Analysis of the variances of South African pig carcass classification parameters

by

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Dedication

This study is dedicated to my grandmother, Marlene Wiley, whose strength, love and unwavering faith brought warmth and inspiration to my life.

Declaration

I, Tamara du Plessis, hereby declare that this dissertation submitted for the degree M.Sc. (Agric) (Animal Science: Production Physiology and Product Quality) at the University of Pretoria, is my own original work and has not previously been submitted to any other institution of higher education. I further declare that all sources cited or quoted are indicated and acknowledged by means of a comprehensive list of references.

T. du Plessis

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Abstract

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This study analysed pig carcass records from a commercial abattoir to determine the existence of variance between/within the parameters, warm carcass mass (WCM) and back fat thickness (Fat), of the South African pig carcass classification system between class, gender, mass cluster and producer. A second part included taking the carcass measurements back fat thickness, eye muscle length (EML), depth (EMD) and area (EMA) and analysing the records to determine the relationship between the parameters and if a predictor could be identified to predict EMA and lean meat percentage (LM%).

A data set of 65 788 pig carcass records from a commercial abattoir was analysed and it was determined that the relationship between Fat and WCM was strong across all the data. When the data was divided into males and females across all the data the relationship between Fat and WCM was stronger ($P < 0.0001$) in females which was also seen within the Sausagers class. However, when the carcasses that are classified into the P, O, R, C, U or S classes were examined the relationship between Fat and WCM was stronger ($P < 0.0001$) for males. Overlaps were found between the mass categories, Porkers, Cutters, Baconers and Heavy Baconers, which is an area of concern as these categories are used along with the P, O, R, C, U and S fat divisions to determine the monetary value of the carcass. However, the amount of variation found within class was low, with the exception of the PP class and S classes, therefore showing that the PORCUS carcass classification system in South Africa can still reliably describe carcass composition. Lastly, the data was analysed to determine the existence of a producer effect. Fifteen producers were chosen on the basis of having produced 200 or more carcasses. The linear and quadratic relationships between Fat and WCM across the 15 producers improved by 10%. Within the 15 producers the R^2 values ranged from 0.12 to 0.72, showing that producer had a significant effect ($P < 0.0001$).

The second part of the study included measuring the carcass characteristics, fat thickness (Sfat), eye muscle length (EML), eye muscle depth (EMD) and eye muscle area (EMA) at the point between the 2nd and 3rd last ribs, 45 mm from the dorsal midline using a calliper, on 87 carcasses and analysing the recorded data. Fat thickness (HGPFat) recorded by the Hennessy Grading Probe (HGP) was also recorded and analysed. Differences were found between the HGPFat and Sfat measurements which may be attributed to the different apparatus being used to take the measurements or because the HGPFat was taken on a warm carcass and Sfat was measured on a cold carcass or a combination of the two factors may have contributed to the difference. Warm carcass mass and EML were found to have the strongest relationship ($P < 0.0001$) out of all the carcass characteristics measured where WCM could explain 41% of the variation seen within EML and had a Pearson's correlation coefficient of 0.64. Eye muscle area was able to explain 25% of the variation within WCM.

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List of Abbreviations

AFMA	Animal Feeds and Manufacturing Association
AFS	Agency for Food Safety
AI	Artificial insemination
BF	Backfat
BFAP	Bureau for Food and Agricultural Policy
BW	Body weight
CCM	Cold carcass mass
CP	Crude protein
CV	Coefficient of variation
DAFF	Department of Agriculture, Forestry and Fisheries
DFD	Dark, firm and dry
DPME	Department of Planning, Monitoring and Evaluation
EMA	Eye muscle area measured between the 2nd and 3rd last ribs with a calliper in centimetres squared
EMD	Eye muscle depth measured between the 2nd and 3rd last ribs with a calliper in centimetres
EML	Eye muscle length measured between the 2nd and 3rd last ribs with a calliper in centimetres
F	Female
FA	Fatty acid
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
Fat	Fat thickness measured between the 2nd and 3rd last ribs, 45 mm from the dorsal midline in millimetres
FCR	Feed conversion ratio
GDP	Gross domestic product
GnRH	Gonadotropin-releasing hormone
HGP	Hennessy Grading Probe
HGPFat	Backfat thickness measured between the 2nd and 3rd last ribs, 45 mm from the dorsal midline with the Hennessy Grading Probe in millimetres
IMQAS	International Meat Quality Assurance Systems
LH	Luteinizing hormone
LM%	Lean meat percentage
LW	Live weight
M	Male
MLCSL	Meat and Livestock Commercial Service Ltd

