Myofibre composition and metabolic aspects in different strains of Belgian white-blue bulls and their relation to meat colour.

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SUMMARY: Investigation of two strains of the Belgian white-blue breed indicates a significant difference in myofibre composition between the double-muscled strain and the normal-conformation animals. The double-muscled bulls show a significantly higher percentage type II B fibres. This is the result of a shift from II A fibres towards II B fibres. The cross-sectional area of the myofibres of the double-muscled animals is generally smaller.

Consequently, this myofibre composition results in a significantly lower aerobic and a significantly higher anaerobic factor. Also the oxidative metabolic capacity (Q = LDH/MDH) follows this tendency. This anaerobic myofibre composition, together with a significantly lower pigment content, results in a significantly paler meat, susceptible to an accelerated postmortem glycolysis.

INTRODUCTION: Earlier experiments show that hypertrophied animals of genetic origin have a characteristic myofibre composition (HOLMES and ASHMORE, 1972; HENDRICKS et al., 1973; WEST, 1974). These double-muscled strains have more and larger white or II B fibres than normal-conformation animals. This change in myofibre composition does not result in an alteration of most of the organoleptical meat quality parameters. Some experiments report a lower shear force value in the case of hypertrophied muscles (BOUTON et al., 1978). Others state that meat of double-muscled animals is characterized by a pale colour (BOCCARD, 1981; BATJOENS et al., 1989).

The aim of this experiment is to compare the myofibre composition of two strains of the Belgian white-blue breed and to evaluate its influence on muscle metabolism and colour of the respective strains.

MATERIALS and METHODS: The experiment is conducted on the Longissimus dorsi (LD) muscle of 5 bulls with normal conformation and 8 double-muscled bulls. Both types belong to the Belgian white-blue breed. Double-muscled bulls are fed a diet of maize silage supplemented with concentrate (1 kg per 100 kg liveweight). The bulls were about 2 years of age.

Within one hour postmortem, a muscle sample of about 1 cm^3 was taken for histochemical analyses from the LD adjacent to the 8 th rib and immediately frozen in liquid nitrogen and stored afterwards at - 30° C. Two transverse cryosections of 10 µm thick, which are stained for myofibrillar ATP-ase activity, as described by BROOKE and KAISER (1970), have been analysed for the myofibre composition. The method of BROOKE and KAISER (1970) is slightly modified for the preincubation pH and time. Optimal differentiation between the three fibre types is obtained at a preincubation pH of 4.3 instead of 4.6 during 90 seconds instead of 10 minutes. At the preincubation pH of 4.3 dark staining fibres are slow-contracting type I fibres with an oxidative metabolism. Type II fibres are fast-contracting divided into two subclasses. Type II A fibres are oxidative and glycolytic in their metabolism and remain unstained, whereas type II B fibres are glycolytic and only weakly oxidative and show an intermediate staining (PETER et al., 1972). The occurrence and the area of the three myofibre types are determined by image analysis. For that purpose a Reichert Polyvar light microscope is directly coupled to a Cambridge Quantimet 970 computer with standardized light intensity and grey levels, provided with an appropriate programm for measuring the three fibre types. Anaerobic fibre ratio (percent area II A and II B fibres to percent area I fibres) and aerobic fibre ratio (percent area I and II A fibres to percent area II B fibres) are derived as parameters of muscle metabolism (HUNT and HEDRICK, 1977).

Due to deterioration of the tissue-structure during storage, some samples were lost for myofibre type determination. So, histochemical data enclose 4 samples from normal-conformation bulls and 7 double-muscled bulls.

The oxidative metabolic capacity (Q, VAN DEN HENDE et al., 1968) of the muscles is also estimated, based on the biochemical determi-

nation of lactate dehydrogenase (LDH) and malate dehydrogenase (MDH), using diagnostic kits (Boehringer 124885 and 124940, respectively).

Finally, the colour is determined by means of an estimation of the brightness and the hue (Hunterlab D-25) and of the pigment content (mg myoglobin/g meat). Muscle pH is measured on the LD 1 h, 2.5 h, 4 h and 24 h after slaughter.

Data are given as means ± standard error and statistically analysed with Students t-test.

RESULTS and DISCUSSION: The histochemical data are summarized in table 1.

Table 1: The effect of the strain on the myofibre composition of the Longissimus dorsi muscle in bulls.

