THE INFLUENCE OF THE MUSCLE FIBER COMPOSITION ON SOME MEAT QUALITY CHARACTERISTICS IN YOUNG BULLS.

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INTRODUCTION:

During several years a lot of research has been done on the occurrence,physiology and biochemistry of PSE pork, but little is known on the incidence of watery,pale beef.
Nearly two decades ago,Hamm & Van Hoof (1970) reported,for the first time,the incidence of bovine longissimus dorsi muscles (LD) with an unusually accelerated post mortem (pm) glycolysis.
In 1973 Khan & Lentz observed bovine muscles with low pH_1 values (1 h pm pH 5.6-6.2) and with low levels of ATP at the time of slaughter.That same year Khan & Ballantyne measured the pH in the semimembranosus muscles of 1200 beef carcasses and observed that in 1.8 to 2 % of the animals the pH_1 values were lower than 5.95.These authers,however,did not evaluate the water-holding capacity (WHC) nor the colour of the meat.
The results of Martin & Fredeen (1974) did not give any significant correlation between the rate in pm drop in pH and either the WHC or tenderness in beef.
Hunt & Hedrik (1977) observed an occasional occurrence of watery,pale and soft beef in the U.S.A..
During previous investigations on DFD-meat in cattle,a small percentage of the carcasses showed an accelerated pm breakdown of glycogen. (ultimate pH 5.5 within 4 h.)
For that reason,it was the purpose of this paper to investigate the possible correlation between an accelerated glycolysis and either the muscle fiber composition or some quality characteristics such as the WHC,the colour,the cooking loss and the tenderness.

MATERIALS AND METHODS:

The experiment was carried out on the m. longissimus dorsi (LD) of 87 1-year old bulls,originating from a selection center and divided into five groups according to the breed:the belgian white-blue breed (WB),the black-pied breed (BP),the red-pied breed (RP) and the respective cross-breeds,the WB x BP and the WB x RP.
Samples for histochemical examination were taken within the first hour after slaughter.The muscle specimens were frozen in liquid nitrogen and stored at -30°C.
Serial cryocut sections (10 µm) were stained for myofibrillar ATP-ase activity (Brooke & Kaiser,1970) and the succinic dehydrogenase (SDH) activity (Nachlas et al,1957).Some modifications were carried through concerning the preincubation pH and time in the method of Brooke & Kaiser.On the basis of the stain intensity,fibers were categorized as having a high,an intermediate or a low enzymic activity.Brooke & Kaiser defined the dark stained fibers (preincubation pH 4.3) as being slow-contracting type I fibers,presenting an oxidative metabolism.Type II fibers are fast-contracting and can be divided into IIA and IIB fibers according to their metabolism.Type IIA is oxidative and glycolytic in its metabolism,whereas type IIB is glycolytic and only weakly oxidative (Peter et al 1972).Ashmore & Doerr (1971) had the same results,but these authers used a parallel nomenclature where beta-red is equivalent to type I,alpha-red to IIA and alpha-white to IIB.
From these histochemically stained sections,three parameters were measured :
- the percentage of each fiber type
- the percentage area of each type
- the mean surface of the fibers (μ^2)

Using the results of the percentage area,two factors could be calculated as indicators of the metabolism,i.e. :
- an aerobic factor (AF)= % area I + % area IIA / % area IIB.
- an anaerobic factor (ANF) = % area IIA + % area IIB / % area I.

Besides this histochemical examination a biochemical determination of lactate dehydrogenase (LDH:Boehringer 124885) and malate dehydrogenase (MDH:Boehrin-

