GENETIC VARIATION IN MUSCLE GLYCEROL, GLYCOGEN, AND PIGMENT IN DANISH PURE BREED PIGS

Niels Oksbjerg[1], Poul Henckel[1], Søren Andersen[2], Birthe Pedersen[2]
[1]Danish Institute of Agricultural Sciences, Research Centre Foulum, P.O. Box 50, DK-8830, Tjele, Denmark
[2]National Commission for Pig Production, Axelborg, Axeltorv 3, DK-1611 Copenhagen, Denmark

Key words: meat quality, heritability, genetic correlations, performance, pigs

Background

During the last decade published results have shown that genetic improvement of performance traits in pigs may result in deterioration of some meat quality traits (Hovenier, 1992; De Vries el al, 1994; Cameron, 1990, Oksbjerg et al., 2000). This can be prevented because most meat quality traits are under genetic control, although the heritability of some traits are low. Meat quality traits are often obtained on slaughtered animals, but if it is possible to obtain or predict meat quality traits on the living animal instead of on slaughtered relatives, efficiency of breeding for meat quality would be greatly enhanced.
The ultimate pH of the meat is important, because it affects several meat quality traits like drip loss, lightness (Bendall and Svatland, 1988), shear force, juiciness etc. The ultimate pH of meat is the result of post mortem conversion of glycogen to lactate and H^+. Thus, results suggest that the muscle glycogen level is inversely related with the ultimate pH of meat (Henckel et al., 1997).
The colour of meat affects the first impression of the consumer. Meat colour, especially the redness is dependent on the content of pigment (Oksbjerg et al., 2000). The eating quality is dependent on the concentration of intramuscular fat and muscle lipase/esterase released glycerol may thus, in turn be related to the concentration of intramuscular fat.

Objectives

We here report the heritabilities of pigment, glycogen, and glycerol analysed on longissimus muscle biopsy samples obtained from 85 kg purebred pigs and their genetic relationships to meat pH, meat colour and performance traits.

Methods

The experiment was conducted on Landrace-, Yorkshire- and Duroc-boars. The boars were groupwise penned (12-14 pigs/pen) and fed ad libitum. The feed intake was individually recorded using the ACEMA-48-feeders. From 30 to 90 kg body weight all boars were performance tested. All pigs were free of the halothane gene.
At 85 kg live weight a muscle biopsy sample (approx. 300 mg) was taken by use of a spring loaded shot-biopsy device (Biotech, Republic of Slovakia) from the M. *longissimus dorsi* (LD) at the level of the last rib curvature as described by Cheah et al. (1997). This technique was approved by and conducted in accordance with the guidelines outlined by the Danish Inspectorate of Animal Experimentation. The biopsy sample was divided into three pieces. The superficial and the deep piece (each appox. 100 mg) was used for analysis of pigment each as described by Oksbjerg et al. (2000). Ten mg of the mid-piece was analyzed spectofotometrically for glycogen (Henckel et al., 1997). Twenty mg of the mid-piece was analyzed flourometrically for glycerol (Boehringer Mannheim: Test-Combination Glycerol, Cat. No. 148 270) after muscle homogenates had been treated with lipase/esterase for 20 minutes to release glycerol from glycerides. The repeatabily between sampling was estimated according to Becker (1992) as R=0.77 for pigment, R=0.74 for glycogen and R=0.50 for glycerol.
At 100 kg liveweight, the pigs were slaughtered at a commercial abbatoir. Transport time was 2 hours, and lariage time was 1 hour. The meat content was determined. Twentyfour hours *postmortem*, the pH was measured in the loin at the level of the last rib curvature and in the ham (semimembranosus). Colour measurement was performed 24 hours post mortem on 2 cm thick chops, excised from the longissimus muscle at the level of the last rib curvature and bloomed for 1 h at 2 °C, using a Minolota Chroma Meter CR-300, with a D65 light source, calibrated against a white tile. The tristimulus parameters L* a* and b* (representing lightness, redness, and yellowness, respectively) were measured on four fixed sites of each chop surface. Furthermore, subjective colour was assessed according to the Japaneese Colour Scale by one trained person.
Genetic parameters for the measured traits were estimated in a multi trait animal model using the VCE4 program (Neumair and Groeneveld, 1998).

Results and discussion

Means, standard deviation and the heritability of measured traits are given in Table 1. The heritability of glycogen was medium (h^2=0.37), but low for pigment (h^2=0.19) and glycerol (h^2=0.14). Larzul et al. reported a heritability of 0.17 for Glycolytic Potential and 0.39 for pigment. In former Danish experiments the heritability of pigment was estimated to 0.65 when samples was obtained on bled animals. The lower heritability of pigment in the present study may be due to smaller samples and/or the fact that haemaglobin contributes to total pigment to a larger extent in *in vivo* samples than in samples from bled animals (unpublished results). The lower heritability of glycerol compared to the heritability of intramuscular fat (0.30-0.62), may also be due to the smaller samples size. Intramuscular fat is not evenly distributed in the muscles.
Glycogen, glycerol and pigment were all to some extent genetically related to performance traits (Table 2). Firstly, glycogen was genetically related to the meat percentage (r_g=0.36) and feed:gain (r_g=-0.23), but unrelated to gain. Secondly, the concentration of muscle pigment was genetically related to gain (r_g=-0.17), feed:gain (r_g=0.14) and meat percentage (r_g=0.11). Finally, the concentration of glycerol was related to gain (r_g=0.28), feed:gain (r_g=-0.43), and meat percentage (r_g=-0.22).
The genetic relationship between the concentration of pigment and colour traits were rather high (Table 3). Thus, the concentration of pigment correlated to the L* (r_g=-0.56), a* (r_g=0.69), and subjectively determined colour (r_g=1.00). The concentration of glycogen was inversely related to the pH of the longissimus dorsi (r_g=-0.54) and of the ham (r_g=-0.33), while glycerol was positively related to the pH of the ham (Table 4).