	Conformation	Fibre types		
		I	II A	II B
Number of fibres (%)	Normal	$32.0^{b} \pm 2.9^{a}$	$31.0^{b} \pm 7.0$	$37.0^{b} \pm 6.4$
	Double-muscled	$29.0^{b} \pm 5.4$	$22.1^{c} \pm 3.4$	$48.9^{c} \pm 3.8$
Relative area of fibres (%)	Normal	$22.1^{b} \pm 2.4$	$31.7^{b} \pm 8.8$	$46.2^{b} \pm 6.9$
	Double-muscled	$13.0^{c} \pm 2.3$	$19.5^{c} \pm 4.7$	$67.5^{c} \pm 4.3$
Mean cross-sectional area (μm^2)	Normal	$2751^{b} \pm 407$	$4023^{b} \pm 705$	$4976^{b} \pm 506$
	Double-muscled	$1350^{c} \pm 300$	$2637^{c} \pm 769$	$4261^{b} \pm 1205$

a: standard error; bc : values of different strains with unlike superscripts are significantly different: number of fibres: $p < 0.01$; relative fibre ratio: $p < 0.05$ for type I and II A fibres; type II B fibres: $p < 0.01$; mean cross-sectional area: type I fibres: $p < 0.05$; type II A fibres: $p < 0.01$.

The occurrence of type I and type II A fibres is low for double-muscled bulls and high for bulls with normal conformation, while the opposite is found for type II B fibres. So, there is a shift from II A fibres to II B fibres in the double-muscled bulls. The percentages area of the different myofibre types follow the same tendency. Type I and type II A mean cross-sectional areas are smaller in double-muscled bulls than in normal-conformation bulls. Type II B fibres do not differ significantly between normal and double-muscled bulls. This results in a lower occupation of the total area by type I and type II A fibres in double-muscled white-blue bulls as compared to normal white-blue bulls. The differences are significant for type II A fibres. Total type II B fibre area is significantly greater in double-muscled bulls in comparison with the other strain. Based on the proportions of total area of the three fibre types, the aerobic and anaerobic fibre ratios are calculated. The lowest aerobic ratio or factor is found for double-muscled animals and the results differ among strains. The anaerobic factor is significantly higher for double-muscled bulls, compared with bulls with normal conformation (Table 2).

Table 2: The effect of the strain on some metabolic characteristics of the Longissimus dorsi muscle in bulls.

	Aerobic fibre ratio	Anaerobic fibre ratio	Metabolic capacity (Q)
Normal white-blue	$1.2^{b} \pm 0.4^{a}$	$3.6^{b} \pm 0.5$	$5.9^{b} \pm 0.5$
Double-muscled white-blue	$0.5^{c} \pm 0.1$	$6.9^{c} \pm 1.2$	$8.6^{c} \pm 1.3$

a: standard error; bc: values of different strains with unlike superscripts are significantly different: aerobic and anaerobic fibre ratios: $p < 0.01$; Q: $p < 0.05$.

A significant strain-effect is observed for the oxidative metabolic capacity. The double-muscled bulls have a significantly higher Q-value than the normal-conformation bulls. Although there are no significant differences in pH-decrease, double-muscled animals show on the whole the most rapid fall of pH postmortem (Figure 1). This is probably the result of the more anaerobic myofibre composition, which enables them to maintain the postmortem metabolism some time at a higher rate by means of the anaerobic glycolysis (Table 2).

The data of the colour estimation are summarized in table 3. Brightness and hue differ significantly between the two strains. The double-muscled white-blue bulls show a very significantly higher brightness and a significantly lower hue in comparison with the normal bulls. The anaerobic myofibre composition also results in a significantly lower pigment content for the double-muscled animals in comparison with the other strain. Although the histochemical data presented here are based on fewer animals than involved in this experiment due to sample losses, significant differences, resulting from the strain, are observed.

Figure 1: The effect of the strain on the postmortem pH-decrease of the Longissimus dorsi muscle in bulls.

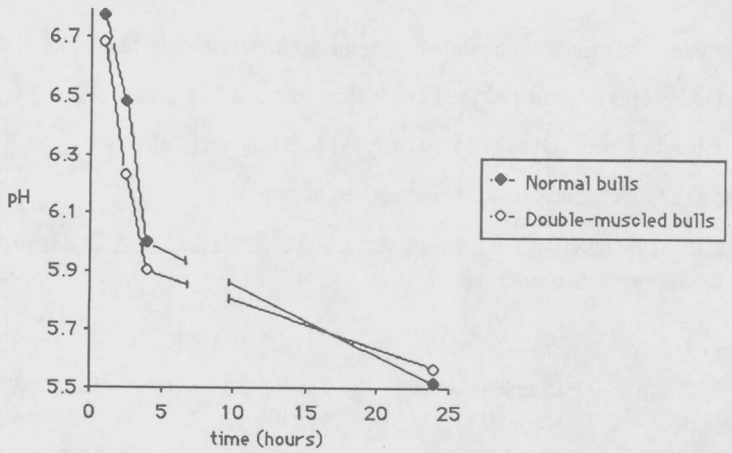

Table 3: The effect of the strain on the colour and pigment content of the Longissimus dorsi muscle in bulls.