ger 124940) activity was carried out as a parameter of the metabolism. Immediately after slaughter blood samples were taken for the determination of the lactic acid content as an indicator of an accelerated glycolysis. Since there is a positive correlation between an accelerated breakdown of glycogen and meat quality characteristics,as mentionned by Fischer & Hamm (1980),the evolution of the pH was measured until 4 h. pm (pH-meter Portamess,type 654 Knick) and correlated with the following meat quality analyses:the WHC,the brightness of colour, the cooking loss and the tenderness. The WHC was determined 48 h. pm by the filter paper press-method (Grau & Hamm 1957).The area of expressed fluid in the filter paper around the film of pressed meat (cm^2/300 mg tissue) was used as a measure for the wateriness of meat.
The brightness of the colour was also measured 48 h. pm by means of the Hunterlab (colour/difference meter D 25-2) In addition to the colour evaluation, an assessment of the pigment content was made by the method of Wierbicki et al (1955).
Eight days pm the cooking loss was determined by heating a steak of 2.5 cm thick to a core temperature of 75°C and from this piece of meat,the shear-force value was measured with the Instron 1140.

RESULTS :

1) pH-measurements and lactic acid (LA) content in the bloodplasm.

Table 1 presents the mean pH_1,$pH_{2.5}$ and pH_4 values as well as the mean LA content (mmol/l) for the five different breeds.All results are compared with the results of the double muscled WB breed,appearing to be the most stress-sensitive breed.
The pH_4 values of the five groups were 5.91 for the WB,6.32 for the BP,6.13 for the RP,6.09 and 6.13 for the WB x Bp and the WB x RP cross-breeds respectively.
So the WB breed seemed to establish a slightly to highly significantly accelerated pm glycolysis in comparison with the other groups (cfr. figure 1 : pH evolution of the five groups).The WB breed also appeared to be the one, showing the highest mean carcass weight (table 1).
Eventhough the WB breed showed the highest LA content of 7.49 mmol/l,this amount was only slightly significantly different for the RP breed ($p < 0.05$).
Table 2 gives the values of pH,LA and carcass weight for all animals,making abstraction of the breed,and dividing them into two groups,according to an arbitrary standard of $pH_4 <$ or $>$ 5.80. Out of that it seemed that,despite a highly significantly lower pH_4 (5.60), the LA content exhibited only a weakly significantly higher rate.Therefore, it could be suggested that in the future the LA content could not be used as a parameter for early detection of an accelerated glycolysis.

2) Quality characteristics.(Table 3)

WHC:No significant differences occurred between the five breeds,presenting values between 44.2 and 45.6 % of bound water.
The expectation that meat from animals with an accelerated glycolysis,should produce a lower WHC, could not be affirmed.

Cooking loss:The WB bulls did not exhibit the expected higher cooking loss.On the contrary,they had the lowest mean cooking loss of 26 %.

Tenderness:An accelerated glycolysis in the WB group could not be correlated to a decrease in tenderness of meat,presenting 42.2 N and 58.9 N as extreme shear-force values,for resp. the pure BP breed and the cross-breed WB x RP.
In general,the shear-force values were rather high in rate.This could possibly be explained by the used fast-cooling system,including the risk of producing meat with cold-shortening. (air-flow : 2 to 3 m/s,air-temperature slightly below 0°C)

Colour and pigment content:
These two aspects came up to the expectations.
In the domain of the brightness of colour (L) and the hue (a/b),the WB animals differred slightly to highly significantly from the others of the same age-group,showing an L-value of 36.2 against values between 32.4 and 33.7 for

the others.The ratio a/b exhibited equally significant differences with a lower hue for the WB bulls,partially due to a highly significantly lower pigment content in that group.As presented in table 4,the pigment content, expressed in mg myoglobin (Mb)/g tissue,amounted 2.21,3.44 and 3.40 mg Mb/g meat for the WB,the BP and the RP breed respectively,and the amount for the cross-breeds fitted in between the results of the pure breeds,showing 2.93 and 3.01 mg MB/g meat for resp. the WB x BP and the WB x RP.

3) Metabolic capacity.

