A review of EAAP and CEC meeting on meat quality in pigs

Walstra P.

in

Aumaître A. (ed.).
The production of pig meat in Mediterranean Countries

Paris : CIHEAM
Options Méditerranéennes : Série Etudes; n. 1989-I

1989
pages 179-185

A review of the EAAP and CEC meeting on meat quality in pigs

Peter WALSTRA

Research Institute for Animal Production "Schoonoord"
Am Zeist - The Netherlands

An overwhelming number of publications has been written over the last 30 years on meat quality. Since this survey had to be restricted to the EAAP meetings it will thus refer to papers presented mainly in the Pig Commission of EAAP, sometimes in joint sessions with other commissions. The emphasis will be placed on sessions with themes especially devoted to meat quality.

Such sessions started in 1970 at the Gödöllö (H) meeting when the PSE phenomenon became an increasing problem in many countries. At that time the halothane test was not yet practised, but the mechanisms by which aberrant meat quality developed were already roughly known.

With regard to CEC meetings, there was only the one held in Dublin in 1985. There the newest developments were elucidated, so we may be able to compare the progress made since 1970.

In some cases we will refer to studies outside the meetings mentioned, as it is unavoidable not to mention them, e.g. pioneers on some aspects of the syndrome. The whole syndrome has its background in the stress susceptibility of pigs and was named porcine stress syndrome (Topel et al., 1968) or malignant hyperthermia syndrome (Sybesma and Eikelenboom, 1969) often leading to PSE (Briskey, 1964) previously called muscle degeneration by Ludvigsen (1954). On the other hand, the problem of pork with a pale and moist surface creating processing problems was already described by Herter and Wilsdorf in 1914 (cited by Johnson, 1971).

Although other symposia on meat quality were held and the meetings of the European Meat Research Workers were not referred to, the EAAP meetings nevertheless cover as well the most important findings, especially from the last decade.

The following abbreviations are used:

PSS	*porcine stress syndrome*
MHS	*malignant hyperthermia syndrome*
MH	*malignant hyperthermia*
Hal+	*halothane positive*
Hal-	*halothane negative*
cAMP	*cyclic adenosine monophosphate*
CPK	*creatinephosphokinase*
PHI	*phosphohexose-isomerase*
6-GPD	*6-phosphogluconate dehydrogenase*
Po2	*postalbumin-2*
LDH	*lactate dehydrogenase*
ATP	*adenosine triphosphate*
PSE	*pale, soft and exudative*
DFD	*dark, firm and dry*
NN	*halothane negative homozygote genotypedative*
Nn	*halothane negative heterozygote genotype*
nn	*halothane positive homozygote genotype*

I - The 1970-1975 period

During these years, most papers presented data concerning phenotypic and genotypic correlations between carcass traits and meat quality characteristics. Heritability estimates were also calculated for meat quality, mainly for colour. The level of the correlations and h^2 estimates indicated that selection of meat quality would be possible (Weniger *et al.*, 1970; Johnson, 1971; Walstra *et al.*, 1971; Kallweit *et al.*, 1973; Jensen, 1974). The h^2 estimate for meat colour (subjective score) amounted to about 0.30 (same authors).

In many papers the differences in meat quality criteria for different breeds were described, mostly together with the differences in carcass composition. Both groups of traits are adversely correlated. With regard to possible selection of meat quality, Haase and Steunhauf (1971), Unshelm *et al.* (1971) and Sybesma *et al.* (1972) argued for standardization of stress and pre-slaughter handling because of the possible relationship between meat quality and adaptibility of the animals.

Reducing the stress would benefit meat quality, though Lister (1971) said that in very sensitive animals, like Piétrain, it would not help much. Sybesma (1970) stated that MH could be evoked by exercise with excitation. The latter was held to be one of the initiating factors for the metabolic acidosis prior to hyperthermia. This acidosis was shown by Muylle *et al.* (1968). The malfunction of mitochondria was held responsible for the heat production. The genetic predisposition determined the impact of environmental influences on meat quality and this predisposition of the muscle was linked up with its physiological background. Adrenal hormones would play a decisive role according to Lister (1971).