The concentration of glycerol was negatively related to the concentration of glycogen (r_g=-0.44±0.20) and glycogen was positively related to the concentration of pigment (r_g=0.30±0.13).

Conclusion

In conclusion, the present data suggest that:

- selection for increased daily gain results in decreased concentration of pigment and increased concentration of muscle glycerol
- selection for improved feed:gain results in increased concentration of muscle glycogen and glycerol and decreased pigmentation.
- selection for increased meat percentage results in increased muscle pigment and glycogen and reduced muscle glycerol.

due to the heritability of muscle glycogen and pigment it is possible to prevent a deterioration or even to improve water holding capacity (increased pH) and meat colour by breeding programmes.

Table 1. Number of observations, means of traits, standard deviation, heritabilities of traits and their standard error in Danish purebreed pigs

	N	Mean	SD	h^2	s.e. of h^2
Glycerol, mg/g	967	1.18	0.23	0.14	0.06
Glycogen, µmoles/g wet weight	1646	87.5	12.0	0.37	0.04
Pigment, mg myoglobin residues/g	1651	1.41	0.34	0.19	0.03
Colour	902	3.31	0.88	0.16	
L*	902	52.4	3.45	0.15	0.06
a*	902	5.82	1.23	0.60	0.07
b*	902	5.47	1.27	0.34	0.06
pH (loin and ham)	821	5.63	0.09	0.30	0.02

Table 2. Genetic correlations (with their s.e.) among glycerol, glycogen, pigment and performance tratis.

	Daily gain	Feed conversion ratio	Percentage of meat
Glycerol	0.28 (0.21)	-0.43 (0.21)	-0.22 (0.19)
Glycogen	-0.06 (0.06)	-0.23 (0.05)	0.36 (0.06)
Pigment	-0.17 (0.07)	0.14 (0.08)	0.11 (0.06)

Table 3. Genetic correlations (with their s.e.) between pigment and colour traits

	L*	a*	b*	Colour
Pigment	-0.56 (0.17)	0.69 (0.18)	0.15 (0.11)	1.00 (0.00)

Table 4. Genetic correlations (with their s.e.) among glycerol, glycogen and pH.

	pH of longissimus	pH of the ham
Glycerol	0.25 (0.21)	0.59 (0.18)
Glycogen	-0.54 (0.09)	-0.33 (0.10)

Litterature

Becker, W.A. 1992. Manual of quantitative Genetics. 5th Edn. Academic Enterprises, Pullman, WA, USA.

Bendall, J.R. and Swatland, H.J. 1988. A review of the relationships of pH with physical aspects of pork quality. Meat Science. 24:85-126.

Cameron, N.D. 1990. Genetic and phenotypic parameters for carcass traits, meat and eating quality traits in pigs. Livest. Prod. Sci. 26:119-135.

Cheah, K.S., Cheah, A.M., and Just, A. 1997. A simple and rapid biopsy technique for obtaining fat and muscle samples from live animals for predicting meat quality. Dansk Veterinærtidsskrift 80 18:775-777.

De Vries, A.G., Van der Wal, P.G., Long, T., Eikelenboom, G., Merks, J.W.M. 1994. Genetic parameters of pork quality traits in Yorkshire population. Livest. Prod. Sci. 40:277-289.

Henckel, P., Oksbjerg, N., Erlandsen, E., Barton-Gade, P., and Bejerholm, C. 1997. Histo- and biochemical characteristics of the Longissimus dorsi muscle in pigs and their rerlationships to performance and meat quality. Meat Science. 47:311-321.

Hovenier, R., Kanis, E., Van Asseldonk, Th., and Westerink, N.G. 1992. Genetic parameters of pig meat quality traits in a halothane negative population. Livest. Prod. Sci. 32:309-321.

Larzul, C., Lefaucheur, L., Ecolan, P., Gogué, J., Talmant, A., Vernin, P., Sellier, P., Roy, P., and Monin, G. 1997. Phenotypic and genetic parameters of longissimus muscle fiber charateristics in Large White pigs. J. Anim. Sci. 75:3125-3136.

Neumaier, A.,and Groeneveld, E. 1998. Restricted Maximum Likelihood Estimation of Covariances in Sparse Linear Models. Genet. Sel. Evol. 30:3-26.

Oksbjerg, N., Petersen, J.S., Sørensen, I.L., Henckel, P., Vestergaard, M., Ertbjerg, P., Møller, A.J., Bejerholm, C., and Støir, S. 2000. Long-term changes in performance and meat quality of Danish Landrace pigs: A study of a current compared to an unimproved genotype. Animal Science 71: 81-92.

Aknowledgements: Mrs. Anna Halborg-Madsen, Mrs. Inge Lise Sørensen, and Marianne Rasmussen are thanked for analysing the samples for glycerol, pigment and glycogen respectively. Mr. Jørgen Hoberg and staff are aknowledged for taken the biopsy samples.