Development of a System for Recording, Evaluation and Improvement of Pork Quality

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Alberta Livestock and Industry Development Fund

Final Report

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Project title: Development of a System for Recording, Evaluation and Improvement of Pork Quality

ALIDF Application number: 2004L022R

Name of the Applicant: Alfred Wahl, P.Ag.

Project team:

Western Swine Testing Assocation (WSTA):

- Alfred Wahl, Project Co-ordinator
- Wim Van Berkel, General Manager

Canadian Centre for Swine Improvement (CCSI)

- Dr. Pramod Mathur, Chief Geneticist
- Laurence Maignel, Geneticist
- Dr. Yuefu Liu, Geneticist
- Brian Sullivan, General Manager

AAFC Research Centre, Lacombe

- Dr. Austin Murray, Research Scientist

Laboratory Services Division, University of Guelph

- Dr. Shu Chen, Professor

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- Acadia Breeders Ltd.
- Five Lakes Farms Ltd.
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- Jakubec Farms
- Neufeld Frams
- PEAK Swine Genetics
- Rose Briar Farm

Thanks are due to Olymel plant in Red Deer Alberta for their support in processing the pigs from this project and extracting the loins that were used in the meat quality evaluations.

The support from the Alberta Livestock Industry Develeopment Fund (ALIDF) is gratefully acknowledged. It would not have been possible to carry out the project without their financial contributions

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1. Abstract

Meat quality is an important element of the pork value chain. There is a need to maintain and possibly improve the pork quality to a level that large volumes of high quality pork are readily available to meet the market needs.

The quality of pork is determined by a number of factors such as pre-slaughter handling, management or production level and genetics. Genetics is not the only factor determining the pork quality but it is an important one. Genetic improvements are permanent and are cost effective. The relatively high heritability of meat quality traits offers greater opportunities for genetic improvement. The use of Candidate genes like HFABP and IGF2 provide additional opportunities to improve intra-muscular fat (marbling), leanness and uniformity that are considered very important to produce value added products for domestic and especially the export markets.

As a result of this project, a system for recording of meat quality traits on pigs from breeders or producers farms has been developed. The pigs from these farms can now be sent routinely for meat quality evaluations through the packing plants and genetic evaluations or estimated breeding values (EBVs) can be obtained. In addition, EBVs can be obtained on their littermates and other relatives from well connected herds. These EBVs can be used to to identify the best breeding animals for a long term and permanent improvement in meat quality traits.

One of the major requrements for genetic evaluations is to have the meat quality records on individual animals, rather than for a group or lot. However, this becomes a practical problem as it is difficult to keep track of the carcass cuts of a pig when it goes through the fast processing chain of the packing plants. A DNA based tracking system was used in this project to solve the problem and match the loin samples to the pigs they came from. This system has been tested, is working well now and can be used for future tracking and genetic evaluations.

The project has identified large varitaions in the meat quality of pigs going to slaughter. There is a need to increase the uniformity of carcass cuts as desired by the packers, retailers and consumers. This can be accomplished partly through better management and pre-slaughter handling and partly through the use of major genes like IGF2. At the same time the large variation also provides opportunities for selection of superior breeding stock and thereby improving the meat quality of the market hogs.

In addition, the project has provided useful information regarding the frequency of the IGF2 gene for leanness in Canadian pigs poulations and estimates of its effects. These DNA based tests can be used by breeders and producers to produce market hogs with desired level of leanness.

The project has laid the foundation for recording, evaluation and improvement of meat quality traits. The breeders, producers and swine industry at large can now take advantage of these results to provide better quality pork to consumers.

2. Background information

The purpose of this project is to develop a system for recording, evaluation and improvement of pork quality. Genetic improvement requires collecting meat quality data on pigs that are sibs or close relatives of pigs tested in nucleus herds to develop a genetic evaluation system. These evaluations are then used to select and produce terminal sires for producing market hogs in commercial herds. The quality of pork produced by the hogs depends upon the interaction between the improved genetics and management factors. Finally the quality in the slaughter plants needs to be monitored and used in the evaluations.

3. Project objectives

- Develop a standardized system for data collection from slaughter plants, commercial pigs and nucleus herds
- Evaluate the usefulness of candidate genes and markers
- Develop a system for genetic evaluation and selection
- Evaluate the effects of genetics and other management practices used by producers
- Develop a system for monitoring to maintain and enhance the quality of pork produced

4. Deliverables

- Standard procedures for measurement of important meat quality traits
- Genetic evaluation and selection methods
- Methods for optimum use of improved genetics by producers and packers
- Internet based web application for recording, evaluation and reporting
- DNA tests results for specific genes and markers
- Reports and extension articles

5. Project design and methodology

An outline of the project design is given in Appenidx 1.

The project was implemented in the following phases:

1) Development of a system for recording of meat quality traits
2) Development of a system for genetic evaluation and selection

Phase 1: Development of a system for recording of meat quality traits

During this phase, necessary data on carcass and muscle quality traits were collected, stored in the CCSI's national database and have been made available through interactive web applications.

The main activities were as follows:

- There were 9 partcipating breeding farms. They sent a total of 766 pigs for meat quality evaluations. These pigs were Duroc, Lacombe, Yorkshire and Landrace breeds. A majority of the slaughterd pigs were sibs of the pigs that were tested for live animal ultrasound and were available for breeding.
- The pigs were slaughtered at the Olymel plant in Red Deer. Commercial loins were removed from the left side of the carcasses and sent to the Lacombe Research Centre for detailed measurement of meat quality traits.
- The loins were evaluated for a number of muscle quality traits including loin colour, marbling, pH and drip loss. At the same time carcass quality traits such as grading backfat, lean depth and loin eye area were also recorded.
- DNA sample were collected from each pig prior to slaughter and from the loins. The loin samples were matched to the blood samples from pigs for their individual identification. The DNA was also used for IGF2 gene tests and the remaining DNA has been retained for further research.

Phase 2: Development of a genetic evaluation system

- A system for routine genetic evaluations for meat quality traits has been developed. New adjustment factors and prediction equations have been developed to accommodate data when some important information such as carcass weights is missing. The genetic evaluations can now be provided for pigs evaluated for meat quality and their relatives from well connected herds

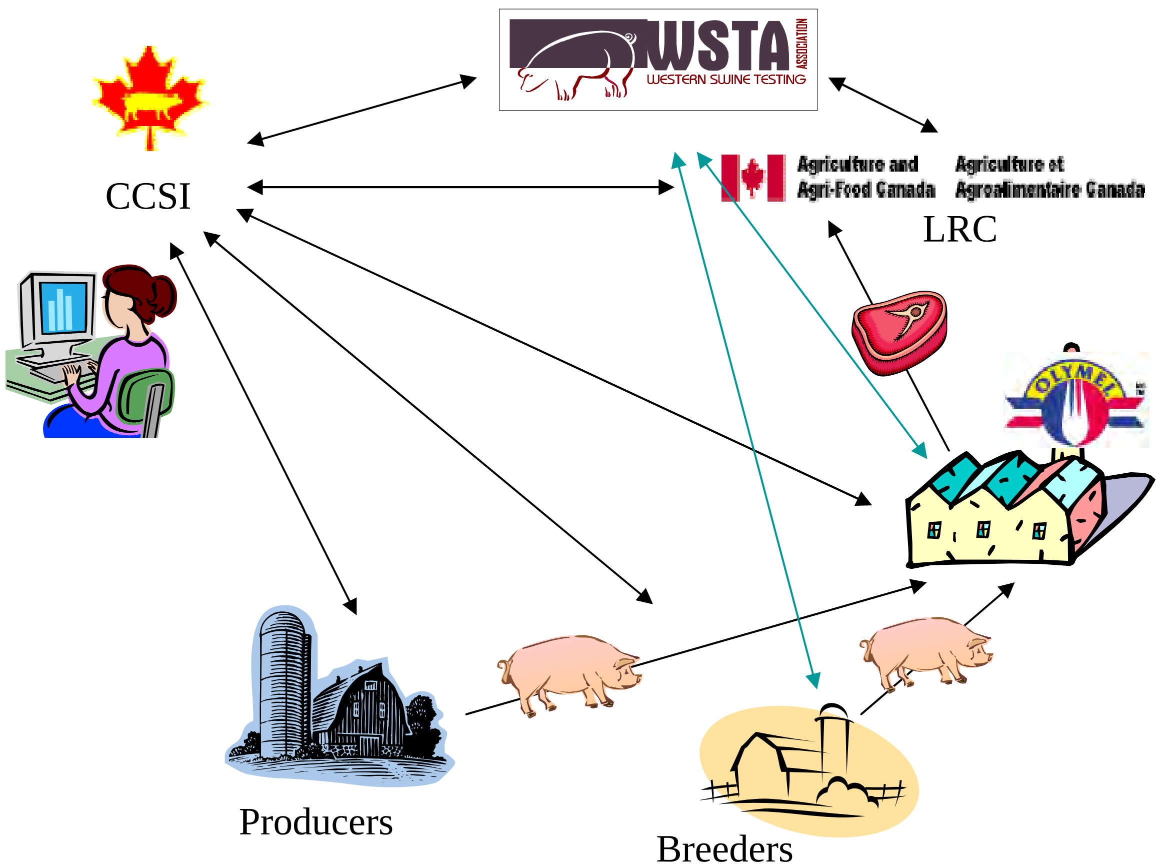
6. Implications of the project with regard to the improvement of Alberta livestock industry

The project has provided tools to the breeding sector for selection of pigs that are not only fast growing and efficient but are also capable of producing superior quality pork. This has helped to increase their competitiveness and ability to meet the needs of their customers. The producers will now have access to improved genetics to produce market hogs that will provide them maximum value on the Olywest payment grid.

The project has also provided important information on the use of important genes like IGF2. This gene offers the possibilities to identify boars and sows that will produce market hogs that are leaner or fatter according to the desired range for the packers, retailers and consumers.

Appendix 1

Project design



Appendix 2

Standard Procedures for Measurement of Meat and Carcass Quality Traits

Meat quality Standards Committee
Draft, May, 2005

1. INTRODUCTION

The main purpose of this document is to review the standards for recording meat quality traits. Standards for evaluation of meat and carcass quality traits have been developed by various organizations in Canada and are being used in different regions. The procedures recommended by the CCSI for use in the genetic evaluations need to be reviewed. These procedures can then be used by the research and service labs that would do meat and carcass quality evaluations for breeders, producers, packers and others in the Canadian swine industry.

2. CARCASS QUALITY

2.1 Grading fat depth (mm), muscle depth (mm) and lean yield (%)

Grading fat depth (mm) and grading muscle depth (mm) should be measured at the $3^{rd}/4^{th}$ last rib, 7 cm off the midline on the left side of the split, hot carcass. Although the Hennessey Grading Probe, the Destron PG-100 and the Danish Fat-O-Meater have been approved for use in Canada, the Destron is used almost exclusively, and therefore it is recommended. Grading lean yield is to be obtained using the currently recommended grading equation.

2.2 Hot carcass weight (kg)

To be measured as the dressed (eviscerated) hot weight of the carcass, including the head (with tongue), leaf lard, kidneys and front and hind feet.

2.3 Cold half-carcass weight (kg)

To be measured as the cold (24 hours post-mortem) weight of the left side not including the head, kidneys or leaf lard, but including front and hind feet.

2.4 Carcass length (cm)

To be measured on the cold carcass from the cranial edge of the first rib to the anterior tip of the aitchbone using:-
●a Foster Gauge Ruler, or
●a measuring tape.

2.5 Weight of primal shoulder (kg)

To be measured as a primal-cut shoulder (bone in, skin and fat on). Shoulder is removed by cutting at right angles to the back through the joint between the 2nd and 3rd thoracic vertebrae. Foot is removed by a cut through wrist (carpal) joint. Jowl is removed by a straight cut parallel to rib side, leaving half moon muscle shoulder

2.6 Weight of primal ham (kg)

To be measured as a primal-cut ham (bone in, skin and fat on). Ham is removed from the side by making a straight cut perpendicular to outer skin surface at a point 50-60 mm anterior to the aitch bone, just missing the juncture of the tail bone and aitch bone tip (approx 3-6 mm). The hind foot is removed by making a straight cut through the hock joint to expose the heel bone. Tail removed from the underside of the tail bone leaving a neat ham surface.

2.7 Weight of primal loin (kg)

To be measured as a primal-cut loin (bone-in, skin and fat on). Loin is removed from the belly by cutting from a point on the rib perpendicularly down from the ventral side of the thoracic vertebrae, where shoulder was removed, to the point about 25 mm from the tenderloin at the ham end. Cut from the belly to leave a 12 cm maximum rib measured from backbone

2.8 Weight of primal belly (kg)

To be measured as a primal-cut belly (bone in, skin and fat on). Belly is the portion of the side remaining after removal of ham, shoulder and loin

2.9 Maximum belly thickness (mm)

To be measured at least 24 hours post-mortem as the maximum thickness of the cross-section of the square-cut, skin-on belly. The measurement is taken at the 3/4 last rib:-

- with a calliper, or
- on a cross-section of the belly, either directly with a ruler or from a digital image using computer software.

2.10 Minimum belly thickness (mm)

To be measured at least 24 hours post-mortem as the minimum thickness of the cross-section of the square-cut, skin-on belly. The measurement is taken at the 3/4 last rib:-

- with a calliper, or

●on a cross-section of the belly, either with a ruler or from a digital image using computer software.