High rates of thyroid secretion also lead to high ATPase activity in muscle (Lister, 1972). The extent of this activity would have the primary biochemical control of meat quality. According to Kallweit *et al.* (1973) the glycolytic metabolites were highly correlated with meat quality criteria. The rate of glycolysis *post mortem* could be influenced by means of climatic and other physiological factors.

Lister (1971) also stressed the importance of the electrolyte balance in the muscle. He found that high plasma K^+ and lowered Na^+/K^+ ratio were associated with inferior meat quality.

According to Walstra *et al.* (1971), crossbreeding would lead to better meat quality, but there was no justified evidence for heterosis on meat quality characteristics.

Jensen (1974) studied the inheritance of meat colour. Based on other Danish work, he concluded that 20 - 30% of the variance is due to additive gene effects, 30 - 40% to dominance, and 40% to random influences. The assumption was made that the dominance variation would arise from the PSE problem and that the inheritance is recessive. Jensen based this on the findings of Hall *et al.* (1966) suggesting that the PSS condition was due to recessive inheritance with variable penetrance. This was confirmed later on by Ollivier *et al.* (1975), Minkema *et al.* (1977) and Smith and Bampton (1977).

CPK activity in blood, as measured in live pigs after standardized stress, also correlated with stress susceptibility and this might have a predictive value for the post mortem meat quality (Cuthbertson *et al.*, 1972; Flock *et al.*, 1974) first described by Bickhardt (1969). For the same purpose, Sybesma *et al.* (1972) measured lactate and glucose-6-phosphate concentrations in muscle biopsies. The correlations, however, were too low to be of any significant help.

II - The 1975-1980 period

During these years much research effort was invested in the halothane test and other testing methods for the PSE syndrome.

Introduction of the halothane test as a predictive test for PSE and induction of MHS was first described by Eikelenboom and Minkema (1974). Stress susceptible pigs react strongly when the anaesthetic halothane is supplied at a young age (eight weeks).

The test was recommended for commercial pig breeding (Eikelenboom *et al.*, 1977). Dutch Yorkshire had 3.1% positive reactors, while in Dutch Landrace 22.2% reactors were found. About the same percentages were found by Schöwrer *et al* *al.* (1979) for the respective Swiss types. Hal+ and Hal- animals differed in meat quality traits, in traits for carcass composition and in growth performance. The differences are less clear in breeds that are stress resistant.

Hal+ animals had inferior meat quality characteristics, were shorter, had a more favourable carcass composition, grew faster and had a higher incidence of deaths during fattening and transport (Eikelenboom *et al.*, 1977). Most of the findings were confirmed later on (Eikelenboom *et al.*, 1979; Poltàrsky *et al.*, 1979; Lüscher *et al.*, 1979; Schmidt and Kallweit, 1979). Cöp *et al.* (1977) discussed the breeding strategies in halothane testing in a simulation study on gene frequencies. A set-up of HH-lines was considered, as was proposed earlier by Minkema *et al.* (1977). The adverse relationship between meat quality and carcass composition was confirmed by Lampo, (1977); and Pedersen (1979). The latter showed that the relationship was only present in shorter meat type Danish Landrace pigs. Lampo (1977) also found such positive correlations between stress susceptibility and indicator enzymes such as CPK, LDH and LDH5 and this was confirmed by Schmidt and Kallweit (1979).

To improve meat quality, genetic markers could be used, e.g. the H blood system and the PHI enzyme system, because they were associated with stress susceptibility (Jensen *et al.*, 1976; Rasmusen and Christian, 1976; Barton *et al.*, 1977). Jensen and Andresen (1979) found that the A factor of the H Blood group system and the BB type of the PHI system were responsible for inferior meat quality. They also mentioned a significant linkage disequilibrium between the Hal locus and the H and PHI loci on meat quality. Routine measuring of these markers was not seen as profitable in selection. That was also stated by Kallweit (1979) with regard to measuring CPK activity. Andresen (1971) also described the linkage of 6-PGD with the marker loci.

Schepers and Schmitten (1979) mentioned that the Hal+ percentage in Belgian Landrace and German Landrace and in their crosses with Piétrain (66 - 87%) could be reduced drastically by crossbreeding with German Yorkshire. The Hal+ pigs had higher CPK values. This was also found by Schöwrer *et al.* (1979), but both tests could not be applied to Large White.

