# GENETICS OF MEAT QUALITY CHARACTERISTICS - AUSTRALIAN WORK

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## Introduction

Genetic improvement of animals is a long term process and breeding programmes need to consider aspects that are of importance in the future. In addition to cost-effective pig production, factors that affect marketing of pork will become increasingly important. One important factor in marketing of pork is leanness. Consumers prefer lean meat for health reasons. This is taken into account in today's payment system which is based on weight, with backfat used as an indirect measurement for leanness of pork. However, due to an antagonism between leanness and meat quality, selection for leanness increases the incidence of meat quality deficiencies.

In Australia, genetic improvement of pork quality has so far only been achieved by selection against stress susceptibility using the halothane gene. Studies in Europe have shown that in the absence of the Halothane gene, meat quality characteristics still have a genetic variation of 20% which could be used in a breeding programme (de Vries, *et al*., 1994). A project was funded by PRDC (UNE17P) to evaluate meat quality characteristics. The estimation of genetic parameters of meat quality traits in Australian pigs is a first step to incorporate meat quality into a breeding programme.

## Background information on PSE and DFD meat

Pale, soft and exudative (PSE) meat is mainly found in pigs that have been selected for rapid and efficient growth, leanness and conformation. These types of animals show the porcine stress syndrome more frequently, which is characterized by muscle tremor, an increased respiratory rate, systemic acidosis and a rise in body temperature. This syndrome can cause death of affected animals in stress situations and is therefore of importance to the producer, but also leads to PSE meat. Characteristics of PSE meat are rapid glycolysis, which leads to a high lactic acid concentration in the muscle before and shortly after slaughter. This causes a rapid pH decline after slaughter which in conjunction with high temperature results in the denaturation of muscle proteins and membrane leakage, which induces a pale appearance and high drip loss.

Dark, firm and dry (DFD) meat is induced in animals that have been subjected to exhaustive exercise or prolonged stress before slaughter, leading to a glycogen deficiency within the muscle. The amount of lactic acid produced by glycolysis depends on the amount of available glycogen, so the final pH of DFD meat remains high. This causes physical characteristics such as dark colour and high water holding capacity. An additional undesired property of DFD meat is its sticky surface which contributes to low shelf life, causing problems in marketing DFD meat on export markets. Threshold values of different meat quality characteristics for classification of PSE and DFD meat are listed in Table 1.

Table 1. Threshold values for different meat quality characteristics used to classify PSE and DFD meat

| **Characteristic** | **PSE - meat** | **DFD - meat** |
|---|---|---|
| pH at 45 minutes p.m. | <6.0 | |
| pH at 24 hours p.m. | | >6.2 |
| colour (L-value) | >57 | <47 |
| drip loss percentage | >4.0 | <0.5 |

## Genetic parameters for Australian pigs

### Project

To achieve information about genetic parameters for meat quality traits and their relationship with other economically important traits, a project was set up by AGBU in cooperation with Bunge Meat Industries. The project started in July 1992 when the first piglets were born. Two male piglets were randomly chosen from litters of Large White, Landrace and Duroc sows, leading to weekly batches of 30 to 40 pigs for data collection. Data recording was completed in June 1995, resulting in a data set of nearly 5000 animals tagged at the age of three weeks. However, due to loss of earmarks during the growing period and especially within the abattoir only 3600 animals could be identified, having production, carcase and meat quality traits available.

### Data

Information about meat quality traits was obtained through a series of measurements. The first measurement taken was the pH of the longissimus dorsi muscle measured 45 minutes after slaughter, giving a first indication of PSE meat. The pH of the longissimus dorsi muscle was measured again on the second day 24 hours later, which gives information about DFD meat. Furthermore the colour of the longissimus dorsi muscle was measured with the Minolta Chromamometer at the same time. The recorded measure is the L-value which has a scale from 0 to 100, with lower numbers reflecting darker meat and higher values reflecting paler meat. Drip loss, an economically important trait, was obtained by placing a 60 to 100 gram sample of the longissimus dorsi muscle in a plastic bag and hanging this plastic bag for further 24 hours. The weight loss during this time gives a measurement of the drip loss.

### Analysis

As a first step in data analysis, fixed effects with an influence on meat quality traits have to be identified. Breed and slaughter day were important for the combined data set. The analysis of meat quality traits for Large White and Landrace pigs showed that meat quality traits for these breeds had to be analysed separately. The number of animals per slaughter day for each breed was not sufficient to give a reliable estimate of the slaughter day effect. It was therefore decided to estimate this effect from a combined analysis of Large White and Landrace pigs. The solutions for the slaughter day obtained from this analysis were then used to pre-adjust meat quality traits. The pre-adjusted meat quality traits were then analysed for Large White and Landrace pigs separately. Variance components were estimated using a restricted maximum likelihood procedure applying an animal model, with the animal breeding value being the only random effect.