2.11 Loin eye area (cm^2)

To be measured on a cold, ribbed carcass or loin at the 3rd/4th last rib by:-
●plastic grid (Grid AS-235e, Iowa State University), or
●tracing the perimeter of the longissimus muscle (loin eye) on acetate paper and determining the area using a planimeter or appropriate software program, or
●tracing the perimeter of the longissimus muscle (loin-eye) on a digital camera or scanner image using appropriate computer software.

2.12 Loin backfat depth (mm) and loin-eye depth (mm)

To be measured on the left side of a cold, ribbed carcass or left loin at the $3^{rd}/4^{th}$ last rib interface, perpendicular to and at the middle of a line bisecting the loin-eye along its longest axis**,** by:-
●ruler, or
●digital camera or scanner image with appropriate computer software.

3. MEAT QUALITY

3.1 Subjective loin marbling score

To be evaluated on longissimus muscle (loin-eye) of a cold, ribbed carcass or loin at the $3^{rd}/4^{th}$ last rib (between 20 and 40 minutes after exposing the muscle surface) using NPPC (National Pork Producers Council) Marbling Standards.

3.2 Subjective loin colour score

To be evaluated on a cold, ribbed carcass or loin at the $3^{rd}/4^{th}$ last rib (at a constant time between 20 and 40 minutes after cutting) using:-
●NPPC Color Standards - score of 1 to 6 with half-point increments, or
●Japanese Color Standards - score of 1 to 6 with half-point increments.

3.3 Fat hardness

Should be objectively assessed by:-
● durometer (Rex Gauge, Type 00), or
● Bristol Fat Hardness Meter.

The fat hardness is measured on the second fat layer at the $1^{st}/2^{nd}$ rib on the intact carcass and near the $3^{rd}/4^{th}$ last rib on the loin cross-section. A minimum of 3 measurements is recommended to obtain an average value. The temperature of the fat at time of measurement should be specified.

3.4 Loin pH_{24}

To be measured 24 hours post-mortem using a pH meter (with automatic temperature compensation and capable of measuring to an accuracy of 0.01 units) with a spear-type pH electrode (probe). Probe to be inserted:-

- in the cross-section of the longissimus muscle (loin-eye) at or near the $3^{rd}/4^{th}$ last rib interface, or
- on a split carcass, between the ribs by first severing the intercostal muscles, or
- on a split carcass, between the spinous processes by first severing the multifidus and spinalis muscles.

A minimum of 2 measurements is recommended to obtain an average value. The pH meter should be recalibrated each time it is used. The calibration buffers should be at approximately the same temperature as the meat.

3.5 Ham pH_{24}

To be measured 24 hours post-mortem using a pH meter (with automatic temperature compensation and capable of measuring to an accuracy of 0.01 units) with a spear-type pH electrode (probe). Probe to be inserted in:

- the semimembranosus muscle, or
- the gluteus muscle (ham face).

A minimum of 2 measurements are recommended to obtain an average value. The pH meter should be recalibrated each time it is used. The calibration buffers should be at approximately the same temperature as the meat.

3.6 Objective color (Loin)

To be measured using a surface color reflectance meter (eg. Minolta CR300) to determine the L*, a* and b* co-ordinates (illuminant C, observer angle 2°, specular component included) on a cross-section of the longissimus muscle (loin-eye) at or near the $3^{rd}/4^{th}$ last rib 24 hours post-mortem (at a constant time between 20 and 40 minutes after cutting). A minimum of two measurements are recommended with most meter models to obtain a representative value (exception - CR 310 with a measurement diameter of 50 mm).

3.7 Objective color (Ham)

To be measured using a surface color reflectance meter (i.e. Minolta CR300) to determine the L*, a* and b* co-ordinates (illuminant C, observer angle 2°, specular component included). The measurement can be made:-

- on the external surface of the primal-cut ham (gluteus medius muscle), or
- internally on the semimembranosus and/or biceps femoris muscle.

A minimum of two measurements are recommended with most meter models to obtain a representative value (exception - CR310 with a measurement diameter of 50 mm).

3.8 Drip loss – Loin/Ham (%)

To be measured using a 25-mm section of the longissimus muscle (loin-eye) at or near the 3rd/4th last rib or biceps femoris (ham). To be measured gravimetrically as the amount of differential weight loss resulting during storage at a consistent temperature between 1 and 4° C for 48 hours:-

- on a Styrofoam tray containing an absorbent pad and over-wrapped with oxygen-permeable polyvinyl film, or
- in a polyethylene bag.

3.9 Tenderness

To be measured as resistance to shear force using Warner-Bratzler shear force device on a minimum of 4 core samples from the *longissimus dorssi* (loin) or *biceps femoris* (ham). Measurements to be determined perpendicular to the muscle fibres on 1.27 cm core samples after cooling to room temperature

References

1. National Pork Carcass and Meat Quality Evaluations Handbook (1997) http://www.ccsi.ca/Meetings/MQstandards/carcass-standards-procedures.pdf

2. National Pork Carcass and Meat Quality Evaluations Handbook (1997): Pictures http://www.ccsi.ca/Meetings/MQstandards/carcass-standards-procedures-pictures.pdf

3. Canadian Pork Buyer's Manual http://www.canadapork.com/english/pages/frmsts/page05.html

4. Procedures used in the purebred tests at Deschambault Test Station.

5. Procedures recommended by researchers at the Agriculture and Agri-Food Research Centre, Lacombe, Alberta.

Overall statistics and distributions of meat quality traits

1. Introduction

A number of meat quality traits were measured at Lacombe Research Centre on 766 loins sampled from pigs slaughtered at the Olymel plant of Red Deer. The pigs came originally from 9 participating herds in Western Canada. The following is a summary of the overall statistics of the meat quality traits.

2. Material and methods

A description of the traits measured and detailed sites and methods of measurement are given in Appendix 4.

3. Results

The overall statistics are given in table 1.

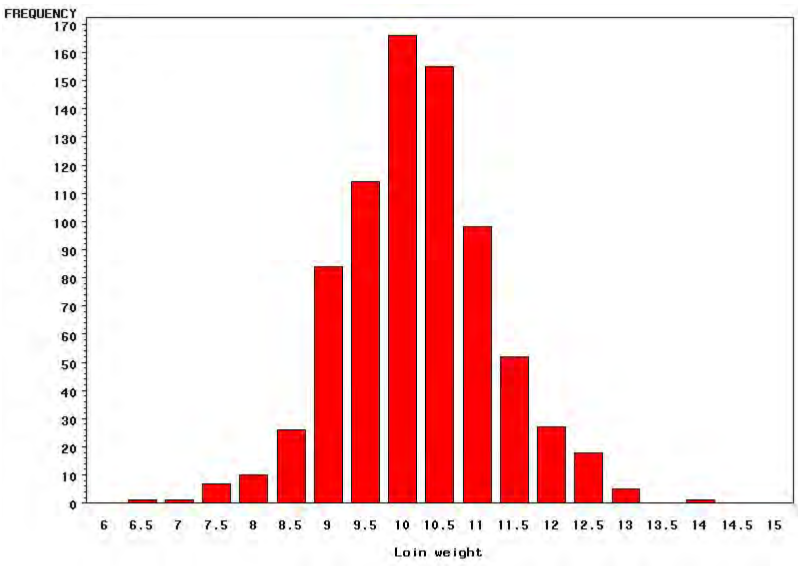
Table 1: Overall statistics for all traits measured on loins (n=766 samples)

Trait	Mean	Std Dev	Minimum	Maximum
Loin Weight (kg)	10.20	1.01	6.28	14.08
Loin Length (cm)	71.47	2.74	63.00	81.00
Backfat Thickness (mm)	15.72	4.42	6.30	32.00
Lean Depth (mm)	62.54	5.93	44.90	83.20
Loin-eye Area (sq cm)	47.45	5.83	29.10	65.80
Backfat Hardness	43.72	12.57	8.20	73.90
Loin-eye Marbling (NPPC)	1.90	0.61	1.00	4.50
Minolta L*	48.59	3.19	40.42	65.29
Minolta a*	7.18	1.20	3.67	11.65
Minolta b*	3.74	1.06	0.82	9.20
Japanese Color Score	3.82	0.70	1.00	6.00
Drip Loss (%)	2.67	1.37	0.60	10.45
Lean Firmness	2.41	0.85	1.00	4.50
Loin pH24	5.62	0.14	5.33	6.24
Loin Moisture (%ww)	72.88	0.15	70.76	74.70
Loin Fat (%ww)	2.21	0.96	0.60	5.79
Loin Protein (%ww)	23.10	0.61	20.21	25.39

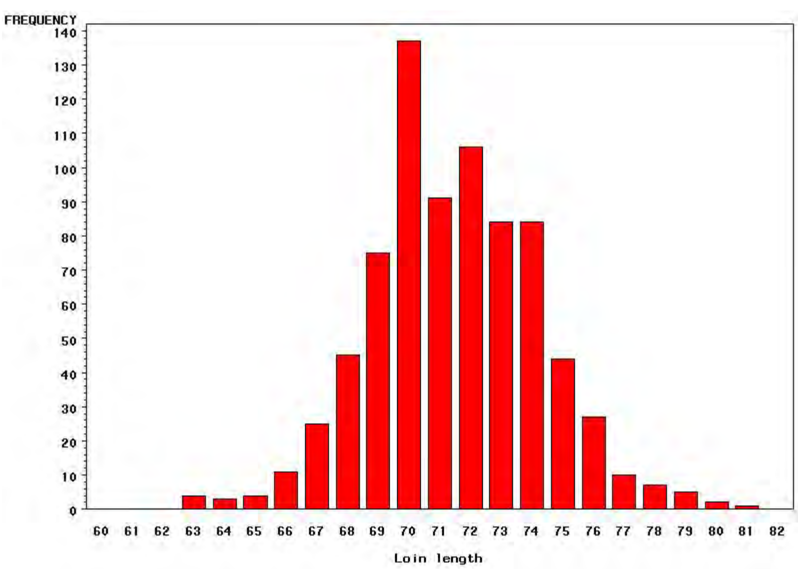
There was a large variation in a majority of the traits. The distributions of the different traits are given in the figures below:

Figure 1: Distributions of meat quality traits in 766 loin samples

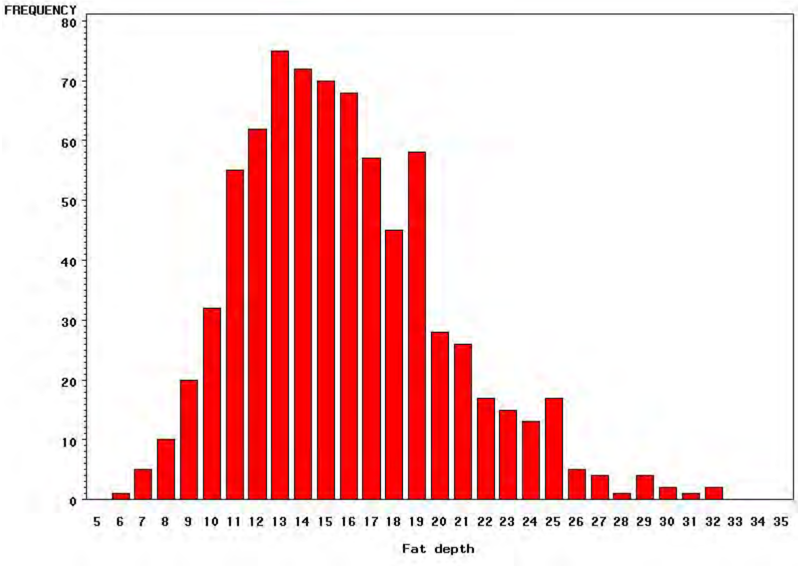
1) Loin weight



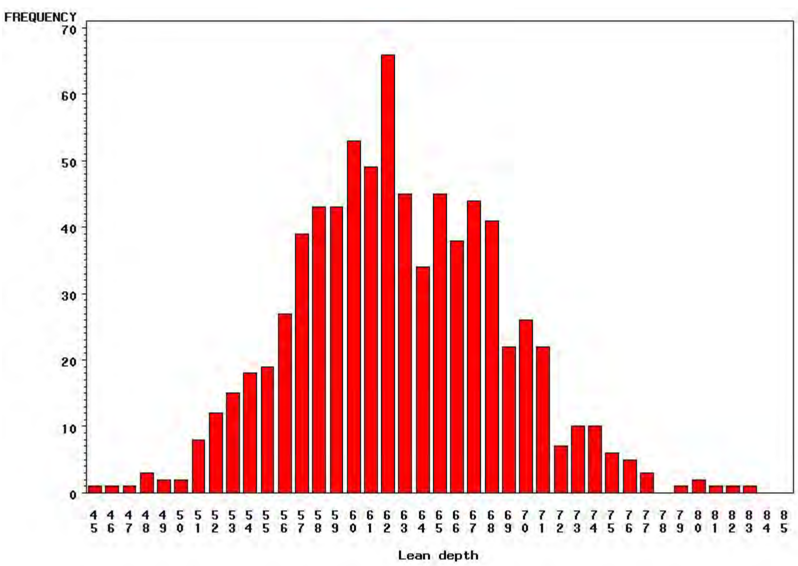
2) Loin length



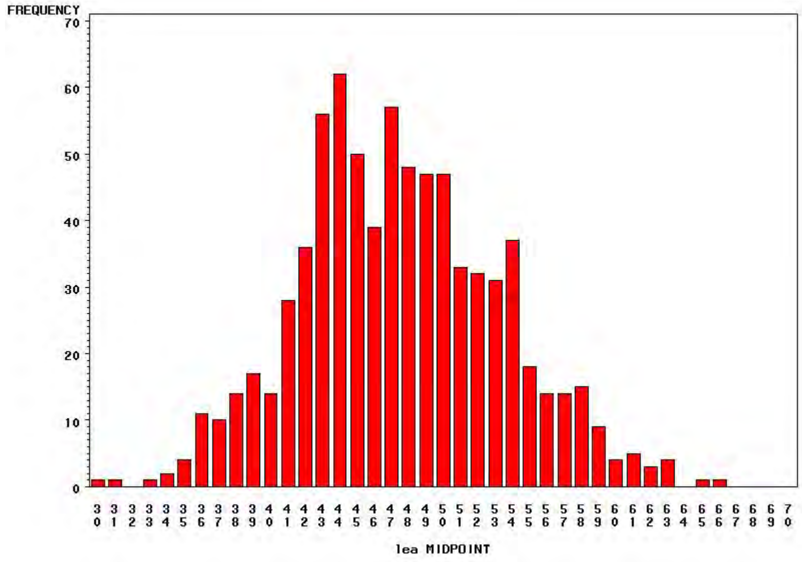
3) Fat depth



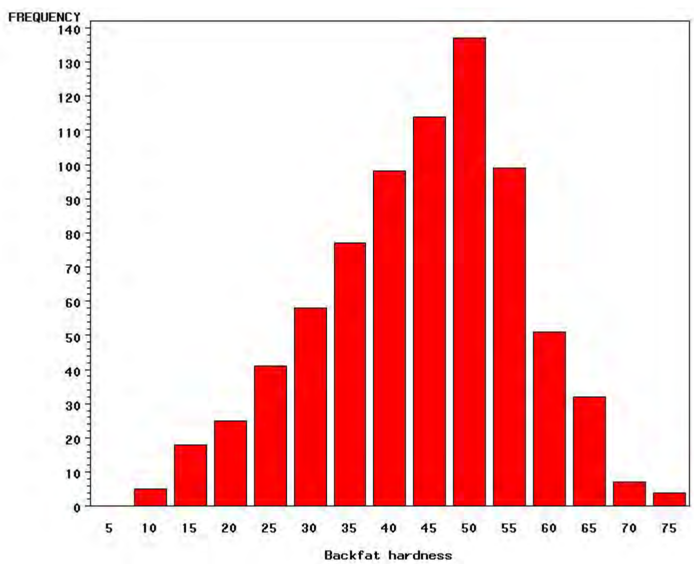
4) Lean depth



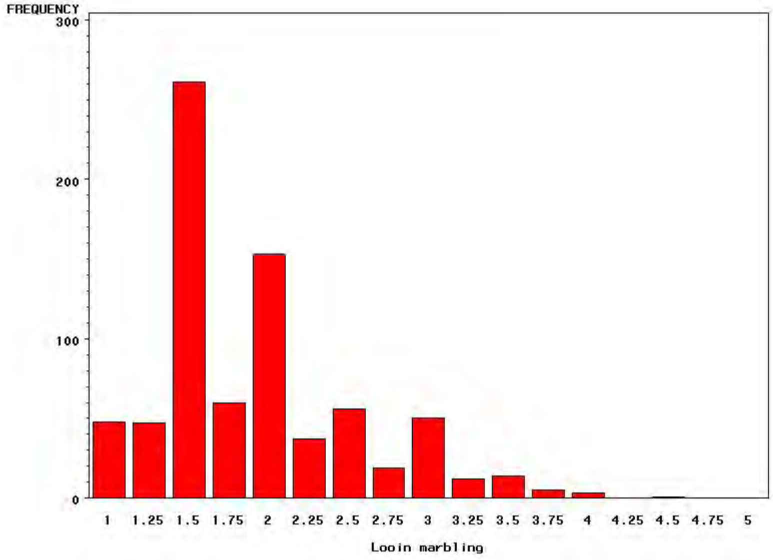
5) Loin eye area (LEA)



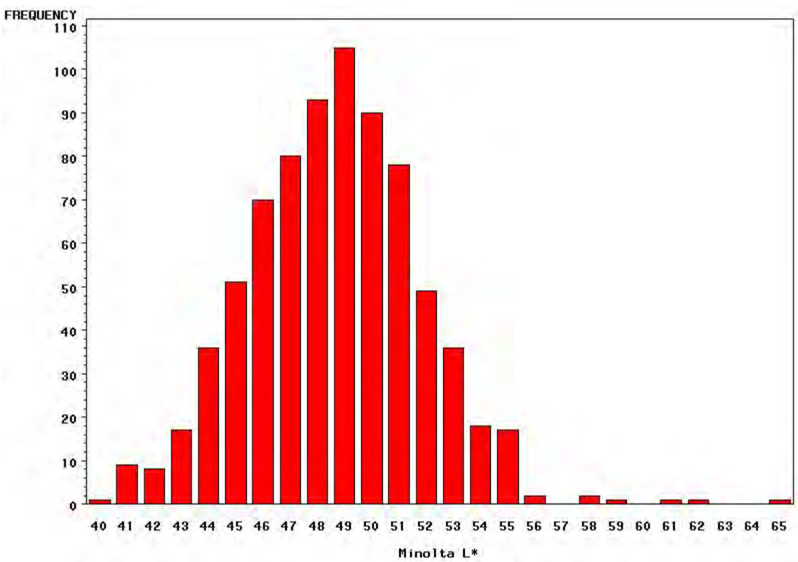
6) Backfat hardness



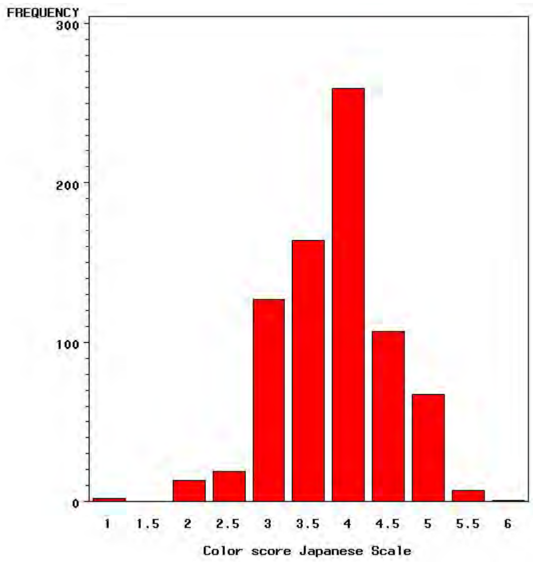
7) Loin marbling



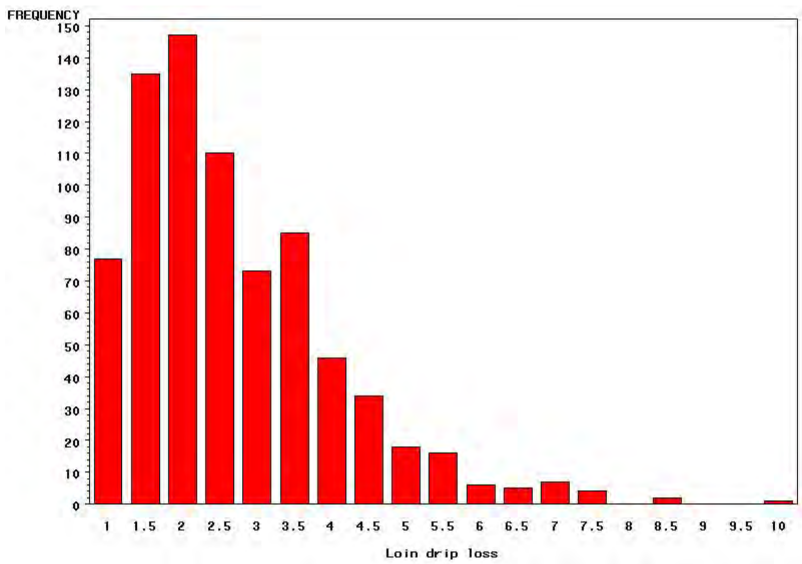
8) Loin color (Minolta L*)



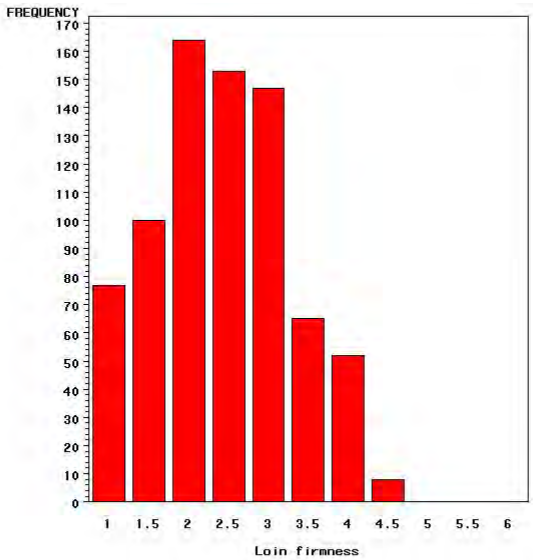
9) Color score (Japanese scale)



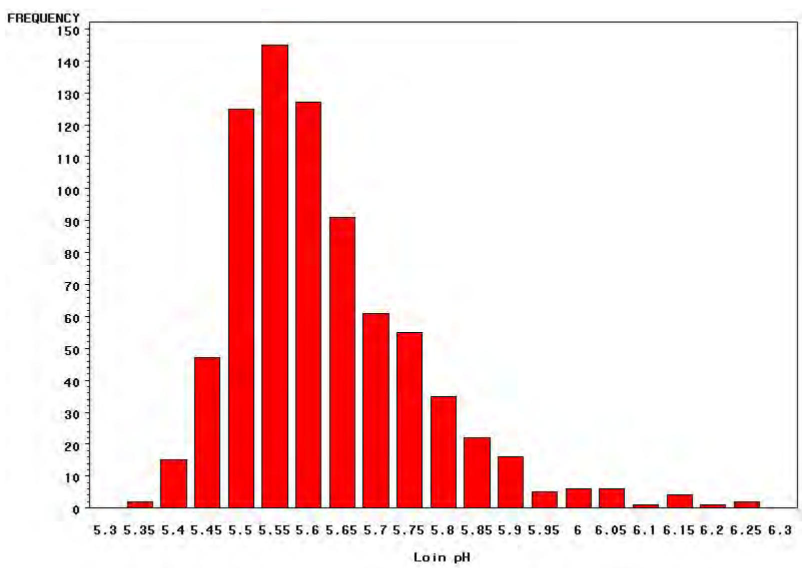
10) Lon drip loss



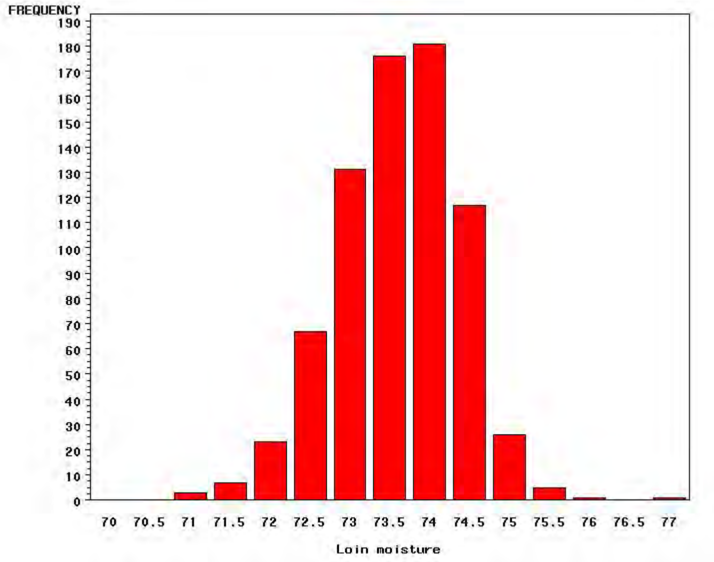
11) Lean firmness



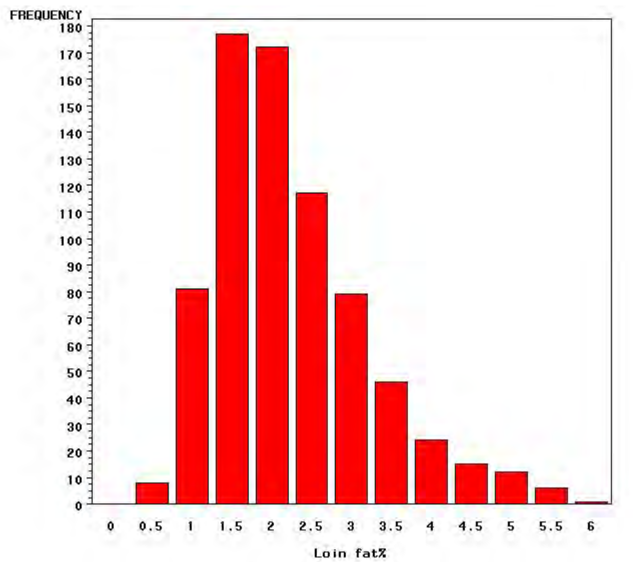
12) Loin pH (24 hours)