Another test method was mentioned by Allen *et al.* (1979): the mitochondrial Ca++ efflux. Very high correlations were reached (up to 0.92) with meat quality criteria (Cheah and Cheah, 1979) and the efflux rates differed highly between the halothane types. This and other tests were not applied in practice because of the low incidence of the PSS and PSE in the United Kingdom. The Ca++ efflux test was developed by Cheah and Cheah (1976). As a negative point for the halothane test, Allen *et al.* (1979) mentioned some social and medical reservations, as a high valuable Hal+ animal might die during the test.

From a simulation study, Malmfors *et al.* (1979) concluded that including meat colour in a selection index seemed to be more efficient than independent selection for meat quality.

III - The effect of monofactorial factors on quantitative traits

A whole session was devoted to this theme in Munich 1980. Breeding strategies were discussed by Simon (1980), Franceschi and Ollivier (1980) and Smith and Webb (1980) for elimination of the recessive genes, for which test matings with nn animals are most effective. Such matings are also worthwhile in forming NN-lines used to produce heterozygotes that show an intermediate position for most carcass traits, thus having an advantage over non-carriers (Eikelenboom *et al.*, 1979; Smith and Webb, 1980). Brascamp *et al.* (1980) also pointed at Hal *locus* as being a pleiotrophic locus affecting various quantitative production traits which accounted for 20 - 60% of the additive genetic variances. The meat quality traits are less intermediate and resemble more the values of the NN-genotype (Eikelenboom *et al.*, 1979; Andresen and Jensen, 1980). The latter also stated that the halothane test was particularly useful at high frequencies of Hal+ pigs, but at moderate to low frequencies marker genes might be useful until disequilibrium disappeared.

The marker genes Ha, PHI and 6-PGD had linkage disequilibrium with the Hal locus (Andresen and Jensen, 1980; Guérin *et al.*, 1980).

The reactors percentage was 17% in French Landrace and 84% in Belgian Landrace; no reactors were found in Large White (Guérin *et al.*, 1980). Kovàchs (1980) also found no reactors in Large White (Guérin *et al.*, 1980), but in four different Landrace types the reactors percentage was between 3% and 52%. In Belgian Landrace and Piétrain these percentages were again found to be much higher (80-87%) by Sönnichsen *et al.* (1980). They found differences in carcass traits between the halothane phenotypes, but because of the rather small differences in stress susceptibility, measured as Göfo value and deaths losses during fattening and transport, the authors were not convinced of applying the halothane test in practice. The same was found by Rogdakis *et al.* (1980) based on the weak relations they also found on most other traits. The situation in Germany will not change if more attention is not paid to stress resistance and meat quality due to lack of interest and economic returns of meat quality (Unshelm, 1980).

On the other hand, Dzapo (1980) postulated a causal dependance between halothane sensitivity and the oxydative energy metabolism in muscle, heart and liver. Breed types also differed in frequency and areas of abnormal muscle fibre structure during growth from 70 to 200 days of age. The differences were in favour of the crossbreds compared to both pure breeds (Finger *et al.*, 1980).

Webb (1980) showed that the halothane test would be delayed until the age of the piglets of at least eight weeks, because the reactors percentage was still increasing from 18 days on. The halothane gene seemed to be not yet fully expressed at younger ages.

IV - The 1980-1985 period

In Swedish Landrace and a crossbreed from it with Large White, the reactors percentages were 28% and 20% respectively (Stanković *et al.*, 1983). The Hal+ pigs had a better carcass quality, but an inferior meat quality. Wörner and Glodek (1983) showed differences between crosses of different origin. The slightly higher lean content in Belgian Landrace crosses, compared to Hampshire crosses, had much poorer meat quality. The backcrossses with German Landrace had a fairly high proportion of PSE. The Large White backcrosses showed an excellent meat quality, but they could not compete with regard to carcass composition.

At the 1985 meeting in Halkidiki, Greece, a special session was also devoted to stress susceptibility and meat quality.

