LE GLYCOGEN DEPLETION PATTERN IN LONGISSIMUS DORSI MUSCLE OF PIGS FED HIGH AND LOW PROTEIN T

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MARY

cle fibre type composition and glycogen depletion pattern and the latter's relation to hnological meat quality were studied in longissimus dorsi muscle of halothane-gene-free dish Yorkshire pigs fed a high or a low protein diet. The muscle consisted of 8% type I, 9% e IIA and 83% type IIB fibres. Low glycogen levels were found in most type I and type IIA res, while a greater variation in glycogen levels was seen within type IIB fibres. The portion of depleted IIB fibres was positively correlated to ultimate pH and pH at ex-guination and negatively to drip loss and EEL value. In pigs on the low-protein diet the portion of depleted IIB fibres was positively correlated to plasma lactate levels and nega-ly to shear force. There were differences in meat quality between pigs fed the two diets e pigs fed the low-protein diet had lower shear force values and higher intramuscular fat tent. Carcasses from pigs on the high-protein diet had a higher lean percentage and less e fat. When 30 % or more of the type IIB fibres were depleted of glycogen, the muscles wed a tendency towards DFD (Dry, Firm, Dark), as the meat had higher ultimate pH, higher er-holding capacity and lower reflectance values (darker meat).

e results from this study indicate that most of the type I and IIA fibres and approximately IIB fibres had been recruited in these pigs due to the preslaughter treatment. This type of ycogen depletion pattern seemed to have a certain influence on technological meat quality.

RODUCTION

ress-situations and treatment of pigs prior to slaughter are known to affect muscle glycogen vels and may result in meat with the DFD condition, which is an important factor in meat ality (LISTER and SPENCER, 1983). Little is known about glycogen content within different bre types at exsanguination, and its relation to meat quality. Muscles from pigs carrying the lothane gene contain numerous glycogen-depleted fibres at slaughter and give meat of poor ality (ESSEN-GUSTAVSSON et al., 1992).

e aim of this work was to study the relationship between muscle glycogen depletion pattern d technological meat quality at slaughter in pigs known to be halothane-gene-free.

TERIALS AND METHODS

Animals: A group of 37 pigs used in a selection experiment (described by STERN et al., 1990) halothane-gene-free Swedish Yorkshire (entire males and gilts) were used, where a high 8.5% crude protein (CP), 0.96% lysine; n=19) or a low-protein diet (13.1% CP, 0.64% lysine; 18) was fed. The metabolized energy content was 11.9 MJ/kg in both diets. The pigs were aughtered the week they reached 103 kg. They were transported 5 km from the research station the abattoir, where they were kept for 2 h in the lairage before they were electrically urned with low voltage on the floor.

Muscle samples: Immediately after exsanguination, muscle samples from M. longissimus dorsi re taken at the last rib, frozen in liquid nitrogen and stored at -80° C until analysis.

Histochemical analyses: Serial sections of the muscle were cut (10 μm) and stained for myo-ATPase after preincubation at pH 4.6 (BROOK & KAISER, 1970) and classified as type I, IIA d IIB fibres, according to the intensity of the staining. The glycogen depletion pattern in muscle was evaluated on sections (20 μm) stained with periodic acid-Schiff (PAS; PEARSE,

1961). Fibres were classified as depleted when unstained, and they were also identified according to fibre type. A computerized image analysis system designed for muscle fibre analysis (BIO-RAD Scan Beam, Hadsund, DK) was used to calculate relative distribution of fibre types in area and number (%) and mean fibre area (μm) for each fibre type. At least 200 fibres from each muscle sample were used in the analyses. The volume distribution of IIB fibres was estimated from the product of the proportional area distribution and the volume (weight) of the dissected muscle according to Oksbjerg et al. (1990).

Biochemical analyses A piece of the muscle was freeze-dried overnight and dissected free from blood, fat and connective tissue. Glycogen content was then analysed according to ESSEN-GUSTAVSSON et al. (1992) and expressed as glucose units on a dry-weight basis. Plasma lactate concentrations were analysed using a lactate analyser (Analox, Analox Instruments Ltd. London, England). Muscle pH at slaughter immediately after exsanguination (pH_e) was analysed by homogenisation of muscle in iodoacetate as described by TARRANT et al. (1972).