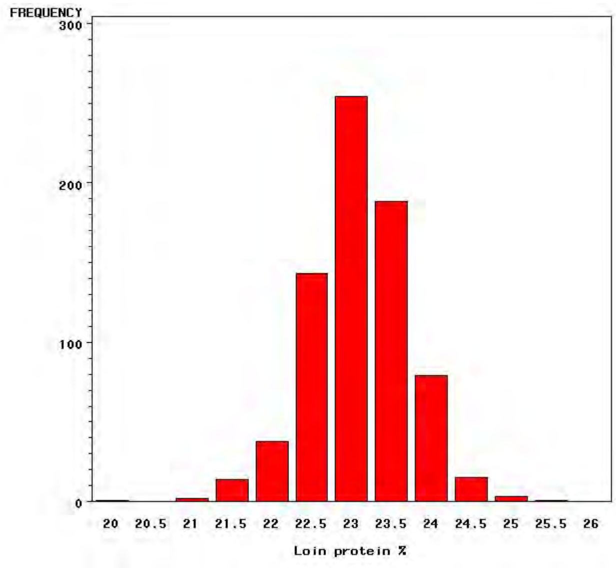
13) Loin moisture (% ww)



14) Loin fat (% ww)



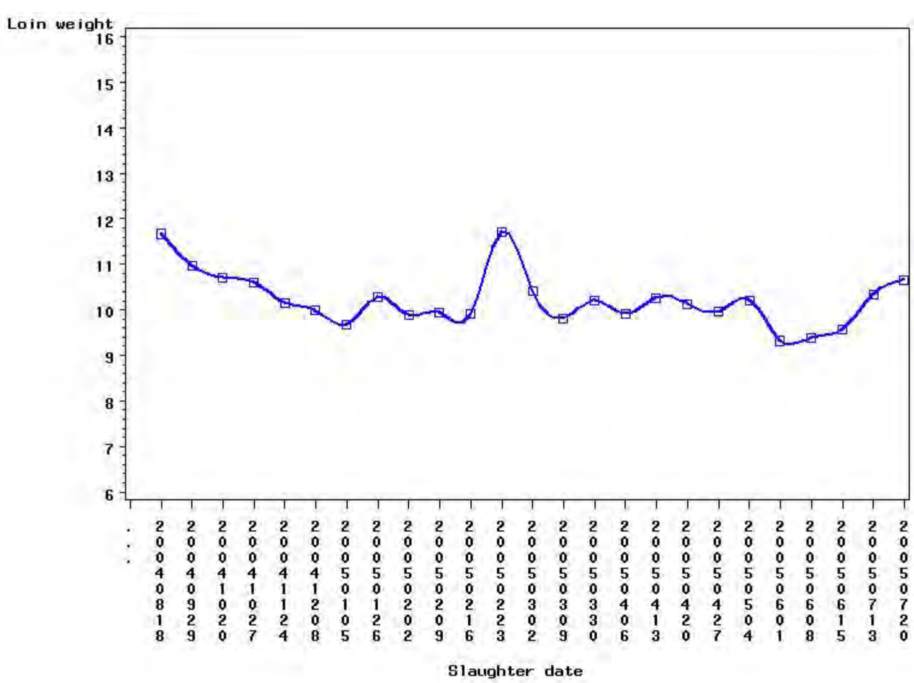
15) Loin protein (% ww)



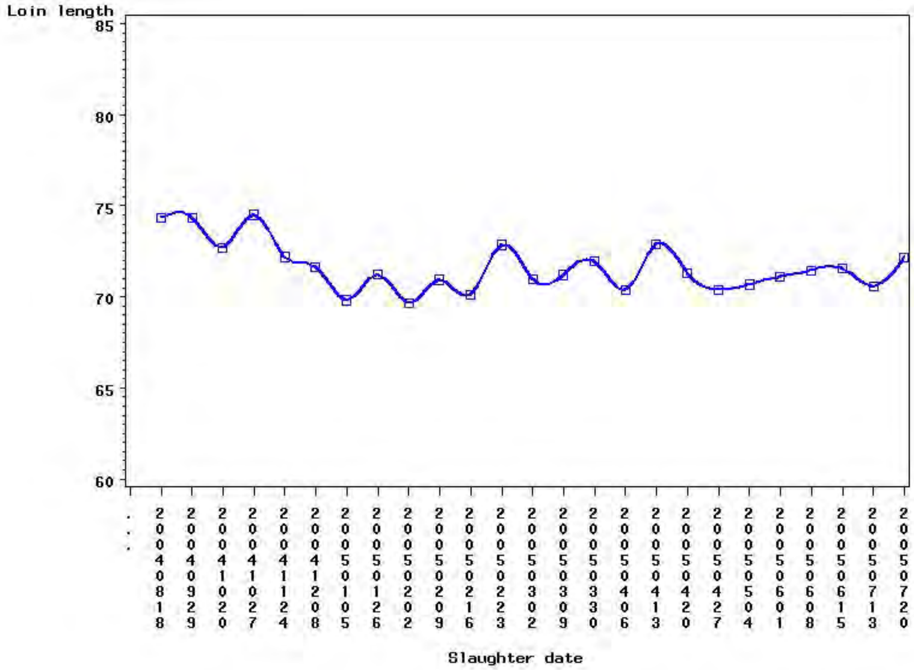
There was also some seasonal variation in various meat quality traits. This is shown in figure 2