Webb *et al.* (1985) reported that there is still no other evidence that PSS is controlled by the autosomal locus responsible for halothane sensitivity. The gene for halothane sensitivity appeared to be largely recessive for stress susceptiblity and meat quality, but additive for the effect on lean content. These statements were in fact confirmed by Gahne and Kumar Juneja (1985) and Jensen and Barton-Gade (1985). Blood typing and use of other marker *loci*, whether or not in combination with the halothane test, were mentioned to differentiate between the Hal- pigs (Webb *et al.*, 1985; Gahne and Kumar Juneja, 1985; Kruff *et al.*, 1985). The order of the three marker *loci* was found to be PHI-Po2-PGD. The position of the Hal locus with regard to PHI could not be assessed (Gahne and Kumar Juneja, 1985).

Selection against the markers Ha and PHI could be recommended in Hungary. It would also improve meat quality without reducing meatiness, while improving litter size (Fesüs *et al.*, 1985).

The expression of the halothane gene is affected by genetic background (Webb *et al.*, 1985): the percentage reactors of progeny from test matings between the homozygotes in British Landrace were 28% versus 12% for the sire being negative or positive respectively, which suggested some form of maternal inheritance.

Besides blood typing, CPK, succinylcholine and red cell fragility are alternatives for genotyping. For the future, DNA manipulation would be most promising (Webb *et al.*, 1985).

Good progress can be made by genotyping as exemplified by Kruff *et al.* (1985). They crossed a NN-genotype German Landrace with Piétrain which resulted in offspring with good meat quality and good fattening performance. Successful application of the halothane test was shown by Eikelenboom (1985). The reactors percentage at one of the testing stations decreased from 36% to 9% in five years.

Eikelenboom (1985) pointed to the considerable genetic variation in the ultimate meat quality which is not controlled by the halothane gene. Pre- and post-slaughter handling may influence it. He also referred to the concern about the "Hampshire type" of meat. Like PSE meat, it leads to lower technological yields for processed products. This watery and pale meat is characterized not by a rapid *post mortem* PH fall as in PSE, but instead by a very low ultimate pH. The condition was found in the Hampshire breed and described by Monin and Sellier (1985).

Besides the normal performance characteristics, Lundström *et al.* (1985) studied the effect of the halothane genotypes on immune response. The Hal+ pigs had the lowest activities. Furthermore a number of muscle metabolites differed between the genotypes, but the activities of various enzymes did not. Hal+ pigs were superior to the other genotypes for daily gain and the feed conversion ratio (emphasis is put on a within litter comparison), and these genotypes also had lighter organ weights.

The effect of the halothane pheno or genotype on growth rate and feed conversion ratio is not conclusive taking into account all contributors.

A number of other characteristics was studied in relation to stress susceptiblity and meat quality: histological lesions in muscle fibres (Bader, 1985), contracture test of isolated muscle strips (Heffron and Mitchell, 1985), K+ supply in the feed (Fogd Jorgensen, 1985) and magnesium aspartate in the feed (Ludvigsen, 1985). Halothane reaction was not correlated with the histological finding, but the CPK levels after stress did. The contracture test is used in humans for diagnosis of MH. In pigs, however, the test appeared to be more difficult, because of a greater variability of the strips in response to drugs and the fact that these strips are less viable compared to human strips.

K+ and magnesium-aspartate supply both delayed the MH during halothane anaesthesia. Due to moderate K+ depletion in the muscle, anaerobic metabolism was reduced and therefore also lactate production (see also Lister, 1970). Magnesium-aspartate supply also reduced the deaths during transport and had a slight improvement in meat quality. The buffer capacity in the muscles, influenced by thyroid hormone and magnesium-aspartate, would play an important role in the intermediary metabolism of Mg^{++} in the antagonism between Ca^{++} and Mg^{++} on the muscle cellular level.

Topel and Hallberg (1985) stated that dopamine lowering in the caudate nucleus of the brain could reduce the inhibitory effect on acetylcholine stimulation under stress conditions, thus resulting in overstimulation of the motor end plates of the skeletal muscles. This in turn would result in excessive Ca^{++} efflux into the sarcoplasm leading to muscle tremors and rigidity and this would initiate and stimulate the lactate acidosis and high muscle temperature. The central nervous system may also play a role in the aetiology.

Müller *et al.* (1985) supposed that the higher amounts of B-adrenergic receptors measured in muscle, heart and fat tissue in Piétrain pigs compared to Large White pigs accelerated muscle glycogenolysis and that stress susceptible pigs have higher concentrations of cAMP in the muscle and heart and higher concentrations of glycerol in the blood at slaughter.