Meat quality analysis: Technological meat quality was measured at 24 h post mortem. Meat colour was measured as surface reflectance (EEL, Diffusion Systems Ltd, London, England), ultimate pH (pH_u; Radiometer PHM63, Radiometer, Copenhagen, DK), drip loss (HONIKEL, 1987) and intramuscular fat content (IMF; Soxtec System H^+, Höganäs, Sweden). Shear force values were measured on cooked samples aged for 2 days, using the Warner-Bratzler apparatus according to the procedure of LUNDSTRÖM et al. (1987). Lean percentage was calculated as described in KARLSSON et al. (1992).

Statistical analysis: The data were analysed by the method of least-squares using the GLM procedure (SAS Institute Inc., 1985). A classification was made depending on the glycogen depleted IIB fibres (more or less than 30 %). The statistical model included the fixed effects of diet and sex, while sire nested within diet was considered as random. The mean-squares for sire were used as error line when diet differences were tested. When analysing differences between glycogen depletion classes, this fixed effect was included in the model above.

RESULTS and DISCUSSION

Results from the comparison between diets are shown in Table 1. There were no marked differences in the glycogen depletion pattern, fibre type distribution, or fibre mean area in muscles from pigs fed the low or high protein diet. A tendency to a difference between animals on the two diets was seen for the percentage type IIA and type IIB relative fibre type area distribution, where animals fed the low-protein diet showed a higher proportion of IIA and a lower proportion of IIB fibres. There was no difference in total glycogen content or plasma lactate between pigs on the two diets. Differences in technological meat quality were found between animals fed the two diets, where animals fed the low-protein diet had a lower shear force value and higher intramuscular fat content than animals given the high-protein diet. When comparing production traits, animals fed the low-protein diet showed a lower lean percentage (53.7 % vs. 60.6 %, P=0.003) and more side fat (22.4mm vs. 14.2 mm; P=0.01) compared with animals given the high-protein diet. Since lean percentage differed between diets, a greater proportion of the total muscle mass consisted of type IIB fibres in pigs on the high-protein diet.

Glycogen was depleted according to the histochemical staining in most type I and type IIA fibres, while approximately 25% of IIB fibres were depleted. A greater variation in glycogen levels was seen in type IIB fibres and the range for this fibre type was from 0 to 60%. The proportion of depleted IIB fibres was positively correlated to ultimate pH (0.37, P=0.02) and pH at exsanguination (r=0.41, P=0.07) and negatively to drip loss (r=-0.30, P=0.07) and EEL value (r=-0.32, P=0.05). In pigs on the low-protein diet the proportion of depleted IIB fibres was positively correlated to plasma lactate levels (r=0.36, P=0.10) and negatively to shear force (r=-0.30, P=0.10). To ascertain whether glycogen-depleted fibres would influence the technological meat quality, animals were divided into two groups according to the proportions of glycogen-depleted type IIB fibres (more or less then 30%). Even when there were no differences in total glycogen content, the animals with more then 30% depleted type IIB fibres showed a