<u>Figure 2: Seasonal variations in the meat quality traits</u>

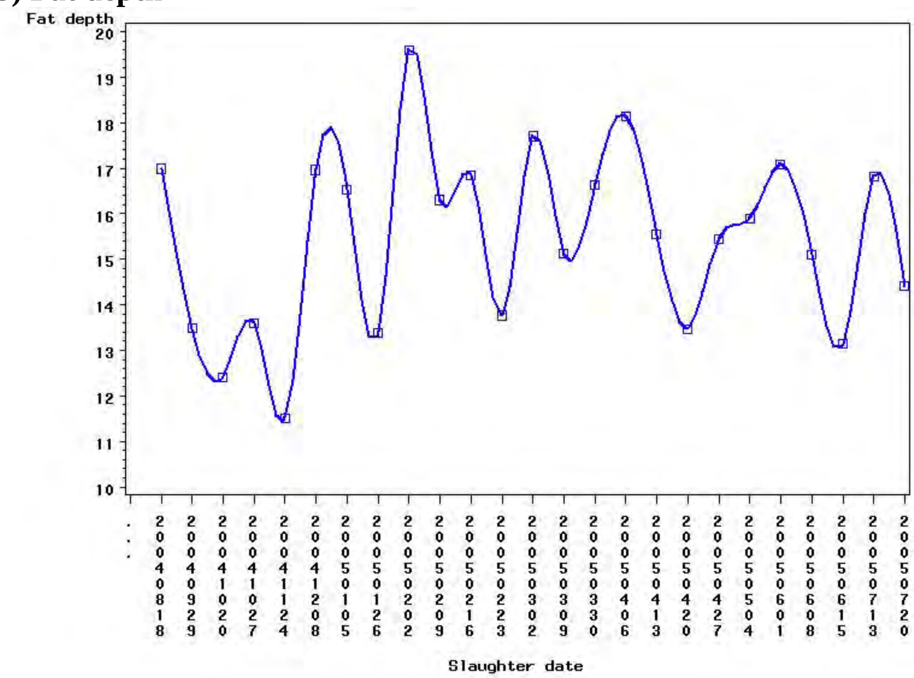
1) Loin weight



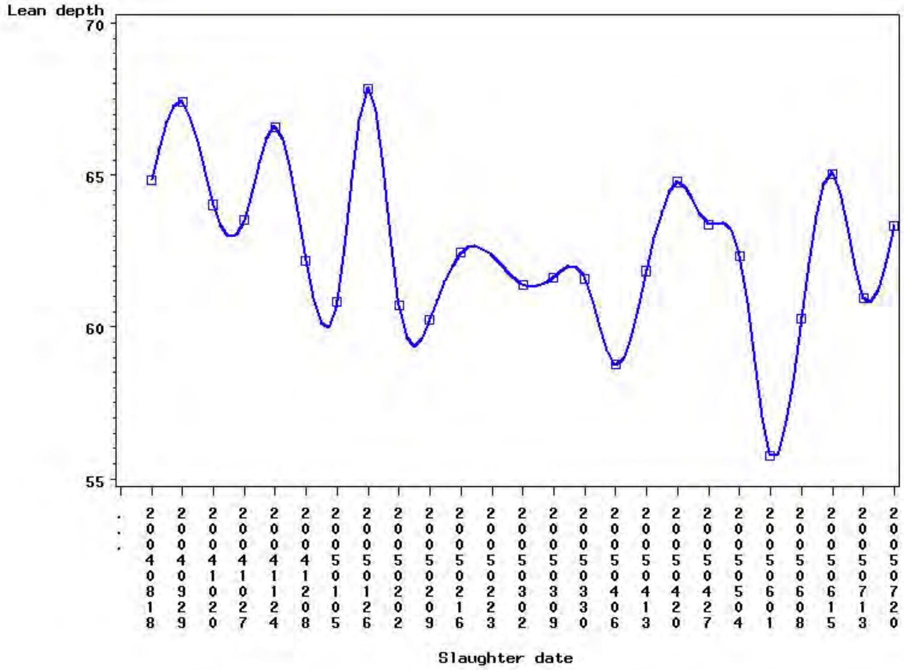
2) Loin length



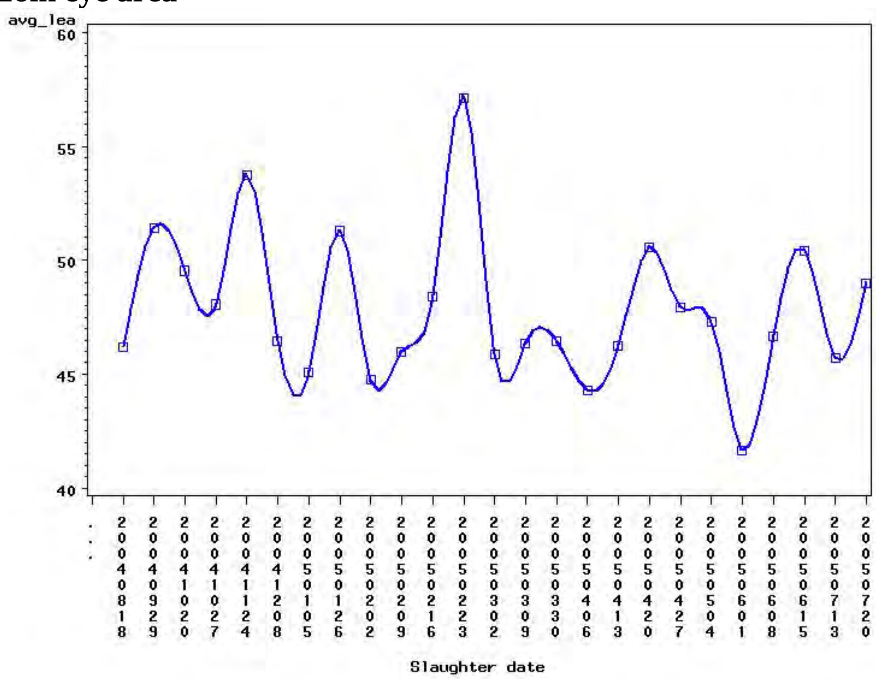
3) Fat depth



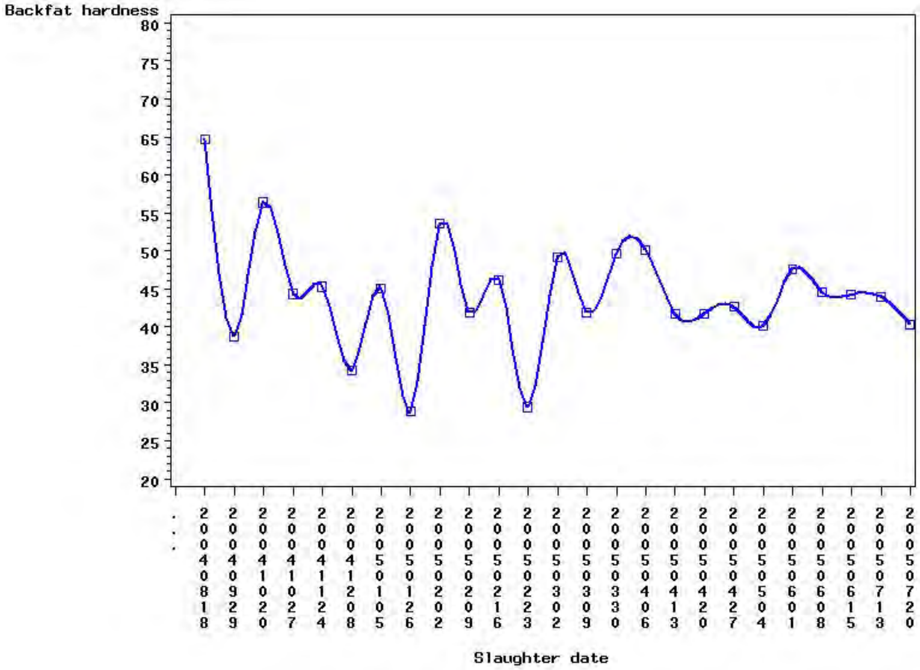
4) Lean depth



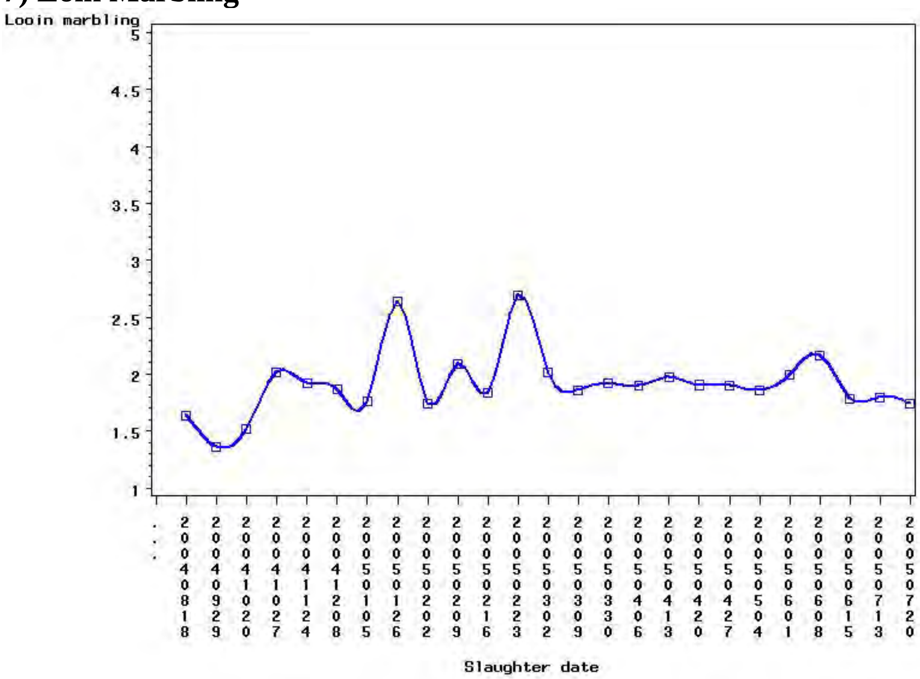
5) Loin eye area



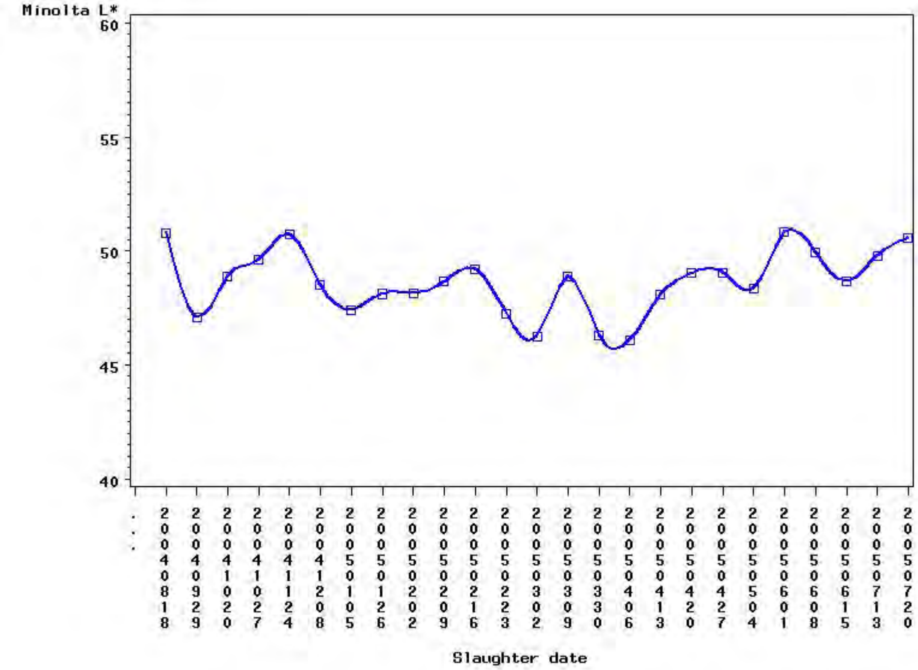
6) Backfat hardness



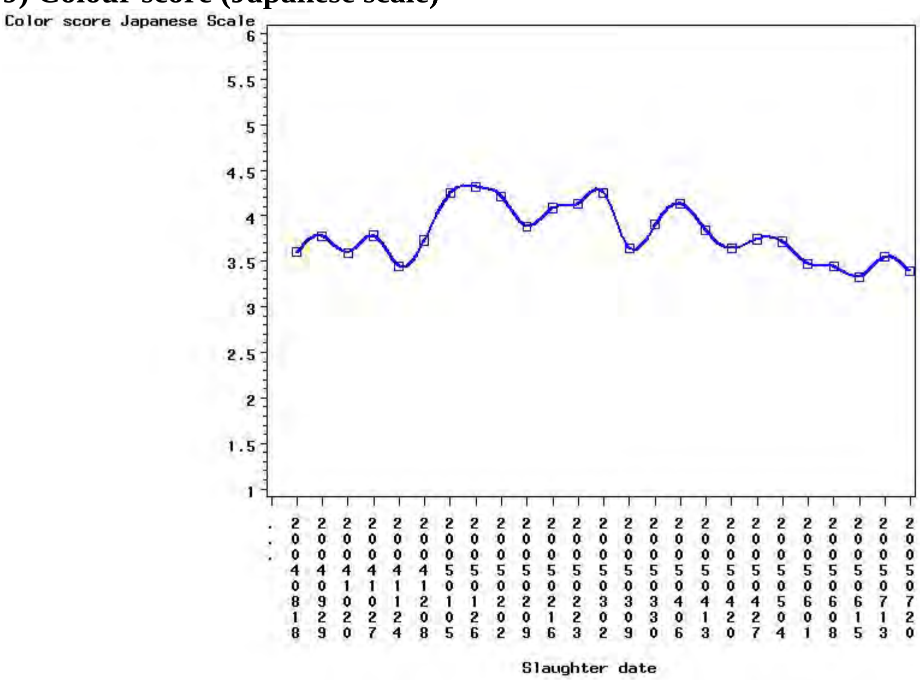
7) Loin Marbling



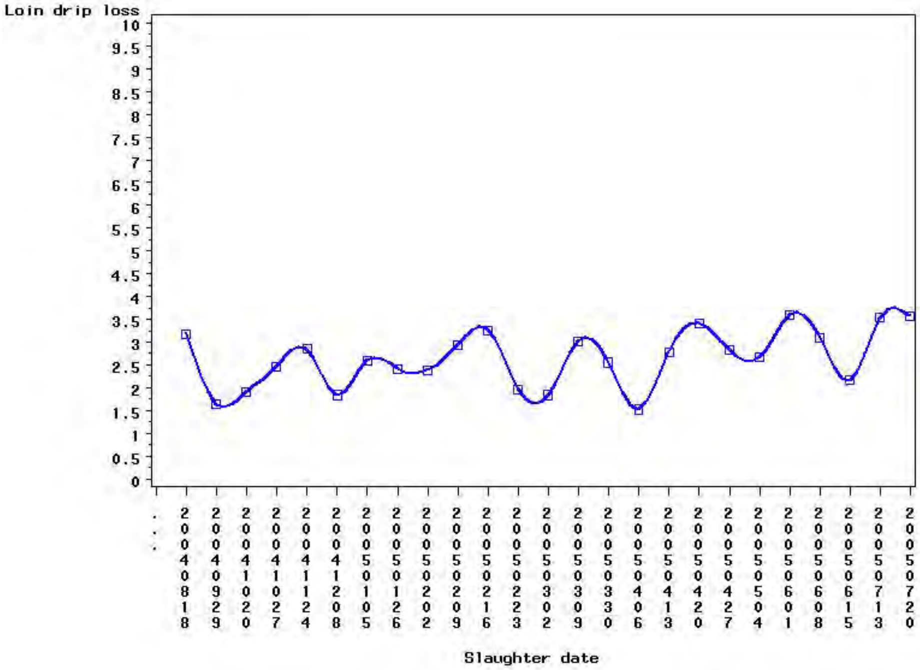
8) Loin colour (Minolta L*)



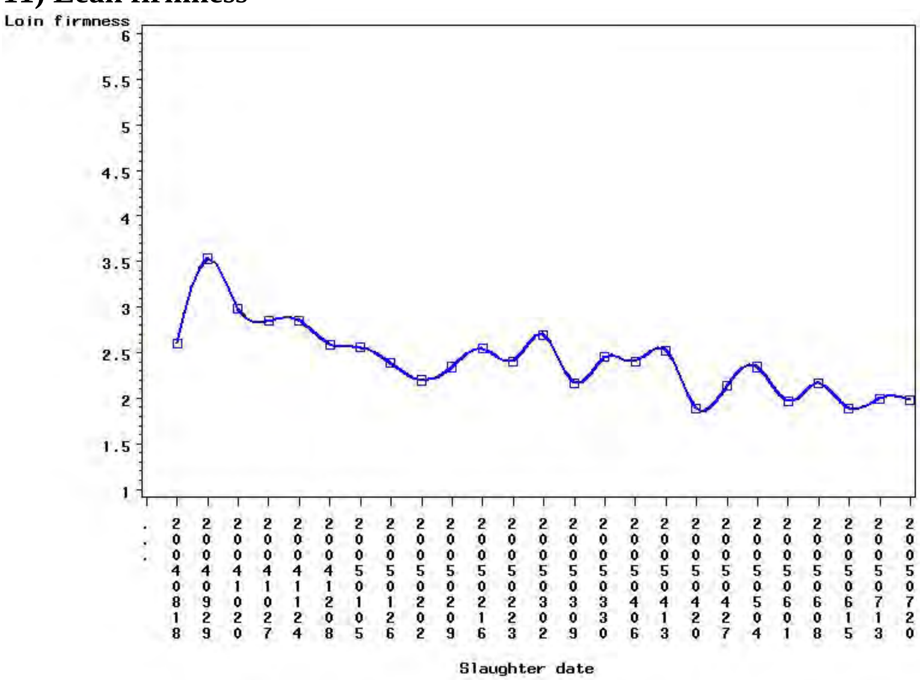
9) Colour score (Japanese scale)