The WB breed was characterized by a higher frequency of an accelerated glycolysis as shown in table 1 (8 animals out of 33).It was obvious to expect that this breed possessed a more anaerobic fiber composition.To find the origin of this faster glycolysis, the metabolic capacity of the muscle was determined,given by the proportion of the two muscle enzymes:LDH/MDH = Q. Figures of Q for the five groups are summerized in table 4.
As expected,the WB animals revealed themselves as having a significantly higher Q-value of 6.80 compared with the BP (4.04) and the RP (4.85) and again the results for the resp. cross-breeds were in between the pure parent breeds i.e. 5.89 and 5.57 for the WB x BP and the WB x RP.The Q-value for the two groups,divided according to the arbitrary standard of pH_4 < or > 5.80, is given in table 5.These figures confirmed the opinion that muscles with an accelerated glycolysis,had a more anaerobic metabolic capacity,with highly significant differences.

4) Muscle fiber composition.

From six animals of each group,the fiber composition was determined with the exception of the WB x BP cross-breed,where only four muscle samples could be analysed because of damage by ice-cristals.The histochemical data were statistically examined by Students t-test and the results are given in table 6 :

- As expected by the biochemical data,the fiber composition of the WB breed was distinguished from those of the other groups by an extremely significantly higher percentage of anaerobic type IIB fibers (51 % against 30-40 % for the other groups) and a significantly lower percentage of type IIA fibers.The percentage of the aerobic type I fibers seemed to be approximately equal for all groups. (22-28 %)
- Generally,the mean surface of the fibers increased in proportion as they were more anaerobic,consequently type I < type IIA < type IIB.At the same time the fibers of the WB animals in general seemed to have smaller surfaces.Since there was such a great variation on those data no significant difference could be revealed.
- The same tendency was found for the percentage of area as for the distribution of the fiber types.The WB breed showed the following proportion i.e.: the percentage area type I < the percentage area type IIA < the percentage area type IIB fibers. In the pure BP and RP breeds the type IIA fibers preponderated the IIB and the I fibers.The cross-breeds did not show any difference between the IIA and IIB fibers.
  Due to the higher percentage area of the IIB fibers in the WB breed,this group was distinct from the others by a highly significantly lower AF (0.50) and an extremely significantly higher ANF (6.65)(cfr. table 4)

CONCLUSIONS:

The WB breed showed a higher frequency of an accelerated glycolysis.The histochemical and biochemical data confirmed the results of the pH-measurements.A pH_4 = 5.91 was correlated with a more anaerobic metabolism and fiber composition.(cfr. Q-value,AF and ANF)
When we tested the correlation between the fiber composition and the quality characteristics,no significant correlation was found between a more anaerobic muscle and paler or more watery meat.
It could be concluded that the WB breed,presenting mainly an anaerobic muscle type (67 % area) had a predisposition for producing an accelerated glycolysis.
However,despite the highly significant

differences in fiber composition and muscle metabolism,no significant consequences could be found for the meat quality.Except for a significantly brighter colour,the meat of the WB breed,was not distinct from that of the other groups.The lower pigment content partially contributed to this brighter colour.
The lower WHC could not be correlated to an accelerated glycolysis.
Two possible hypotheses could explain this result :

1) Because of the lower collagen content and the less rigid structure of the collagen fibers,the muscle of a WB animal is less submitted to a squeezing effect in the rigor mortis phase.(Rowe,1988)
2) Despite the significant difference with the other groups,the pH decline was possibly not extreme enough to cause alterations in the WHC and the tenderness.

Since the results of the cross-breeds proved the genetic background of the fiber composition and the muscle metabolism,as shown in the data of Q,AF, ANF and the pigment content,it could be concluded that further selection on a double muscled animal could result in a more anaerobic muscle type.

REFERENCES:

1) Ashmore,C.R. & Doerr,L. (1971):Exp. Neurol.,31,408.
2) Brooke,M. & Kaiser,K. (1970) : Three "Myosin Adenosine Triphosphatase" systems: The nature of their pH lability and sulfhydryl dependence.J. Histochemistry and Cytochemistry,18,670-672.
3) Grau,R. & Hamm,R. (1957) : Z. Lebensm. Unters. - Forsch.,105,446.
4) Hamm,R. & Van Hoof,J.(1970) : Fleischwirts.,50,215.
5) Hunt,M.C. & Hedrik,H.B. (1977) : J. Food Science,42,716.
6) Khan,A.W. & Ballantyne,W.W. (1973): J. Food Science,38,710.
7) Khan,A.W. & Lentz,C.P. (1973) : J. Food Science,38,56.
8) Martin,A.H. & Fredeen,H.T. (1974) : Can. J. Anim. Sci.,54,127.
9) Nachlas,M.,Tson,K.,De Sonza,E., Cheng,C. & Seligman,A. (1957) : The cytochemical demonstration of succinic dehydrogenase by the use of a new p-nitrophenyl substituted ditetrazole.J. Histochemistry and Cytochemistry,5,420-436.
10)Peter,J.B.,Barnard,R.J.,Edgerton,V. R.,Gillespie,C.A. & Stempel,K.E.(1972) Biochemistry,11,2627.
11)Rowe,R. (1988) : Personal communication.
12)Wierbicki,E.,Cahill,V.R.,Kunkle,L.E. Klosterman,E.W. & Deatherage,F.E. (1955) : Effect of castration on biochemistry and quality of beef. J. Agric. Food Chem.,3,244-249.

BREED	CONFORMATION	pH 1	pH 2.5	pH 4	LA (mmol/l)	C.W. (Kg)	x < 5.8
White-blue n = 33	Double muscled	6.64 ± 0.28	6.17 ± 0.27	5.91 ± 0.24	7.49 ± 2.73	347 ± 36	8 / 33
Black-pied n = 14	Normal	6.86 ** ± 0.11	6.54 *** ± 0.20	6.32 *** ± 0.22	6.78 ± 2.47	280 ± 24 ***	1 / 14
Red-pied n = 15	Normal	6.75 ± 0.15	6.42 *** ± 0.19	6.13 ** ± 0.18	5.83 ± 1.91 *	301 ± 17 ***	1 / 15
WB x BP n = 10	Normal	6.76 ± 0.26	6.34 ± 0.19	6.09 * ± 0.15	7.36 ± 2.42	315 ± 18 **	1 / 10
WB x RP n = 15	Normal	6.86 ** ± 0.11	6.41 ** ± 0.16	6.13 ** ± 0.14	6.40 ± 2.49	317 ± 23 **	0 / 15

Table 1 : pH - Lactic acid content (LA) - Carcass weight (C.W.)

*** p < 0.001
** p < 0.01
* p < 0.05

	C.W. (kg)	pH 1	pH 2.5	pH 4	LA (mmol/l)
pH 4 > 5.80 n = 76	316 ± 33	6.81 ± 0.12	6.40 ± 0.18	6.14 ± 0.17	6.66 ± 2.27
pH 4 < 5.80 n = 11	349 ± 45 **	6.33 *** ± 0.24	5.85 *** ± 0.20	5.60 *** ± 0.13	8.43 ± 3.68 *

Table 2 : pH & LA content in relation to pH 4 < or > 5.80.

*** p < 0,001
** p < 0,01
* p < 0,05

BREED	WHC (% bound H_2O)	Colour			Cooking loss (%)	Tenderness (N)
		L	a / b	$\sqrt{a^2 + b^2}$		
White-blue n = 12	44.2 ± 2.8	36.2 ± 1.4	1.90 ± 0.15	12.58 ± 0.63	26.1 ± 5.5	51.0 ± 8.8
Black-pied n = 6	45.7 ± 3.6	32.9 ** ± 2.8	2.25 ** ± 0.28	12.70 ± 0.47	30.8 ± 3.0	42.2 ± 12.7
Red-pied n = 6	44.6 ± 4.5	32.4 *** ± 1.2	2.38 *** ± 0.25	12.24 ± 0.54	29.9 ± 2.3	57.9 ± 12.7
WB x BP n = 5	45.0 ± 2.9	33.7 * ± 2.6	2.19 ** ± 0.23	12.41 ± 1.00	32.2 ± 4.6	54.9 ± 12.7
WB x RP n = 7	45.5 ± 2.1	33.2 *** ± 1.6	2.29 *** ± 0.23	12.81 ± 0.67	31.0 ± 1.6	58.9 ± 13.7

