 kg (n=25)
BW (n=14)	mean	499.3^{a,1}	608.6^{B,1}	11.7^{a,1}	17.6^{B,1}	1764^{a,1}	2256^{B,1}
	SD	17.0	20.4	0.7	4.1	67	192
BWC (n=12)	mean	544.6^{a,2}	586.42^{B,2}	12.7^{a,2}	14.3^{b,2}	1822^{a,2}	2031^{b,2}
	SD	6.5	23.6	1.1	1.5	94	136
BWL (n=9)	mean	526.8^{a,1}	652.1^{B,1}	13.3^{a,2}	19.3^{B,1}	1898^{a,2}	2451^{B,1}
	SD	20.5	30.1	1.4	6.3	86	157
BWS (n=9)	mean	516.5^{a,1}	577.7^{B,1}	15.3^{a,1}	18.1^{b,1}	2207^{a,1}	2596^{B,1}
	SD	36.7	21.5	2.5	1.5	45	96

^{a,b,A,B}Within rows and traits means bearing different superscript letters differ significantly at: P≤0.05 (small letters) or P≤0.01 (capitals).
^{1,2}Within columns means bearing different superscript numbers differ significantly at P≤0.05.
BW – Black-and-White.
BWC – BW × Charolaise.
BWL – BW × Limousine.
BWS – BW × Simmental.

Most positive, *i.e*. the least, differences were observed between BWC and BWS crossbreds. In these bulls an increased (by mean of 51.5 kg) slaughter weight resulted in increased LD mean muscle fibre diameter by 2.2 μm and mean muscle fibre area by 300 μm^2. In BW and BWL bulls, an increase in slaughter weight was most marked, negatively affecting the LD muscle fibre diameter and area. The differences between slaughter weight groups were biggest in BWL crossbreds, reaching up to 6.0 μm in muscle fibre diameter and 553 μm^2 in muscle fibre area for group I and II, respectively. Mean slaughter weight in groups with least positive (least recommended) structure of muscle fibres was 117.3 kg. Vestergaard *et al*. [1994] while analysing the effect of body weight on fibres area of

Table 1. Means and their standard deviations (SD) for physico-chemical traits of *longissimus dorsi* muscle in bulls slaughtered at different body weight levels (<550 kg vs. >550 kg)

Trait			Group I (<550 kg)				Group II (>550 kg)			
			BW (n=[illegible])	BWC (n=[illegible])	BWL (n=[illegible])	BWS (n=[illegible])	BW (n=[illegible])	BWC (n=[illegible])	BWL (n=[illegible])	BWS (n=[illegible])
Colour (Hunter Lab)	L	mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	a	mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	b	mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Marbling (points)		mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Protein (%)		mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fat (%)		mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dry matter (%)		mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
pH		mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WHC (%)		mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		SD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

a,b,A,B – within rows, means for genetic groups bearing different superscripts letters differ significantly at: P≤0.05 (small letters) or P≤0.01 (capitals)

BW – Black-and-White
BWC – BW x Charolaise
BWL – BW x Limousine
BWS – BW x Simmental

LD muscle noticed that in animals heavier by 146 kg, the fibres area was bigger by mean 0.6 μm and in those heavier by 234 kg, bigger by 1.3 μm.

Data presented in Table 2, concerning meat colour, show that the trait was mostly affected by the bulls' weight at slaughter and confirm the results of Vestergaard *et al.* [2000], and Daszkiewicz and Wajda [2001], as well as by genetic factors as stressed by Gregory *et al*. [1995], Maltin *et al*. 1998, and Campo *et al*. [2000]. Negative efect of increased body weight was observed mainly for colour lightness (Hunter L-R = -0.1; Tab. 3). The most marked effect of increased slaughter weight on worsening colour parametres of meat was observed in BWL and BWS bulls. Decrease in colour lightness of meat from BWL and BWS crossbreds reached up to 1.8%. Not significant colour lightening of meat in BW bulls of group II was probably related to significant increase in marbling and fat content of meat (Tab. 2). Similar values have been obtained by Keane and Allen [1998]. In animals slaughtered at 720 kg live weight they found higher colour lightening (Hunter-L; 35.2%) and more saturated red colour of the raw material (Hunter-a; 18,2%). These animals had bigger (reaching up to 59 g/kg) fat content of meat. Results presented in Table 3 show the increase of meat colour saturation towards red (Hunter-a, $r = 0.5$; $P \leq 0.05$).

Intensity of red colour (Hunter-a) increased significantly with elevated slaughter weight, particularly in meat from group where decrease of meat colour lightening (Hunter-L) occurred (Tab. 2). It mostly involved the BW, BWL and BWS bulls, where biggest differences between slaughter groups were noticed (up to 3.7, 2.5 and 1.4 units). That increase can be explained by longer fattening period, which resulted in bigger pigment concentration in muscles of older animals.