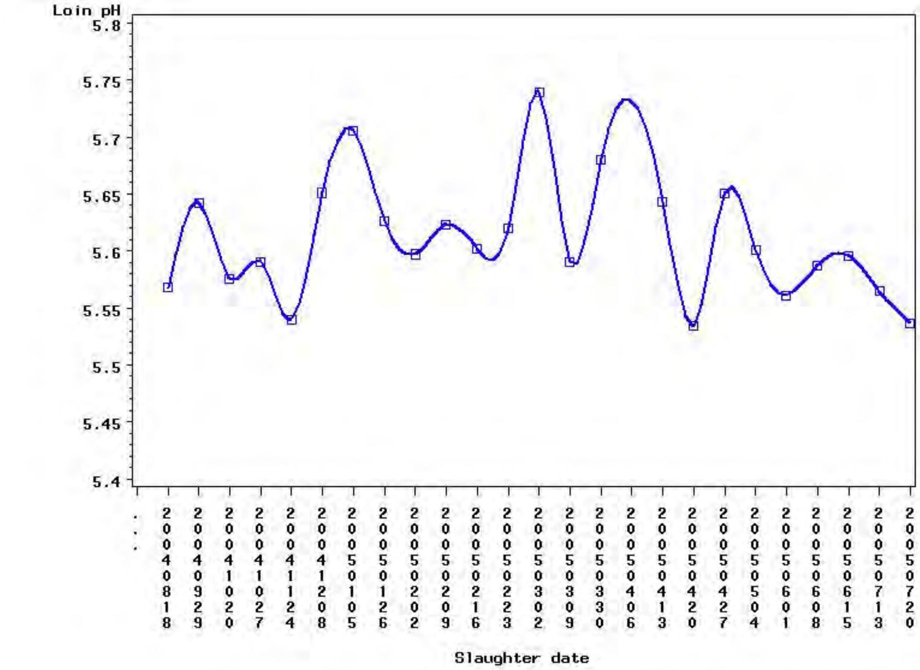
10) Loin drip loss



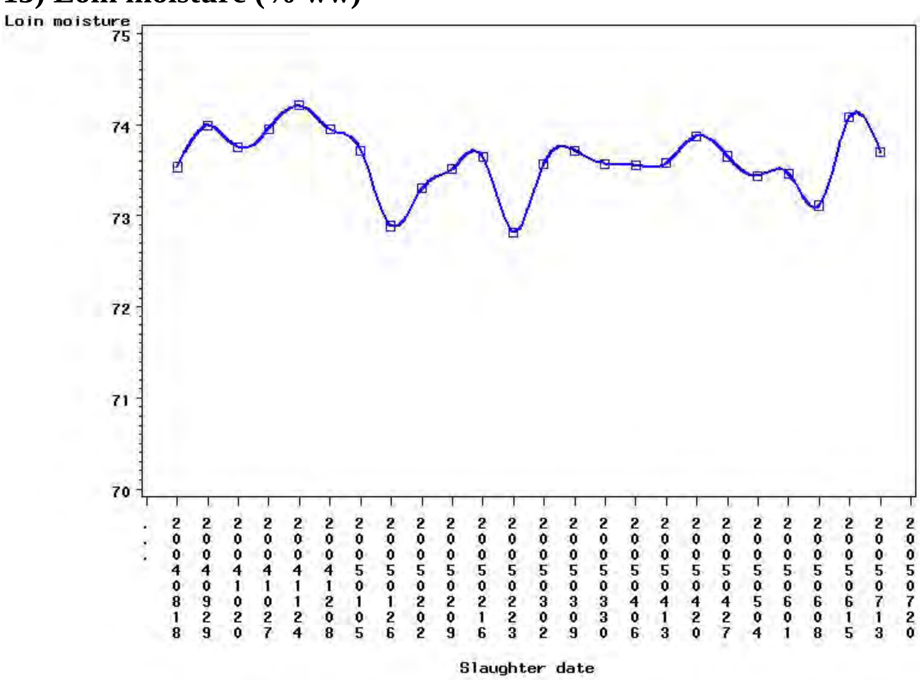
11) Lean firmness



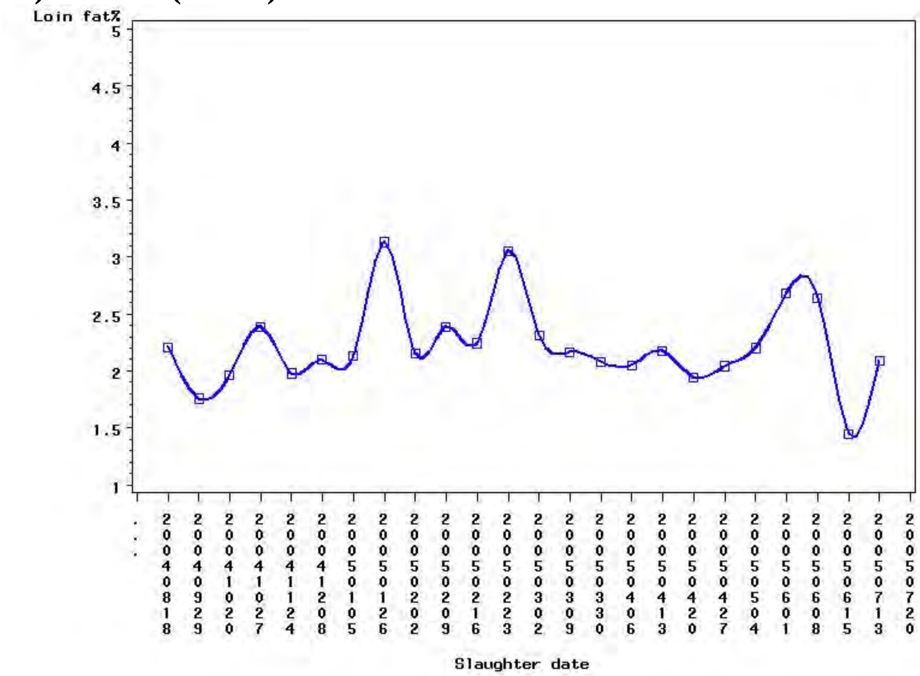
12) Loin pH (24 hours)



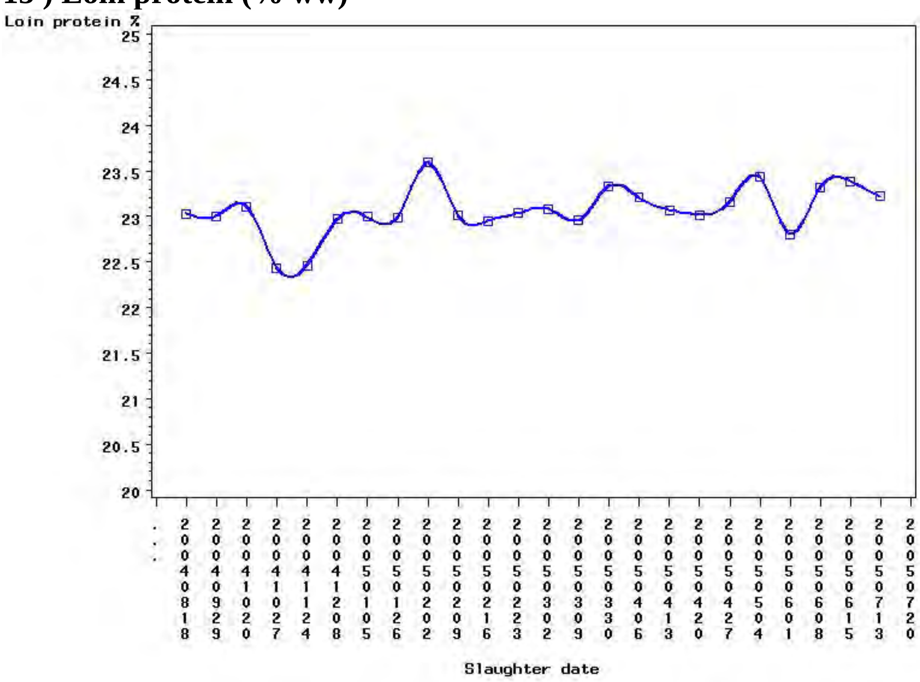
13) Loin moisture (% ww)



14) Loin fat (% ww)



15) Loin protein (% ww)



4. Discussion and conclusions

As expected the variations in the loin marbling and loin fat % follow similar patterns. The same is true for the subjective and objective colour scores. The drip loss seems to be relatively steady. There were significant fluctuations in the pH which can be attributed a number of factors such as pre-slaughter handling and exact time of evaluation after slaughter that also varied slightly from one batch to the other. It is interesting to note a decrease in the lean firmness over the one year period. This is in agreement with the observation by some packing plants that the pork loins are loosing their firmness and there are increased incidences of floppy loins.

Appendix 4

Meat quality measurements

Austin Murray
Lacombe Research Centre, Agriculture and Agri-food Canada

The fewest fresh-muscle traits that adequately define the quality of the pig longissimus (loin-eye) muscle are:

Trait	Method for Measuring
Muscle Size	Length of Loin, Area at 12th/13th Rib
Muscle Color	Reflectance Meter at 11th/12th Rib
Muscle Marbling/Intramuscular Fat	Subjective Marbling at the 12th/13th Rib
Muscle Water Holding Capacity	Drip Loss at the 12th Rib
Muscle Firmness/Softness	Subjective Firmness at the 11th Rib
Muscle pH (24h)**	pH Meter at the 11th/12th Rib

**The value of pH measurement at 24h post-slaughter (not ultimate pH) is over-rated, but since it is so frequently requested and measured, it is also included.

Carcass weight and backfat should be included because they may be required to ascertain how the above traits are affected by pig weight and fatness.

Note: Muscle color, drip loss, firmness and pH are affected by pre-slaughter management. It is important to assure that pigs are not subjected to undue stress during the 48h prior to slaughter and it is important that feed (but not water) be removed from pigs for 16-20h prior to slaughter.

Materials and Methods

Design: (To be decided. The number of pigs sampled will impact the ability to insert this project into ongoing programs at the Lacombe Research Centre.) *The timing of delivery to Olymel, slaughter and removal of the loin will have to be discussed in detail.*

Grading Measurements: Fat thickness and lean tissue depth will be measured with a Hennessey Grading Probe at the 3rd/4th last ribs, 70 mm from the carcass mid-line. Hot carcass weight will also be obtained with the other grading information.

Commercial loins will be removed from the left sides of carcasses at Olymel (Red Deer) by Olymel staff on the day following slaughter and transported (~20 min) to the Meat Centre of Lacombe Research Centre, where they will be held at 1-2°C until assessed.

Quality Traits to be Measured

Loin Length. The length of the bone-in loin will be measured with a tape measure.

Loin Measurements from Digital Images. The loin will be cut at the 12th/13th ribs (*could be cut at 3rd/4th last rib*) into two sections and the cross-section of the loin near the 12th rib will be digitized by camera. The following measurements will be obtained from the cross-sectional view.

Loin/LT Dimensions. Subcutaneous fat thickness and loin-eye area will be determined from the digital image using a simple computer image analysis program.

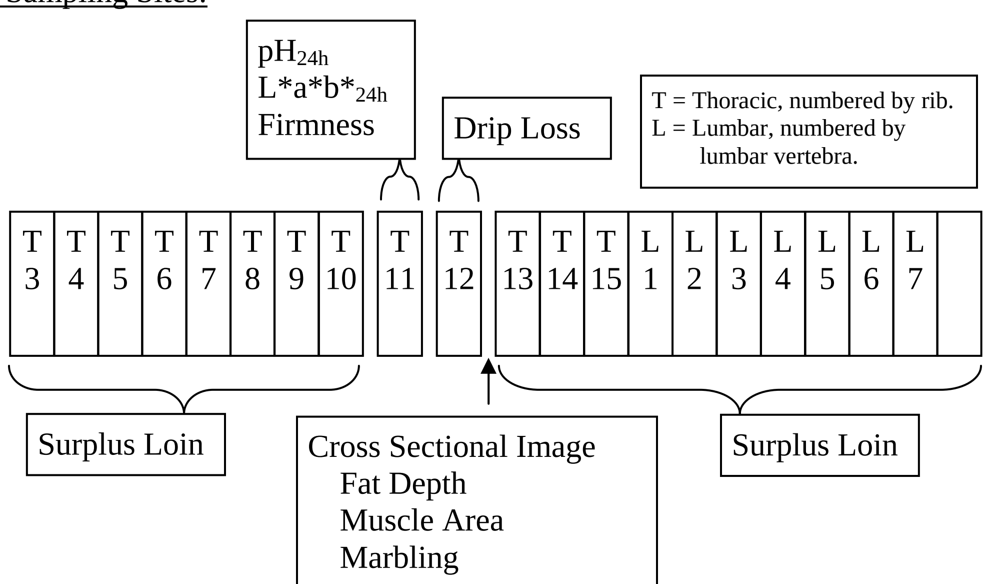
Marbling Assessment. Marbling of the LT muscle at the 12/13th rib interface will be assessed subjectively from the digital image as a consensus of two raters from these digital images using the NPPC (National Pork Producers Council) Pork Marbling Standards (1=none to 10=extremely abundant; NPPC/AMSA 2000).

Drip Loss. At approximately 24h post-slaughter, a 2 cm chop will be removed at the 12th rib, weighed, over-wrapped with oxygen-permeable polyvinyl film on a Styrofoam tray containing an absorbent pad and stored for 48 hr at 4C. The initial and final chop weights will be used to calculate drip loss as % wet weight.

pH and Reflectance (LT muscle, 48h). At approximately 24 h post-harvest, a 2 cm chop will be removed at the 11th rib for the measurement of reflectance and pH. Approximately 20 min after exposing the muscle surface, CIE L*, a*, b*, chroma and hue angle of the chop surface will be measured in triplicate using a Minolta CR-300 reflectance meter. Then the 24h pH will be measured in triplicate with a Hanna Instruments Model 9025 pH/temperature meter, fitted with a temperature probe and a Mettler-Toledo spear-type pH electrode.

Firmness: Firmness will be measured subjectively on a 5 pt scale (1=very soft, 2=soft, 3=neither soft nor firm, 4=firm, 5=very firm) using the same piece of meat that was used for color and pH measurement.

Loin Sampling Sites:



Appendix 5

Genetic Evaluation for Meat Quality traits

Laurence Maignel and Pramod Mathur
CCSI, December 2005

1. Introduction

An important objective of the project was to develop a system for genetic evaluation for meat quality traits.

This document describes the traits evaluated and methods used to estimate breeding values. Preliminary results are provided, as well as recommendations for further steps.

2. Material and Methods

2.1 Matching of loin samples to pig identifications

The pigs came originally from 9 participating herds in Western Canada. One of the major steps in the genetic evaluations was matching the loin samples to the pigs they came from. As it is a routine practice, the identifications of individual pigs were lost at the packing plant when the pig carcasses were processed and cut into various pieces. The Olymel plant provided full co-operation in delivering the loin samples of the pigs from the breeder participating in the project on the given day. However, these loins did not bear individual identifications. A DNA matching technique was therefore used to match the loins back to the pigs they came from. In addition, during the later phase of the project, specific tattoo numbers were printed on the locations of loins of live pigs that were then collected back on the loins received from the plant. In some instances it was not possible to collect the blood sample for DNA extraction from the live pigs before slaughter. In some cases the pig carcasses were also mixed with other carcasses in the plant. As a result the loins analysed did not match to the pigs slaughtered. Therefore individual identifications could not be obtained on all the 766 loin samples. This was a new learning experience for genetic evaluations.

Among the loin samples that were matched to individual identifications, there were a total of 269 pigs that were purebreds and had their pedigree records in the national database at CCSI database. A majority of these pigs also had live animal measurements at the time of probing that included live animal fat depth and lean depth. These pigs were included in a genetic evaluation system in order to compute estimated breeding values (EBVs) for carcass and meat quality traits. In addition, their relatives probed during the same period and their parents were also included. This procedure provides an opportunity to obtain genetic evaluation on pigs that could be used for breeding based on the information on their relatives that are slaughtered and no longer available for selection.