er water-holding capacity (measured as drip loss), higher ultimate pH and lower EEL values, ared with those having less then 30% depleted IIB fibres. These results show that if a le has more then 30% of depleted IIB fibres already at slaughter, this will influence the nological meat quality towards DFD meat. In the present study these results were not depen- on the protein diet given to the pigs. One reason for the glycogen depletion here may be entire males were used, as they fought a lot during lairage. Essén-Gustavsson et al. 2) who studied the differences in meat quality and muscle metabolism in pigs with different thane genotypes (NN and nn) found a significant difference in glycogen depletion pattern een the two halothane groups, where nn-pigs showed the highest proportion of depleted IIB es (29%). These findings - and ours - show that when 30% or more of the IIB fibres are ogen depleted, this has an effect on meat quality. In the study by Essén-Gustavsson et al. 2) where pigs carried the halothane gene, they developed PSE, while the halothane-gene-free in our study instead developed meat towards DFD quality. LACOURT and TARRANT (1985) ied the effect of how different forms of stress affected glycogen depletion pattern in erent muscle fibre types in Friesian bulls. The different forms of stress indused were (1) ng with strangers for 5 h or (2) subcutaneous injections of adrenaline. The main findings that glycogen depletion pattern varied with different kinds of stress. During mixing s glycogen loss from type IIA and IIB fibres were more extensive than that from type I es. This pattern was similar to that expected after work of high intensity and short dura- . Adrenaline caused a very high loss of glycogen in type I fibres compared with the type and IIB fibres. Their conclusion was that fibre type responce to stress is determined by nature of the stressor. A slaughter stress that is physically demanding in terms of muscle , glycogen depletion will tend to be greater in type II fibres than in type I fibres. ional stress during the pre-slaughter period may result in sympathic arousal and adrenaline ase, and as type I fibres have a better blood supply, this fibre type can have a greater ogen loss. The glycogen depletion pattern seen in our study seems to be caused by a mixture both types of stressors described by LACOURT and TARRANT (1985), with a varying proportion individual animals.

LUSIONS

results show that the pre-slaughter handling can cause biochemical and physiological reac- which may lead to the development of DFD meat.

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Table 1. Least-squares means with standard errors for differences in M. longissimus dorsi between diets

	Diet		
	High	Low	Prob. value
Relative frequency, %			
Type I	8 ± 1.1	8 ± 1.1	0.92
Type IIA	8 ± 1.2	10 ± 1.2	0.36
Type IIB	84 ± 1.5	82 ± 1.5	0.52
Relative fibre area, %			
Type I	5 ± 0.86	6 ± 0.90	0.28
Type IIA	4 ± 0.63	6 ± 0.65	0.08
Type IIB	90 ± 1.0	87 ± 1.0	0.06
Glycogen-depleted fibres, %			
Type I	58 ± 6.7	82 ± 6.9	0.04
Type IIA	65 ± 9.0	58 ± 9.3	0.62
Type IIB	23 ± 2.2	20 ± 2.3	0.45
Glycogen, mmol*kg^{-1} dry wt	220 ± 11	207 ± 12	0.44
Muscle volume, ml			
Type IIA	177 ± 26	224 ± 27	0.25
Type IIB	3970 ± 67	3323 ± 70	0.0003
Technological meat quality			
Drip loss, %	4.0 ± 0.43	4.0 ± 0.45	0.99
EEL value	19.7 ± 1.5	19.4 ± 1.5	0.88
pH_e	6.18 ± 0.07	6.22 ± 0.06	0.59
pH_u	5.58 ± 0.07	5.59 ± 0.07	0.86
Shear force, kg/cm^2	4.82 ± 0.23	4.10 ± 0.23	0.06
Intramuscular fat content, %	1.5 ± 0.18	2.5 ± 0.19	0.005

Table 2. Least-squares means with standard errors for differences in M. longissimus dorsi between glycogen depletion classes

	Glycogen class		
	Depleted	Non-depleted	Prob. value
Glycogen-depleted fibres, %			
Type I	61 ± 12.3	73 ± 6.8	0.42
Type IIA	74 ± 9.3	57 ± 5.1	0.12
Type IIB	40 ± 3.1	15 ± 1.7	0.0001
Glycogen, mmol*kg^{-1} dry wt	199 ± 16.3	219 ± 9.6	0.30
Muscle volume, ml			
Type IIB	3662 ± 116	3642 ± 64	0.88
Technological meat quality			
Drip loss, %	2.8 ± 0.5	4.4 ± 0.3	0.007
EEL value	16.5 ± 0.9	20.6 ± 0.5	0.0005
pH_e	6.29 ± 0.07	6.18 ± 0.04	0.38
pH_u	5.62 ± 0.04	5.52 ± 0.02	0.079
Shear force, kg/cm^2	4.3 ± 0.3	4.5 ± 0.1	0.44
Intramuscular fat content, %	2.1 ± 0.2	2.0 ± 0.1	0.68