V - CEC-seminar on evaluation and control of meat quality in pigs, Dublin 1985

There were four sessions during this seminar. Each session had a rapporteur who summarized the papers in that particular session. The reports of these rapporteurs will be closely followed here, but the points raised during the EAAP meetings will not be repeated in detail.

VI - Aetiology of the porcine stress syndrome (*Rapporteur:* Honikel)

Many details are known about the sequence of events, but the connecting links between them are still missing. Extra-cellular signals induce the PSS and an accelerated energy turnover in muscle cells ends up with PSE meat after slaughter. How the signals are transferred to the cell and how the increase of ATP turnover starts is not yet clear. In MH Ca^{++} is one of the triggering substances of the syndrome; Ca^{++} release may not be the primary cause, but would at least be indicative of lesions of membranes of the cells or those of the sarcoplasmic *reticulum* and *mitochondria* could be affected.

The rapid utilization of energy in the muscle leads to heat production. The energy rich ATP is hydrolised; its breakdown is the central reaction in PSE muscle, controlling anaerobic glycolysis. The following events may occur induced by signals from outside and/or by genetic defects:

a) an altered membrane permeability;

b) altered enzyme activities or control mechanisms of glycolytic or adenine nucleotide converting systems;

c) mitochondrian malfunction with early and solely anaerobic ATP production. One or more of these events may occur in PSE susceptible muscles. The sequence of reactions in the muscle cell may be caused by the autonomic nervous system and/or stressors and induced in the cell by hormones, where the thyroid function may play a role.

VII - The evaluation of meat quality

(Rapporteur: Eikelenboom)

A great number of methods for measuring meat quality is used. Comparison of data between countries and experiments is thus difficult. There clearly was a need for standardisation of the methods. On the other hand countries may evaluate quality for a specific destination for typically locally processed products.

New methods for measuring meat quality are becoming available with the development of fibre optics. The carcass grading instruments will probably also measure meat quality by means of light reflectance. It is still questionable whether such data will lead to payment for meat quality. The measurements may also be used for sorting carcasses to various destinations such as fresh and processed meat. These assessments of meat quality may possibly be supplemented by other measurements for typing the correct meat quality. In recent years there is also the development of assessment of the meat quality by means of electrical conductivity. The results presented were quite promising.

VIII - Control of meat quality in transport, lairage, slaughter and chilling

(Rapporteur: Monin)

With regard to measurement of meat quality, the results are difficult to compare due to large variations in experimental conditions. In general improvements in transport will lead to improvements in meat quality.

Lairage of more than six hours is mostly unfavourable to meat quality.

The technique of hot boning was limited in preventing the PSE condition. Application of the technique requires assessment of meat quality in the slaughterline, especially for DFD meat.

IX - Control of meat quality in breeding and selection

(Rapporteur: McGloughlin)

There is a need for a quick, cheap method for genotyping at the halothane locus. For the longer term, research should be directed to separation of the beneficial and deleterious effects of the halothane gene and to the possible mitochondrial inheritance of PSS.

Breeding strategies for exploiting the halothane gene may differ between breeds and countries, depending on the magnitude of favourable and unfavourable effects of the halothane gene on the various performance traits in the homo- and heterozygotes. Complete elimination of the halothane gene, if wanted, will be hard to obtain unless an accurate test for identifying the heterozygote is found. The benefits of exploiting the halothane gene will not be fully realised in situations where payment is not based on lean content. A possible approach of identifying the heterozygote would be by applying molecular biotechnology and genetic engineering techniques in studying the PSS. It is also hoped that the underlying genetic lesion may be identified. Some examples were mentioned where the classical view that there is not heterosis for meat quality traits did not hold any more.

References

Andresen, E., 1971. Linear sequence of the autosomal loci PHI, H and 6-GPD in pigs. Anim. Blood Groups Biochem. Genet. 2:119-120.

Barton, P., P. Fod Jorgensen, P. Baüner Nielsen and J. Moustgaard, 1977. Blodtypesystemer og kodkvalitet hos svin. En undersogelse over sammen-haengen mellem et enzymsystem, et blodtype system og kodkvalitet hos Danks Landrace. Arsbertn.Inst.Sterilitetsforskn. 20:93-100.