2.2. Meat quality traits under genetic evaluation

A genetic evaluation system has been developed at CCSI for meat quality traits. The 9 traits listed below were used in the genetic evaluations.

Table 1. List of meat quality traits included in the genetic evaluations and their acronyms

Trait	Acronym	Description
• Loin marbling score	MARB	Assessed subjectively from the digital image (12^{th}/13^{th} ribs) as a consensus of two raters, using the NPPC Pork Marbling Standards (1 to 10)
• Loin color score	SCOL	Measured at the 11^{th} rib, 24h post-slaughter, using the Japanese color scale (1 to 6)
• Loin reflectance - Minolta L* value	MINL	Measured in triplicate with a Minolta CR-300, at the 11^{th} rib, 24h post-slaughter
• Loin 24h pH	LPH	Measured in triplicate with a Hanna Instruments Model, at the 11^{th} rib, 24h post-slaughter
• Loin drip loss	DRIPL	At about 24h post-slaughter, a 2 cm chop is removed from the 12^{th} rib, weighed, over-wrapped with oxygen-permeable polyvinyl film on a Styrofoam tray containing an absorbent pad and stored for 48h at 4C. Initial and final weights are used to compute drip loss as a percentage of wet weight.

Table 2. List of live animal measurements used and their acronyms

• Fat depth • Lean depth • Loin eye area	FAT LEAN LEA	From live animal measurements. In case where the live animal measurements were not available the grading measurements were converted to the live measurements using prediction equations derived earlier

2.3. Animals

Among all samples taken for meat quality assessment, a group of 269 pigs were identified as purebred pigs known in CCSI database. The 269 pigs, 232 females and 37 males, were originally from 7 herds (Acadia Breeders Ltd, Five Lakes Farms Ltd, Bloomsbury Farms Ltd, Fast Pigs H&M, Fast Pigs Beatty, Edulia Farms Ltd, Jacubec Farms). These pigs were shipped to the Olymel plant in Red Deer between January 5, 2005 and July 20, 2005. Table 3 shows numbers of pigs with meat quality records, as well as number of different sires and dams involved.

Table 3: Number of purebed records used in genetic evaluations

	Duroc	Lacombe	Landrace	Yorkshire
animals with meat quality records	25	63	65	116
females with meat quality records	19	52	61	100
males with meat quality records	6	11	4	16
sires	13	24	35	45
dams	19	47	53	105
herds	5	2	5	5

General statistics for traits considered in genetic evaluation are presented in Table 4. Table 5 shows means and standard deviations by breed and sex.

Table 4: General statistics on meat quality records used in genetic evaluation

Trait	Mean	Standard Deviation	Minimum	Maximum
FAT (mm)	16.03	4.59	6.90	32.00
LEAN (mm)	62.07	5.64	47.80	82.10
LEA (cm2)	47.17	5.64	33.60	63.00
MARB	1.84	0.55	1.0	3.9
SCOL	3.91	0.79	1.0	6.0
MINL	48.06	3.28	40.40	65.30
LPH	5.64	0.15	5.33	6.17
DRIPL(%)	2.67	1.44	0.67	10.45

Table 5: Means and standard deviations (*in italics*) by breed and sex

Breed	Duroc		Lacombe		Landrace		Yorkshire	
Sex	F	M	F	M	F	M	F	M
# animals	19	6	52	11	61	4	100	16
FAT (mm)	13.77 *2.53*	13.77 *1.58*	17.90 *5.35*	22.87 *3.94*	13.94 *3.98*	18.75 *6.3*	15.78 *3.87*	17.43 *3.64*
LEAN (mm)	66.61 *6.48*	66.07 *5.10*	60.69 *5.48*	55.40 *5.48*	63.74 *5.60*	58.35 *3.11*	62.26 *4.82*	58.86 *4.40*
LEA (cm2)	50.31 *6.33*	49.35 *5.90*	46.53 *5.14*	40.82 *4.70*	49.16 *5.49*	40.28 *3.66*	47.31 *4.93*	42.30 *4.50*
MARB	2.68 *0.61*	2.83 *0.76*	1.73 *0.40*	2.03 *0.57*	1.54 *0.40*	1.85 *0.64*	1.82 *0.47*	1.91 *0.38*
SCOL	4.21 *0.63*	4.08 *0.20*	4.18 *0.79*	4.18 *0.72*	3.48 *0.89*	3.50 *1.29*	3.95 *0.66*	3.84 *0.72*
MINL	47.65 *2.36*	48.90 *1.42*	46.88 *3.05*	46.97 *3.13*	49.60 *3.98*	48.75 *4.09*	47.84 *2.88*	48.13 *3.09*
LPH	5.62 *0.09*	5.62 *0.09*	5.72 *0.17*	5.75 *0.15*	5.56 *0.12*	5.78 *0.28*	5.64 *0.13*	5.66 *0.13*
DRIPL(%)	2.26 *1.16*	2.62 *1.02*	2.20 *1.26*	2.14 *0.91*	3.44 *1.86*	2.12 *0.69*	2.62 *1.23*	2.63 *1.25*

2.4. Statistical model used to estimate breeding values (EBVs) for meat quality traits

Statistical model

In order to properly estimate breeding values, it is necessary to account for any identified environmental effect influencing the traits of interest. The following effects were taken into account in the genetic evaluation model

Fixed effect	contemporary group = combination of herd of origin×plant×technician×date of slaughter
Covariate	hot carcass weight
Random effects:	litter effect animal effect (breeding value)

Probe records (FAT and LEAN) were analyzed with a model including contemporary group (as defined in the current backfat and age evaluation), litter and animal effects.

Pre-correction for sex

To partially settle the problem of small contemporary groups, the data was pre-corrected for sex, using conversion factors computed from differences between females and barrows within slaughter date. Using these factors, all the barrows were transformed into females. More information about these adjustments is provided in Appendix 5.1.

Estimation of hot carcass weight

Carcass weight is known as an important effect on meat quality characteristics. Unfortunately, carcass weight was not available for the pigs in this project. However, most of the pigs with meat quality measurements also had probe measurements available in CCSI database, that is to say weight, fat and muscle depth measured on live animals, at about 100kg live weight. Weight at probing was used jointly with the age at slaughter to predict the carcass weight, using the following formula:

Predicted carcass weight (kg) = 0.737 × probe weight + 0.645 × (Age at slaughter-Age at probing)

For animals with no probe measurements in CCSI database, the age at slaughter was used to predict the hot carcass weight, using the following formula:

Predicted carcass weight (kg) = 0.492 × Age at slaughter (days)

More information about these prediction formulas are provided in Appendix 5.2.

Genetic parameters

The evaluation was carried out separately for each breed. Heritabilities and genetic correlations among the eight traits are shown in table 6. Meat quality traits are moderately heritable (20 to 30%) and show significant correlations between each others. The highest genetic correlations are found between drip loss and pH, and between pH and color/reflectance.

Table 6: Heritabilities and genetic correlations used in genetic evaluations for meat quality

	FAT	LEAN	LEA	MARB	SCOL	MINL	LPH	DRIPL
FAT	0.52[d]	-0.26[d]	-0.42[d]	0.30[a]	-0.03[a]	-0.21[b]	0.15[b]	-0.18[a]
LEAN		0.25[d]	0.55[d]	-0.08[a]	-0.06[a]	0.10[b]	-0.08[b]	0.15[a]
LEA			0.47[d]	-0.43[a]	-0.35[a]	0.16[b]	-0.13[b]	0.34[a]
MARB				0.19[a]	0.26[a]	-0.23[f]	0.26[f]	-0.31[a]
SCOL					0.21[a]	-0.22	0.43[c]	-0.54[f]
MINL						0.28[b]	-0.53[b]	0.54[f]
LPH							0.21[b]	-0.64[f]
DRIPL								0.21[a]

[a] from OPCAP
[b] from Genetics of the Pig (average of several studies)
[c] from Hovenier et al (1992)
[d] according to CCSI's current evaluation system
[f] from Sonesson et al (1998)

Notes:

- For the traits already evaluated in the national program (FAT, LEAN and LEA), the genetic parameters of the current evaluation system were used.
- For the other traits, the genetic parameters were based on literature values
- As far as possible, the correlations were taken from the same study as the heritability estimates
- The estimates were compared to other studies as well e.g. those recently estimated in France. The estimates are quite similar to those reported here.

3. Results

The genetic evaluation module included all purebred animals with meat quality records, and animals probed in the enrolled herds during the first three quarters of 2005, in order to include contemporary animals of all slaughtered pigs.

Table 7 shows general statistics about meat quality EBVs computed in this project. Results for Duroc, Lacombe, Landrace and Yorkshire breeds are given below, for probed animals with at least one full-sib or half-sib with meat quality measurements.

Table 7: General statistics for meat quality EBVs

	Duroc				Lacombe			
	Mean	Std	Min	Max	Mean	Std	Min	Max
MARB	0.043	0.108	-0.417	0.463	-0.050	0.103	-0.469	0.330
SCOL	0.008	0.040	-0.236	0.227	0.004	0.050	-0.312	0.209
MINL	-0.164	0.284	-1.206	0.758	-0.024	0.298	-1.712	1.346
LPH	0.008	0.009	-0.043	0.046	0.009	0.015	-0.074	0.083
DRIPL	-0.045	0.066	-0.353	0.693	-0.058	0.092	-0.495	0.491

	Landrace				Yorkshire			
	Mean	Std	Min	Max	Mean	Std	Min	Max
MARB	-0.056	0.112	-0.592	0.532	-0.002	0.103	-0.443	0.461
SCOL	0.010	0.038	-0.432	0.250	0.003	0.034	-0.310	0.272
MINL	0.110	0.292	-1.385	3.345	-0.106	0.310	-1.742	1.935
LPH	-0.005	0.011	-0.056	0.094	0.005	0.011	-0.075	0.070
DRIPL	-0.058	0.092	-0.495	0.491	-0.013	0.071	-0.511	0.753

From general statistics on meat quality EBVs, we can see a quite large variability, which is required for efficient selection. In order to select animals based on meat quality EBVs, it is also useful to know how their individual breeding values rank compared to overall population, in order to select for a given top percentage.

Table 8: EBV percentiles by breed

Duroc breed

Trait	1%*	5%	10%	25%	50%	75%	90%	95%	99%
MARB	-0.42	-0.20	-0.10	-0.01	0.06	0.22	0.47	0.62	0.86
SCOL	-0.10	-0.04	-0.02	0.00	0.03	0.11	0.19	0.24	0.33
MINL	-2.30	-1.75	-1.47	-0.96	-0.34	-0.05	0.06	0.20	0.54
LPH	-0.03	-0.01	0.00	0.00	0.01	0.03	0.06	0.07	0.11
DRIPL	-0.39	-0.29	-0.23	-0.13	-0.05	-0.01	0.01	0.05	0.16

** Threshold below which the animal is in the bottom 1% of the population*

Lacombe breed

Trait	1%	5%	10%	25%	50%	75%	90%	95%	99%
MARB	-0.31	-0.23	-0.18	-0.11	-0.04	0.00	0.07	0.11	0.19
SCOL	-0.16	-0.08	-0.05	-0.01	0.01	0.03	0.05	0.07	0.13
MINL	-0.79	-0.49	-0.36	-0.17	-0.01	0.12	0.29	0.47	0.81
LPH	-0.03	-0.02	-0.01	0.00	0.01	0.02	0.03	0.03	0.04
DRIPL	-0.29	-0.20	-0.16	-0.11	-0.06	-0.01	0.04	0.09	0.20

Landrace breed

Trait	1%	5%	10%	25%	50%	75%	90%	95%	99%
MARB	-0.36	-0.25	-0.20	-0.12	-0.04	0.01	0.08	0.14	0.26
SCOL	-0.11	-0.03	-0.01	0.00	0.01	0.02	0.04	0.05	0.08
MINL	-0.74	-0.42	-0.25	-0.04	0.09	0.28	0.46	0.58	0.83
LPH	-0.03	-0.02	-0.02	-0.01	0.00	0.00	0.01	0.01	0.02
DRIPL	-0.17	-0.11	-0.08	-0.03	0.00	0.04	0.09	0.15	0.23