### Influence of environmental effects

Putting slaughter day into the model is an attempt to take environmental effects of the slaughter procedure into account that have an influence on meat quality traits. The effect of slaughter day accounted for 20 percent of the total variation in colour and drip loss and accounted for 40 percent of the total variation in pH measurements at 45 minutes and 24 hours after slaughter. This shows that pH measurements are more sensitive to differences in slaughter and measurement procedures than the other two measurements. These environmental effects consists of weather conditions as well as handling and transport of the animals and differences in lairage time before slaughter. Additionally differences between slaughter days might arise from varying stunning, slaughter and chilling procedures. Finally each measurement is dependent on the accuracy of the operator and the equipment itself.

## Genetic variation of meat quality characteristics

Results from the single trait analysis along with the number of records per trait and raw standard deviations are presented in Table 2 for Large White pigs and in Table 3 for Landrace pigs. The colour and the drip loss of the longissimus dorsi muscle show moderate heritabilities with values of 0.15 for colour and 0.20 for drip loss percentage in Large White pigs. The two pH measurements were less heritable with estimates of 0.11 for the pH measured 45 minutes after slaughter and 0.09 for the pH measured 24 hours post mortem. Estimates of heritabilities were higher in Landrace pigs for each trait. The colour of the longissimus dorsi muscle shows a heritability of 0.35. Drip loss percentage is highly heritable for Landrace pigs with a value of 0.47. Lower heritabilities for pH measurements are also existent for this breed with a value of 0.16 for both pH measurements at 45 minutes and at 24 hours.

Table 2: Number of records, raw standard deviations (s.d.), heritabilities ($h^2$) with standard errors (s.e. of h2), additive genetic variance ($\sigma^2_a$) and environmental variance ($\sigma^2_e$) for meat quality traits in Large White pigs

| Trait | No of records | s.d. | $h^2$ | s.e. of $h^2$ | $\sigma^2_a$ | $\sigma^2_e$ |
|---|---|---|---|---|---|---|
| Colour of LD muscle | 1354 | 4.95 | 0.15 | 0.06 | 2.66 | 14.69 |
| drip loss percentage | 1441 | 1.89 | 0.20 | 0.07 | 0.64 | 2.62 |
| pH at 45 minutes p.m. | 1188 | 0.46 | 0.11 | 0.04 | 0.015 | 0.123 |
| pH at 24 hours p.m. | 1307 | 0.27 | 0.09 | 0.04 | 0.003 | 0.031 |

Table 3: Number of records, raw standard deviations (s.d.), heritabilities ($h^2$) with standard errors (s.e. of $h^2$), additive genetic variance ($\sigma^2_a$) and environmental variance ($\sigma^2_e$) for meat quality traits in Landrace pigs

| Trait | No of records | s.d. | $h^2$ | s.e. of $h^2$ | $\sigma^2_a$ | $\sigma^2_e$ |
|---|---|---|---|---|---|---|
| Colour of LD muscle | 1181 | 4.93 | 0.35 | 0.08 | 7.39 | 13.80 |
| drip loss percentage | 1264 | 1.86 | 0.47 | 0.11 | 2.00 | 2.24 |
| pH at 45 minutes p.m. | 1033 | 0.45 | 0.16 | 0.06 | 0.020 | 0.101 |
| pH at 24 hours p.m. | 1172 | 0.25 | 0.16 | 0.06 | 0.006 | 0.033 |

## Relationships between meat quality traits

Genetic, environmental and phenotypic relationships between meat quality traits are presented in Table 4 for Large White pigs. The genetic correlation between colour of the longissimus dorsi muscle and drip loss percentage is of low magnitude and not significant different from zero. These two traits show a stronger environmental relationship which is shown through the moderate environmental correlation. The genetic correlations between colour and pH measurements are negative, showing the relationship of a lighter colour with a lower pH. This relationship is stronger between colour and pH measured 24 hours after slaughter, then between colour and pH measured 45 minutes post mortem. The genetic correlations between drip loss percentage and pH measurements are contradictory. Drip loss percentage shows a genetic correlation of 0.20 to pH recorded 45 minutes after slaughter and -0.30 to pH measured 24 hours after slaughter. The positive correlation between drip loss percentage and pH at 45 minutes cannot be explained physiologically but is not significantly different from zero taking the high standard error of this estimate into account. The two pH measurements at 45 minutes after slaughter and 24 hours after slaughter are lowly genetically associated.

Table 4: Genetic (first line above diagonal), environmental (second line above diagonal), and phenotypic correlations (below diagonal) for meat quality traits in Large White pigs

| | CLD[1] | DLP | | pH45 | | pH24 | |
|---|---|---|---|---|---|---|---|
| **CLD** | | 0.12<br>0.57 | (0.26)* | -0.13<br>-0.17 | (0.26) | -0.82<br>-0.49 | (0.10) |
| **DLP** | 0.49 | | | 0.20<br>-0.24 | (0.24) | -0.30<br>-0.34 | (0.25) |
| **pH45** | -0.17 | -0.17 | | | | -0.11<br>0.15 | (0.28) |
| **pH24** | -0.53 | -0.33 | | 0.12 | | | |