The highest nutritive value of meat (Tab. 2) was observed in crossbreds (with no reference to the weight at slaughter). In group I the LD of BWS bulls contained most protein, while that of BW most fat and showed most intensive marbling. Most marked effect of slaughter weight, resulting in increase of the fat content of meat in group I, occurred in BW bulls – by 1,18 and in BWS crossbreds – by 1.58 per cent points. Similar values of protein content in BWC crossbreds were given by Groth *et al*. [1999] who noticed 21.13 % protein of meat from bulls with mean slaughter weight 570 kg. Content of dry matter (23.07%) was lower than in this study, which probably resulted from lower (1.18%) content of fat. Similar results have been published by Renand *et al*. [2001] who dealt with Charolaise bulls of body weight reaching up to 455 kg.

Both meat pH_{48} and WHC occurred worst in BWL crossbreds of group II where the pH_{48} was 5.7 and WHC reached 22.06%, the latter being lower only from that found in group II BWS bulls (23.99%). Similar tendencies in WHC were found in BWS bulls by Daszkiewicz and Wajda [2001]. Contrary to the mean pH_{48} values of meat obtained for BWC bulls in this study (5.6 and 5.4 for group I and II, respectively), Keane and Allen [1998] found pH_{48} ranging from 5.72 to 5.80 in meat of Charolaise crossbreds fattened to body weight over 640 kg. Meat pH in that study was interpreted as related to intensity of feeding. Less intensive feeding caused increased meat pH values (5.84) in extensively fattened bulls.

Correlation coefficients (*r*) of traits examined showed particularly close relation between the slaughter weight of bulls and histological traits of muscle fibres (Tab. 3), where *r* values ranged from 0.6 to 0.8 (P≤0.05). Lower *r* values (0.37-0.30) between live weight of cattle and muscle fibres area have been found by Seideman and Crouse [1986] who also showed a relation between the fibre area (particularly those of "red" type) and colour of meat (-0.34 to -0.16; P≤0.05). Correlation coefficients between histological traits and physico-chemical indicators of meat occurrred smaller and ranged from -0.1 to 0.5 (P≤0.05), generally confirming the results published by Renand *et al.* 2001 and Młynek and Litwińczuk 2001]. The relation between muscle fibre area and meat marbling was found similar to the values reported by Renand *et al.* [2001 and Młynek and Litwińczuk [2001] and ranged from -0,05 do 0,18. Whiple *et al*. [1990] found correlation coefficients between slaughter value indicators and meat pH to range from -0.9 to 0.36, while those between pH and histological traits (myofibrillar fragmentation indices) from -0,1 to 0,38.

Table 3. Correlation coefficients between slaughter weight and histological and physico-chemical traits of *longissimus dorsi* muscle (genetic groups pooled)

Trait	Slaughter weight (kg)	pH_{48}	Colour		WHC (%)	Marbling (points)
			Hunter L	Hunter a		
Muscle fibre diameter (μm)	0.6*	-0.1	-0.2*	0.3*	0.2*	0.2*
Muscle fibre area (μm²)	0.8*	-0.1	-0.2*	0.5*	0.1	0.1
Slaughter weight (kg)	–	-0.2*	-0.1	0.5*	0.1	0.2*

*P≤0.05.

The results presented here can be summarized as follows. Increased slaughter weight resulted in worsening of histological indicators of meat, particularly in cross-bred BWL bulls. Similar negative effect of increased slaughter weight was proved in BWL and BWS crossbreds on meat colour, fat content, pH_{48} and WHC. This suggests that fattening of BWL and BWS bulls should be terminated at body weight of 550 kg. Correlation coefficients, and particularly those between slaughter body weight and histological and physico-chemical traits of beef prove that production of culinary beef should consider factors affecting meat structure.

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Wybrane histologiczne i fizykochemiczne cechy mięsa buhajów cb oraz mieszańców F_1 cb × charolaise, cb × limousine i cb × simental, ubijanych przy różnej masie ciała

S t r e s z c z e n i e

Analizowano dwie cechy histologiczne i podstawowe wskaźniki jakości mięsa buhajów cb (BW) oraz mieszańców towarowych F_1 pochodzących z krzyżowania krów cb z buhajami rasy charolaise, limousine i simental (odpowiednio BWC, BWL i BWS). Średnia masa ciała ubijanych buhajów wyniosła 564±24,9 kg. Buhaje ubijane przy masie ciała ≤550 kg charakteryzowały się mniejszą średnicą włókien mięśniowych (11,7-15,3 µm). Przeciętne zwiększenie masy ciała buhajów o około 73 kg powodowało wzrost średnicy włókien od 1,6 do 6,0 µm. Zależność tę potwierdziły również współczynniki korelacji, które kształtowały się w granicach od 0,6 do 0,8 ($P \leq 0,05$). Stwierdzono niekorzystny wpływ wzrostu masy ubojowej na barwę i wodochłonność mięsa oraz zawartość w nim tłuszczu.