MUFA	Monounsaturated fatty acids
NDA	National Department of Agriculture
n	Number
PSE	Pale, soft and exudative
PUFA	Polyunsaturated fatty acids
r	Pearson’s correlation coefficient
RAC	Ractopamine hydrochloride
RMAA	Red Meat Abattoir Association
RMIF	Red Meat Industry Forum
RSD	Relative standard deviation
R^2	Coefficient of determination
SAMIS	South African Meat Industry Services
SAPPO	The South African Pork Producers’ Organisation
SEIAS	Socio-Economic Impact Assessment System
SFA	Saturated fatty acid
Sfat	Backfat thickness measured between the 2nd and 3rd last ribs, 45 mm from the dorsal midline with callipers in millimetres
SID Lys	Standard ileal digestible Lysine
WCM	Warm carcass mass in kilograms
WHC	Water holding capacity

CHAPTER 1
INTRODUCTION

1.1. Background

Carcass classification and grading are ways of describing carcass composition and quality so that all parts of the meat marketing chain can understand it; where buyers know what they are paying for and consumer preferences can be met by providing a monetary incentive for producers (Gu *et al.*, 1992b). Both systems can be used to help produce a meat product that can meet consumer preferences, help maintain a consistent level of meat quality that the consumer is presented with and provide buyers/consumers with a choice of different types of carcasses with varying compositions.

The pig carcass classification system that is currently used in South Africa (PORCUS carcass classification system) is more than 20 years old and was suggested by Bruwer (1992) in a response to a call for a re-evaluation of the previous carcass grading system as there were some areas of concern. In their study they found that the previous grading system could not accurately describe the meat yield for the consumer and that a specific grade could cover a large range of fat thickness.

Bruwer (1992) took genotype, sex and weight into consideration when developing the current regression prediction equations so that any group of pigs regardless of these three factors could be accurately classified as these three factors can introduce biases and ultimately affect the accuracy of the prediction of lean meat percentage (LM%). The prediction of LM% can be calculated by using either of the two prediction equations formulated by Bruwer (1992), depending on whether the Hennessy Grading Probe (HGP) or the Intrascope is used. Although, in the end it was decided not to account for genotype or sex biases in the prediction equations as the improvement made to the accuracy of the LM% prediction did not outweigh the impracticality of using these factors in the equations and was not worth the effort. Warm carcass mass (WCM) was excluded too on the basis that it did not increase the accuracy of the prediction equations as to have any significant impact. The only factors included in the prediction equations for LM% were fat thickness and muscle thickness both measured at the point 45 mm from the dorsal midline between the 2nd and 3rd last ribs when the HGP is used and fat thickness measured at the same point when the Intrascope is used.

Concerns regarding the PORCUS carcass classification system have risen as breeding goals have shifted towards producing heavier leaner carcasses in a sustainable manner (Merks *et al.*, 2012) since the introduction of the LM% prediction equations. These goals have resulted in the improvement of pig genotypes, nutrition regimens and management strategies; all of which allow animals to be taken to heavier body masses without negatively affecting the feed conversion ratio (FCR), meat quality traits and in the case of boars have decreased the risk of boar taint (Cisneros *et al.*, 1996; Correa *et al.*, 2006). The advances that have been made in genetics to meet consumer and market demands, have reduced the amount of backfat and improved the production efficiency of pigs (Merks *et al.*, 2012), as a result ‘new genotypes’ are being classified. Therefore, biases such as genotype, sex, weight and treatments (for example the use of ractopamine or performing immunocastration) may need to be accounted for as these factors could cause tissue distribution within the body to have changed and result in the inaccurate prediction of LM% (Gu *et al.*, 1992b; Hicks *et al.*, 1998).

Orcutt *et al.* (1990), Sather *et al.* (1991b) and Hicks *et al.* (1998) suggested that prediction equations should be updated or re-evaluated on a regular basis as to account for the advances made in improving/changing pig genotypes and for weight changes in the carcasses over time to ensure that the accuracy of the equations is maintained.

The PORCUS carcass classification system divides pig carcasses into classes based on backfat thickness and calculated LM% with WCM being used to break down the fat classes (P, O, R, C, U and S) further regardless of genotype and production system, making the system generic. Therefore, motivation for this study is that because pigs have become leaner due to the perceived preference of the consumer being leaner meat (Ngapo *et al.*, 2007) and due to the production of leaner and later maturing pigs is more monetary efficient as better FCR and growth rates are achieved, the result is that the primary producer is being rewarded twice for producing leaner pigs as a higher monetary value for a carcass is received if it falls within the preferred classes of the PORCUS carcass classification system. This may result in the introduction of biases when classifying pig carcasses, it may lead to certain classes in the carcass classification system being targeted and other classes not being used. This defeats the purpose of having a carcass classification system as it is supposed to present the meat industry and the consumer with a choice of various carcasses, and it may cause the variation between carcasses within a class to increase leading to meat products of inconsistent quality from the same class. Another problem is that with leaner and later maturing genotypes it is possible to take animals to heavier weights without the consequences of excessive fat deposition or a poor FCR (Cisneros *et al.*, 1996). Resulting in heavier carcasses (> 90 kg) being classified which could affect the accuracy of the prediction of carcass composition and the accuracy of a class to describe the carcasses because the study conducted by Bruwer (1992) was done on carcasses weighing 90 kg and less. Also, the prediction equations do not take bias created by treatment, although beyond the scope of this study, into consideration therefore with the use of Improvac®, for immunocastration, accuracy in determining Improvac® treated pig's composition needs to be studied. Inaccurate prediction equations can lead to over- or underestimation of LM% which will result in retailers overpaying or underpaying for carcasses.