Bickhardt, K., 1969. Ein enzymatisches Verfahren zur Erkennung von Muskelschäden beim lebenden Schwein. Dtsh. Tierärtzl.Wschr. 76:601-604, 691-694.

Briskey, E.J., 1964. Etiological status and associated studies in pale, soft, exudative porcine musculature. Advances in Foods Res. 13:89-178.

Cheah, K.S. and A.M. Cheah, 1976. The trigger for PSE condition in stress susceptible pigs. J. Sci. Fd Agric. 27:1137-1144.

Christian, L.L., 1972. A review of the role of genetics in animal stress susceptibility and meat quality. In: Proc. Pork Qual. Symp., Univ. Wisconsin (Eds. R.G. Cassens, F. Griesler and Q. Kolb). Univ. Wisconsin Press: 91-115.

Eikelenboom, G. and D. Minkema, 1974. Prediction of pale, soft and exudative muscle with a non-lethal test for the halothane-induced porcine malignant hyperthermia syndrome. Neth. J. Vet. Sci. 99:421-426.

Hall, L.W., N. Woolf, J.W.P. Bradley and D.W. Jolly, 1966. Unusual reaction to suxamethonium chloride. Brit. Med. J. 2:1305-1037.

Jensen, P., H. Staun, P.B. Nielsen and J. Moustgaard, 1976. Underogelser over sammenhaengen mellem blodtypesystem H og points for kodfarve hos svin. Medd. Statens Husdyrbrugsforog :83.

Jorgensen, P.F., 1977. Studies on the association between halothane sensitivity blood group and enzyme systems in Danish Landrace pigs. Arsberetn. Inst. Sterilitetsforskn. 20:101-108.

Ludvigsen, J.B, 1954. Undersogelser over den sakaldte "Muskeldegeneration" hos svin. I.272. Beretn. fra Forsogslab. 112 pp.

Minkema, D., G. Eikelenboom and P. van Eldik, 1977. Inheritance of MHS-susceptibility in pigs. IN: Proc. 3rd Internat. Conf. on Production Disease in Farm Animals, Wageningen, 1976. PUDOC, Wageningen:203-207.

Monin, G. and P. Sellier, 1985. Pork of low technological quality with a normal rate of muscle pH fall in the immediate *post mortem* period: the case of the Hampshire breed. Meat Sci. 13:29-35.

Muylle, E., C. van de Hende and W. Oyaert, 1968. Stoffwechsel von Michlchsäure bei Schweinen. Dtsch. Tierärtzl. Wschr. 75:29-35.

Ollivier, L., P. Sellier and G. Monin, 1975. Déterminisme génétique du syndrome d'hyperthermie maligne chez le porc de Piétrain. Ann. Génét. Sél. Anim. 7:159-166.

Rasmusen, B.A. and L.L. Christian, 1976. H blood types in pigs as predictors of stress susceptibility. Science 191:947-948.

Smith, C. and P.R. Bampton, 1977. Inheritance of reaction to halothane anaesthesia in pigs. Genet. Res. 29:287-292.

Sybesma, W. and G. Eikelenboom, 1969. Malignant hyperthermia syndrome in pigs. Neth. J. Vet. Sci. 2:155-160.

Topel, D.G., E.J. Bicknell, K.S. Preston, L.L. Christian and C.Y. Matsushima, 1968. Porcine stress syndrome. Mod. Vet. Practice 49:40-41, 59-60.

IN: Evaluation and control of meat quality in pigs. Proc. CEC-Seminar, Nov. 21-25, 1985, Dublin (in press).
Rapporteurs: G. Eikelenboom, K. O. Honikel, P. McGloughlin, and G. Monin.

See also papers from the Annual Meetings of EAAP:

21st in Gödöllö, 1970
22nd in Versailles, 1971
23rd in Verona, 1972
24th in Vienna, 1973
25th in Copenhagen, 1974
28th in Brussels, 1977
European Pig Testing Conference, Harrogate, 1979
30th in Harrogate, 1979
31st in Munich, 1980
34th in Madrid, 1983
36th in Halkidiki, 1985