Table 3 : Meat quality characteristics

*** p < 0,001
** p < 0,01
* p < 0,05

BREED	$Q\frac{LDH}{MDH}$	Pigment (mg Mb / g meat)	ANF	AF
White-blue n = 12	6.80 ± 1.47	2.21 ± 0.32	6.65 ± 1.04	0.50 ± 0.13
Black-pied n = 6	4.04 ± 0.81 ***	3.44 ± 0.62 ***	3.94 ± 0.97 ***	2.08 ± 0.25 ***
Red-pied n = 6	4.85 ± 1.30 *	3.40 ± 0.50 ***	4.56 ± 1.24 **	2.06 ± 0.37 ***
WB x BP n = 5	5.90 ± 0.30	2.93 ± 0.10 ***	5.58 ± 0.93	1.32 ± 0.04 ***
WB x RP n = 7	5.58 ± 0.56 *	3.01 ± 0.40 ***	4.24 ± 1.04 **	1.40 ± 0.28 ***

Table 4 : Metabolic capacity ($Q\frac{LDH}{MDH}$) & Pigment content

*** p < 0,001
** p < 0,01
* p < 0,05

	Q $\frac{LDH}{MDH}$	Pigment (mg Mb / g m.)
pH 4 > 5.80 n = 29	5.28 ± 1.29	3.09 ± 0.54
pH 4 < 5.80 n = 7	$^{\bullet\bullet\bullet}$ 7.20 ± 1.03	$^{\bullet\bullet}$ 2.28 ± 0.50

Table 5 : Metabolic capacity & pigment content in relation to pH 4 < or > 5.80

$^{\bullet\bullet\bullet}$ p < 0,001
$^{\bullet\bullet}$ p < 0,01
$^{\bullet}$ p < 0,05

BREED	Type I (dark stained)			Type II A (not stained)			Type II B (intermediate stained)		
	% fibers	Area %	Surface (μ^2)	% fibers	Area %	Surface (μ^2)	% fibers	Area %	Surface (μ^2)
White-blue	26 ± 4	13.31 ± 2.13	1080 ± 116	23 ± 4	19.65 ± 5.28	1762 ± 139	51± 5	67.09 ± 6.22	2724 ± 381
Black-pied	28 ± 4	20.91 $^{\bullet\bullet}$ ± 4.21	1566 $^{\bullet\bullet\bullet}$ ± 241	$^{\bullet\bullet\bullet}$ 42 ± 5	46.50 $^{\bullet\bullet\bullet}$ ± 4.84	2296 $^{\bullet}$ ± 437	$^{\bullet\bullet\bullet}$ 30 ± 3	32.59 $^{\bullet\bullet\bullet}$ ± 2.65	2332 ± 544
Red-pied	26 ± 5	18.94 $^{\bullet}$ ± 5.32	1767 $^{\bullet\bullet\bullet}$ ± 347	$^{\bullet\bullet\bullet}$ 43 ± 6	47.98 $^{\bullet\bullet\bullet}$ ± 6.39	2754 $^{\bullet\bullet\bullet}$ ± 390	$^{\bullet\bullet\bullet}$ 31 ± 5	33.08 $^{\bullet\bullet\bullet}$ ± 4.09	2674 ± 622
WB x BP	22 ± 2	15.41 ± 1.98	1515 $^{\bullet\bullet}$ ± 203	$^{\bullet\bullet\bullet}$ 39 ± 2	41.59 $^{\bullet\bullet\bullet}$ ± 1.93	2291 $^{\bullet\bullet}$ ± 274	$^{\bullet\bullet}$ 40 ± 2	43.00 $^{\bullet\bullet\bullet}$ ± 0.72	2332 ± 292
WB x RP	28 ± 4	19.73 $^{\bullet\bullet}$ ± 4.08	1590 $^{\bullet}$ ± 414	$^{\bullet\bullet\bullet}$ 37 ± 4	37.99 $^{\bullet\bullet\bullet}$ ± 5.29	2321 $^{\bullet}$ ± 456	$^{\bullet\bullet\bullet}$ 35 ± 3	42.27 $^{\bullet\bullet\bullet}$ ± 4.99	2748 ± 495

Table 6 : Muscle fiber composition in the m. longissimus dorsi.