* approximate standard errors of genetic correlations in brackets
[1] Abbreviations:
CLD - Colour of longissimus dorsi muscle
DLP - Drip loss percentage
pH45 - pH measured at 45 minutes after slaughter
pH24 - pH measured 24 hours after slaughter

Table 5 summarizes the genetic, environmental and phenotypic relationships between meat quality traits for Landrace pigs. The colour measurement shows a high positive correlation to drip loss percentage and a high negative correlation to pH measured at 24 hours after slaughter. A light colour is therefore strongly associated with a high drip loss percentage and a low pH at 24 hours in Landrace pigs. The genetic association between colour and pH measured shortly after slaughter is moderately negative. The environmental correlations between colour and the other meat quality characteristics follow the genetic relationships with a lower magnitude. A high drip loss is genetically associated with a low pH. This relationship exists for both pH measurements at 45 minutes and at 24 hours. The environmental association between drip loss percentage and pH measured at 45 minutes after slaughter is slightly positive, showing the different influence of environmental effects on these two traits measured at the slaughter day itself and the following day. The two pH measurements show no significant genetic and environmental association.

Table 5: Genetic (first line above diagonal), environmental (second line above diagonal), and phenotypic correlations (below diagonal) for meat quality traits in Landrace pigs

| | CLD[1] | DLP | | pH45 | | pH24 | |
|---|---|---|---|---|---|---|---|
| **CLD** | | 0.81<br>0.31 | (0.06)* | -0.28<br>-0.14 | (0.19)* | -0.76<br>-0.47 | (0.09)* |
| **DLP** | 0.53 | | | -0.54<br>0.06 | (0.15)* | -0.65<br>-0.22 | (0.12)* |
| **pH45** | -0.17 | -0.20 | | | | -0.03<br>v 0.05 | (0.26)* |
| **pH24** | -0.53 | -0.35 | | 0.04 | | | |

* approximate standard errors of genetic correlations in brackets
[1] for abbreviations see Table 4

Although most of the genetic correlations for Large White pigs are not significantly different from zero, they are consistent with results for Landrace pigs and reflect the different PSE and DFD characteristics. An exception is the positive genetic correlation between drip loss percentage and pH measured at 45 minutes. This genetic correlation indicates possible problems in obtaining reliable pH measurements at 45 minutes.

### Discussion

Meat quality traits are influenced by genetic and environmental effects. The environmental effects account for 20 percent of the total variation in colour and drip loss percentage. This result is consistent with those reported in a Dutch study (de Vries, *et al*., 1994). The pH measurements are more strongly influenced by environmental effects. Part of this environmental effect might be due to the accuracy of the operator and the sensitivity of the equipment to an exact calibration. The pH measurement is temperature dependent and an additional measurement of the temperature while recording pH could improve the accuracy of this measurement.

Heritabilities for meat quality traits are higher for Landrace pigs than Large White pigs. An Australian study (McPhee, 1979) found no positive halothane reactors for Australian Large White pigs and a level of 5 percent of positive reactors for Australian Landrace pigs. The influence of the Halothane gene on meat quality is well known and could partly explain the differences in heritabilities found in this study for Large White and Landrace pigs. The estimates of heritabilities for meat quality traits in Large White pigs are slightly lower than literature values estimated recently for halothane negative pigs (de Vries, *et al*., 1994; Hovenier *et al*., 1992). The range of these literature values was 0.15 to 0.30 for meat quality traits. Heritabilities for colour of the longissimus dorsi muscle and drip loss percentage in Landrace pigs were higher then the range of literature values.

The genetic associations between meat quality characteristics reflect the characteristics of PSE and DFD meat. A light colour is associated with a high drip loss percentage and a low pH. These relationships are stronger for Landrace pigs than for Large White pigs.

The most economically important meat quality trait is drip loss percentage. Its measurement is labour intensive and is only available two days after slaughter, which is not feasible under practical conditions. Comparing the different meat quality traits, pH measured at 45 minutes has the advantage of being available soon after slaughter but at the same time has the disadvantage of a lower heritability and is highly influenced by environmental effects. The colour measurement is not as much influenced by environmental effects but is only available on the second day after slaughter.

## Conclusions

- Meat quality traits are influenced by both, environmental and genetic effects. A genetic improvement of meat quality characteristics is therefore possible through the incorporation of meat quality traits into the breeding programme. This improvement then has to be accompanied by optimal production and slaughter conditions.
- Genetic variation of meat quality traits differs between breeds. Meat quality traits are lowly heritable for Large White pigs and moderately to highly heritable for Landrace pigs.
- The genetic association between meat quality traits reflect different characteristics of PSE and DFD meat. The genetic correlations are of higher magnitude for Landrace pigs than for Large White pigs.
- Drip loss percentage is the trait with the highest economical importance. pH measured at 45 minutes is a first indication of meat quality deficiencies but is highly influenced by environmental effects. A more reliable measurement of ultimate meat quality is the L-value of the Minolta Chromamometer, which was obtained 24 hours after slaughter.

## References

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