	Brightness	Hue	Pigment content
Normal white-blue	$36.9^{b} \pm 0.8^{a}$	$1.24^{b} \pm 0.05$	$4.5^{b} \pm 0.3$
Double-muscled white-blue	$39.2^{c} \pm 2.6$	$1.14^{c} \pm 0.07$	$3.5^{c} \pm 0.5$

a: standard error; bc: values of different strains with unlike superscripts are significantly different: brightness: $p < 0.05$; hue and pigment content (mg myoglobin / g meat): $p < 0.01$.

We assume that the different diets did not exert a major effect on the histological properties. Nevertheless, muscle fibre type characteristics in cattle may be related to the method of feeding (JOHNSTON et al., 1981). MOODY et al. (1980) state that the available source of energy in the diet appears to cause a physiological shift in muscle fibre types. This is confirmed by SOLOMON and LYNCH (1988) in lambs, which were fed diets containing 7.82 and 11.67 MJ metabolizable energy, meaning 49 % more energy for the high-energy diet. The diets in our experiment differ less than 5 % in energy density and only range between 7.05 and 7.37 MJ net energy and therefore it is thought that the effect of the diet is neglectible.

Double-muscled bulls are characterized by more II B fibres (HOLMES and ASHMORE, 1972). Furthermore, II B fibres are the largest of the fibre types (HOLMES and ASHMORE, 1972; HUNT and HEDRICK, 1977). Because of this anaerobic fibre composition, muscles of double-muscled cattle contain less myoglobin to transport oxygen, which results in a lower capillary distribution (COOPER et al., 1969). The higher percentage of type II B fibre area corresponds with a lower aerobic fibre ratio and a higher anaerobic ratio and also a higher Q-value. This has been found typical for double-muscled animals (BATJOENS et al., 1989).

The shift towards a higher percentage area of "whiter" type II B fibres, together with the lower pigment content, may induce a paler meat. This phenomenon is previously encountered in double-muscled animals (BOCCARD, 1981). Previous results (BATJOENS et al., 1989) indicate a brighter colour in white-blue bulls in comparison with animals of other genotypes. On the other hand, it is possible that deterioration of the sarcoplasmatic proteins is responsible for the brighter colour, known from the PSE-phenomenon in pork meat (DILDEY et al., 1970; VAN ZEVEREN et al., 1990). HUNT and HEDRICK (1977) therefore evaluated the transmission value, as a parameter of this denaturation effect. The transmission value is not determined in this experiment. Other experiments have learnt that only a small percentage of the double-muscled white-blue bulls performed this alteration (BATJOENS, unpublished). In this experiment the rate of pH-fall is not that fast to cause denaturation of the sarcoplasmatic proteins.

pH-decrease is also typical for double-muscled white-blue animals. Although not significantly different, the double-muscled bulls show a postmortem glycolysis that reaches lower pH-values at 4 hours postmortem. This is also a result of the more anaerobic composition and metabolic capacity to maintain metabolism some time after slaughter (without oxygen) at a higher rate.

CONCLUSIONS: The double-muscled strain of the white-blue breed shows the typical myofibre composition, described previously by many authors (HOLMES and ASHMORE, 1972; HUNT and HEDRICK, 1977; BOCCARD, 1981; BATJOENS et al., 1989). Not only they have a higher percentage type II B fibres, but these II B fibres also show the largest mean cross-sectional area. Consequently, the percent area represented by type II B fibres is the largest in the double-muscled bulls. This results in a significantly higher anaerobic fibre ratio, which includes a more anaerobic metabolism. The significantly higher Q-value confirmes this result. Another consequence of this "whiter" myofibre type composition is the occurrence of a paler meat colour. II B fibres are also called α-white fibres according to an equivalent nomenclature (PETER et al., 1972). The paler colour is not only the result of the anaerobic myofibre composition. These glycolytic myofibres do not need as much myoglobin as oxidative myofibres, which includes a significantly lower pigment content (COOPER et al., 1969;ASHMORE, 1974). A third possibility, which has not been evaluated in this experiment, is the effect of protein denaturation on the colour. Finally, it can be concluded that the double-muscled condition in the white-blue bulls shifts myofibre composition to a more anaerobic type and enhances the occurrence of paler meat.

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