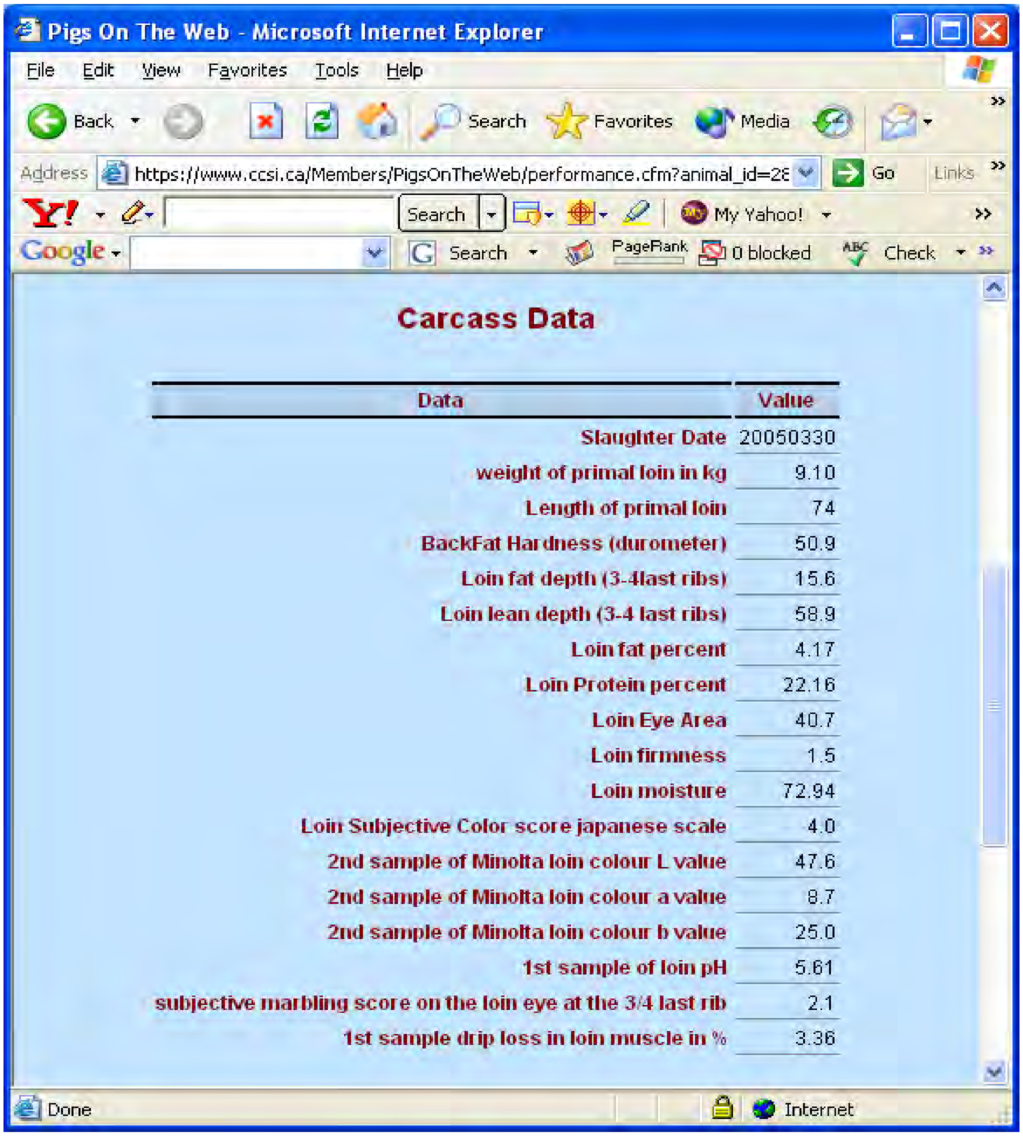
Yorkshire breed

Trait	1%	5%	10%	25%	50%	75%	90%	95%	99%
MARB	-0.31	-0.18	-0.13	-0.05	0.00	0.07	0.20	0.28	0.45
SCOL	-0.26	-0.13	-0.07	-0.02	0.00	0.02	0.06	0.11	0.20
MINL	-1.46	-0.86	-0.60	-0.27	-0.03	0.11	0.42	0.76	1.46
LPH	-0.03	-0.01	-0.01	0.00	0.00	0.01	0.03	0.04	0.06
DRIPL	-0.33	-0.21	-0.15	-0.06	-0.01	0.01	0.06	0.10	0.24

These tables provide information about the estimated genetic superiority (or inferiority) of the populations' subgroups based on EBV ranking. For instance, in the Yorkshire breed, top 10% animals for marbling will have an EBV higher or equal to +0.20. From this data set, it can be shown that this group of pigs will have an average Marbling EBV of +0.30. Their progeny will have an average loin marbling score on average 0.15 higher than the population average, since half of the genome is transmitted to progeny. Applying this system to several generations of selection, with enough meat quality data to provide accurate enough EBVs, could lead to a substantial genetic progress on this trait.

4. Reports and tools

Several new web pages are under development in order to provide participating breeders with tools to access their meat quality records and EBVs. Among them, a 'carcass and meat quality' section was added to the performance record page in PigsOnTheWeb. Every pig with meat quality record available has a table with the main meat quality traits showing up. An example is provided in Figure 2.



Carcass Data

Data	Value
Slaughter Date	20050330
weight of primal loin in kg	9.10
Length of primal loin	74
BackFat Hardness (durometer)	50.9
Loin fat depth (3-4last ribs)	15.6
Loin lean depth (3-4 last ribs)	58.9
Loin fat percent	4.17
Loin Protein percent	22.16
Loin Eye Area	40.7
Loin firmness	1.5
Loin moisture	72.94
Loin Subjective Color score japanese scale	4.0
2nd sample of Minolta loin colour L value	47.6
2nd sample of Minolta loin colour a value	8.7
2nd sample of Minolta loin colour b value	25.0
1st sample of loin pH	5.61
subjective marbling score on the loin eye at the 3/4 last rib	2.1
1st sample drip loss in loin muscle in %	3.36

Figure 2: Example of carcass data provided in the PigsOnTheWeb section of CCSI website (members services area)

Another report with the following format is also available, and can be obtained after selecting a herd, breed, and probe period:

Table 9: Format of the 'Meat Quality EBVs report' on CCSI website

								Meat Quality Estimated Breeding Values				
Tattoo	Sex	Breed	Bdate	Own meat quality records ? (Y/N)	#full sibs with meat quality records	#half-sibs with meat quality records	#progeny with meat quality records	Marbling EBV	Loin colour EBV	Loin reflectance EBV	Loin pH EBV	Loin drip loss EBV

This report can be used to rank animals on any meat quality EBV.

5. Recommendations

- More pigs can now be included in the genetic evaluations for meat quality traits thanks to DNA matching technology results. Meat quality EBVs can be estimated whenever needed.

- So far the number of pigs included in genetic evaluation for meat quality traits is relatively small, but there is clearly a potential to select pigs using meat quality EBVs. More emphasis should be put on testing half-sibs or full-sibs (females, males or castrates) of boars probed on farm and potentially kept for reproduction or sent to AI studs afterwards. Meat quality EBVs for those boars would be very valuable information and would make genetic progress on meat quality easier and quicker.

- Regarding selection on meat quality, it is important to notice that most meat quality traits have desired ranges that are neither maximum nor minimum. For instance, one might want to increase marbling but to a certain extent, or to decrease drip loss but not to a too dry meat. It is essential to be aware of the population current level, and the exact needs for improvement.

- This project results suggest large variability of meat quality traits measured, and the possibility for improvement through genetic selection. However, it is also well-known that environment, especially pre-slaughter handling has a large impact on meat quality characteristics. A good selection program on meat quality should be based on proper pre-slaughter management, standardized measurements and accurate breeding values.

- Meat quality data coming from other projects (Deschambault purebred tests for instance) are being inserted in the same genetic evaluation programs, after being checked for data consistency with the current project. This will increase the accuracy of meat quality breeding values, especially for the herds which provided animals in both projects.

- As an extension of this project, more traits could be added to the EBV module, for example fat hardness and loin firmness. This would require more data recorded in order to estimate genetic parameters and check the statistical model currently used.

Appendix 5.1

Sex-adjustment factors for some meat quality traits
CCSI, December 2005

Objective

Regarding meat quality traits, as for several other traits, male and female are different on mean and deviation. This can be a source of problems in genetic evaluations, leading to possible bias and/or difference of EBV range according to the sex.

Data used

The data collected on 2611 Duroc and 2043 Yorkshire pigs, slaughtered between 1998 and 2002, were used to estimate sex-adjustment factors.

Duroc Breed

	Castrates			Females		
Trait	N	Mean	Std Dev	N	Mean	Std Dev
Loin eye area (sq cm)	497	37.67	4.29	2114	40.60	4.29
Marbling (subj. score)	497	4.01	1.19	2114	3.52	1.16
Colour score (subj. score)	412	3.03	0.48	1929	3.13	0.47
Minolta colour (min. units)	454	46.48	2.70	1420	45.63	2.87
Loin ultimate pH (pH units)	435	5.79	0.18	1359	5.81	0.16
Drip loss (%)	323	1.10	0.48	1082	1.11	0.56

Yorkshire Breed

	Castrates			Females		
Trait	N	Mean	Std Dev	N	Mean	Std Dev
Loin eye area (sq cm)	1525	39.06	4.73	519	42.14	5.36
Marbling (subj. score)	1525	2.18	0.95	519	1.74	0.94
Colour score (subj. score)	1369	2.63	0.63	478	2.75	0.64
Minolta colour (min. units)	803	49.19	3.37	374	48.52	3.42
Loin ultimate pH (pH units)	786	5.66	0.15	360	5.68	0.14
Drip loss (%)	637	1.72	0.88	262	1.68	0.75

Statistical Method

Sex adjustment factors were derived based on within slaughter groups differences.
The model used was the following :

$$Y = CG + S + e$$

Where Y is the performance trait, CG is the fixed effect of contemporary group (combination of herd of origin, plant, slaughter date and technician), and S is the effect of the sex (female or castrate); e is a random residual.

The multiplicative correction factors to use for castrates (CFc) were estimated using the following formula :
CFc = meanF / (meanF – solF + solC)
Were meanF is the mean for females, and solF and solC are the solutions, respectively, for female and castrate effects in the data set.

Results

The following table shows the correction factors for loin eye area and five meat quality traits. Depending on the trait and breed, the adjustment will remove or add from 0 to 18% for the castrates. For Minolta colour and pH, the corrections factors are very close to 1.

Breed	Sex	Loin eye area	Marbling	Colour score	Minolta colour	Loin ultimate pH	Drip loss
Duroc	Female	1.000	1.000	1.000	1.000	1.000	1.000
	castrate	1.082	0.893	1.017	0.989	0.997	1.021
Yorkshire	Female	1.000	1.000	1.000	1.000	1.000	1.000
	Castrate	1.093	0.839	1.090	0.982	0.999	0.920

Appendix 5.2

Prediction of hot carcass weight using probe weight and/or age at slaughter
CCSI, December 2005

Objective

Carcass weight is one of the factors affecting carcass and meat quality, especially loin eye area, marbling and colour, but also other traits to a lesser extent. In a genetic evaluation system, it is essential to take in to account all potential effects in order to estimate breeding values of animals in an accurate way. In the current project, carcass weights were not available. For purebred pigs known in CCSI database, carcass weight was predicted using weights collected at probing and/or age at slaughter. Prediction formulas were developed based on information available from different sources in CCSI database, on animals wit both probing and carcass information.

Data used

Data collected on 3887 purebred pigs, born between 2000 and 2004, were used to develop prediction formulas.

Data available by breed and sex

Breed	Barrows	Females	Boars	Total
Duroc	635	438	356	1429
Yorkshire	119	1770	569	2458
Total	754	5108	925	3887

Summary statistics

Variable	Mean	Std Dev	Minimum	Maximum
Probe weight (kg)	103.4	8.5	75	130
Age at probing (days)	157.3	8.2	129	199
Carcass weight (kg)	81.8	5.3	65.2	102.4
Age at slaughter (days)	166	8.4	143	200

Multiple regressions were carried out using different models. The results of each prediction formula were compared to actual carcass weights from the data sample. The best model, based on R2, correlation with actual carcass weights, and mean and variance of predicted values, is shown in the table below.

Covariate(s)	R^2 of the model	Regression coefficients	Correlation between predicted carcass weight and actual carcass weight
Probe weight (Age at slaughter-Age at probing)	61 %	0.737 0.645	0.78

For animals without probe information in CCSI database, the only useful information available is the age at slaughter. Based on regression, we suggest the following formula: Predicted carcass weight=0.492×age at slaughter.

DNA tests for IGF2 gene for leanness

Introduction

IGF2 is considered as a gene for a quantitative trait locus (QTL) in pigs affecting muscularity. The large effects of IGF2 gene on lean meat content and backfat thickness of swine were detected by several studies. More information about the gene test is available at the CCSI website www.ccsi.ca/IGF2. A total of 257 loin samples from the project were used to evaluate the frequency of the gene in the western pig population and to estimate its effect on meat quality traits.

Genotypic frequencies

The genotypic frequencies of pigs tested are given in the following table. A majority of the pigs were IGF2 +/+ type. This means that they carried both the alleles for leanness. This result is somewhat expected since the pigs on the national program are selected for leanness.

	IGF2 +/+	IGF2 +/-	IGF2 -/-	Total
Pigs	165	60	32	257
Frequency	64.2%	23.2%	12.4%	100%

Effect of IGF2 genotypes on meat quality

The meat quality characteristics according to the IGF2 gene are summarised on the following table.

	IGF2 +/+	IGF2 +/-	IGF2 -/-
Number of pigs	160	60	32
Backfat (mm)	14.2	17.3	21.3
Lean depth (mm)	66.0	61.1	58.6
Loin eye area (sq cm)	50.7	45.8	43.5
Marbling (NPPC)	1.9	1.9	1.8
Minolta (L)	48.4	47.1	45.8
Drip loss (%)	2.3	2.2	2.2

The main comparison of the effect of the gene can be based on the IGF2 +/+ and IGF2 -/- genotypes. Since the gene is paternally imprinted, the expression of the heterozygotes (IGF2 +/-) depends upon weather the gene was inherited from the father or from the mother. The gene has apparently very large effect on backfat.