$^{\bullet\bullet\bullet}$ p < 0,001
$^{\bullet\bullet}$ p < 0,01
$^{\bullet}$ p < 0,05

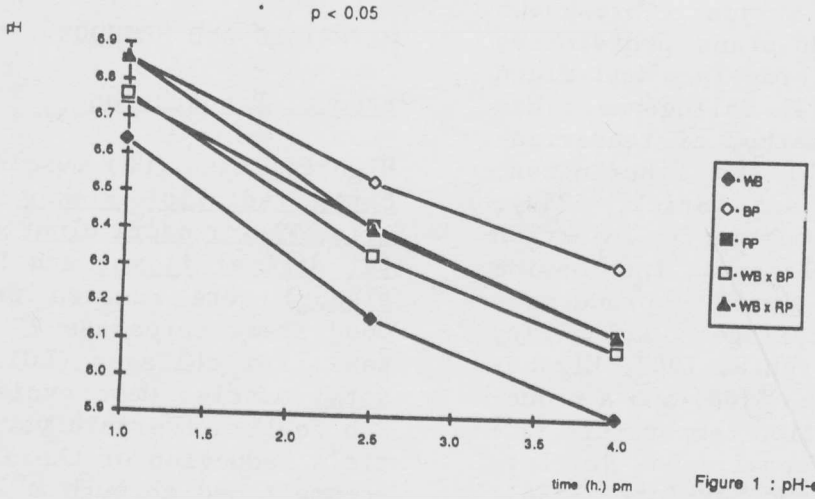

Figure 1 : pH-evolution of the 5 groups.

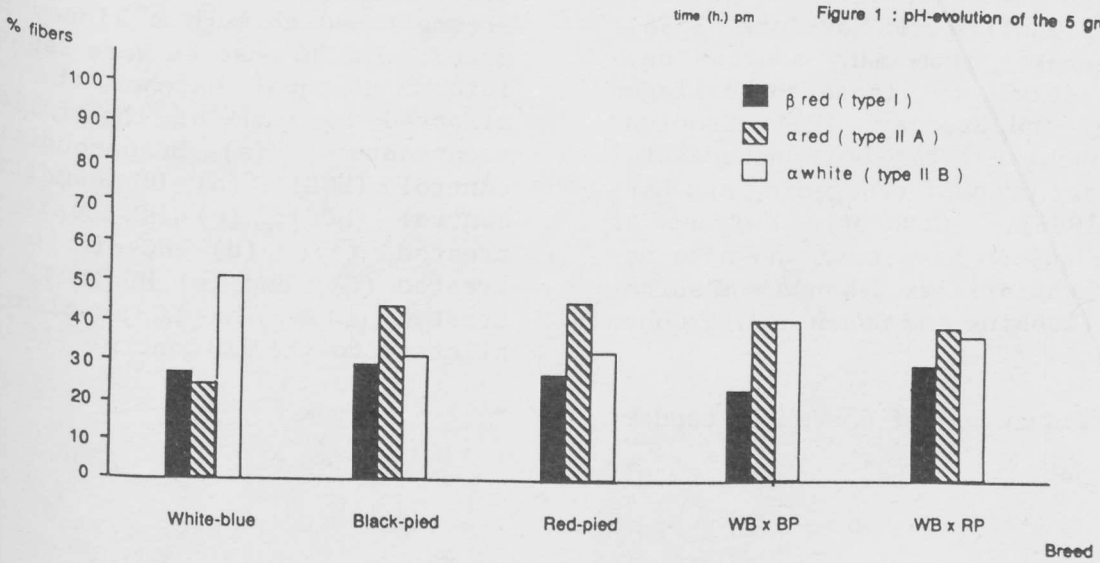

Figure 2 : Fiber distribution in the m. longissimus dorsi.