1.2. Objective

The objective of this study is to determine whether the current pig carcass classification system in South Africa needs to be revised and if it is still able to reliably and accurately predict carcass composition. The study was divided into two parts where Part 1 was conducted in order to identify the existence of variation within and/or between carcass parameters by conducting data analyses on a dataset of carcasses that were classified according to the PORCUS carcass classification system at a selected abattoir. Part 2 consisted of physically measuring fat thickness (Fat, mm) and eye muscle area (EMA, cm^2) of selected carcasses to determine if any variation existed between and/or within carcass parameters of carcasses within selected weight clusters.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Carcass classification systems aim at relaying chosen carcass characteristics further along the meat value chain and back to the producer in order to promote communication and transparency between all industries and the consumer. This helps promote improved farming techniques by offering a higher monetary value for carcasses of a preferred standard. Which in turn has led to livestock with leaner later-maturing genotypes. Classification systems vary according to the needs of a specific country's meat industry. They also aim to provide the consumer with a range of meat products that differ according to carcass characteristics to fulfil consumer wants.

The European classification system determines predicted LM% with the use of a backfat measurement. The Australian pig grading system describes carcasses according to meat categories (brief description of weight and gender) and carcasses weighing ≥ 25 kg are further classified according to weight and backfat thickness. The United States grading system distinguishes between five different genders namely barrow, gilt, sow, stag and boar. The quality of lean and fat is determined along with the expected lean yield from each of the primal cuts: ham, loin, picnic shoulder and Boston butt.

The South African pig carcass classification system measures fat and muscle depth to determine LM% by way of regression equations. The classification system was derived by Bruwer (1992) and is currently under question as to whether it needs to be revised. The formulas used are descriptive and generic allowing for a wider variety of the pig population in South Africa to be accommodated without the introduction of bias. Concerns as to the reliability of the classification system have resulted due to improvements made within the industry, from the breeding level to the abattoir level. The improvements range from improved genetics, breeding programmes, feeding regimes, vaccination programmes, management strategies, infrastructure and technologies such as electrical stimulation, as all these factors may influence the quality and the level of consistency of this quality of the meat that reaches the consumer. The classification system does not take meat quality parameters such as age, marbling score, pH, lean and fat colour, firmness and texture into consideration.

The South African pig carcass classification system rewards producers for producing leaner pigs by putting a premium price on the leaner classes. Leaner pigs are more efficient to produce as the FCR will be smaller resulting in lower feed costs; rewarding the producer twice. The premium price on leaner classes has led to communal and small-scale farmers shunning the formal red meat sector as the indigenous breeds do not display the preferred carcass characteristics as do the exotic breeds, which may ultimately lead to contaminated meat entering the meat value chain through the informal sector (Soji *et al.*, 2015b).

Various factors influence carcass composition like intrinsic factors, such as age, body weight, gender and genotype, and by extrinsic (environmental) factors such as feeding regime, temperature, castration and the use of exogenous hormones which could lead to the redistribution of tissues in the body (Kouba & Sellier, 2011). For this reason, researchers have suggested that LM% prediction equations should be re-evaluated on a regular basis or be updated to ensure that bias from improving genotypes or treatments (for example the use of ß-agonists or immunocastration) are not introduced and the accuracy is not compromised (Orcutt *et al.*,1990; Sather *et al.*,1991b; Hicks *et al.*,1998). Grading probes should be recalibrated on a regular basis too to promote accuracy of the prediction equations.

2.2 The South African Pig Industry and Pork Value Chain

2.2.1 Pig industry

South Africa’s agricultural industry and in particular the pig industry is relatively small compared to other countries in the world. In comparison to China, one of the biggest pig producers in the world, South Africa’s pig population in 2016 comprised of 0.33% of China’s live pig numbers and 0.43% of their producing/slaughtered pig numbers (FAOSTAT, 2017).

In 2016, the agriculture, forestry, hunting and fishing industry contributed 2.4% to the annual gross domestic product (GDP) of South Africa. The livestock sector contributed 47% to the gross value of agricultural production, this amounts to a contribution of R116 729.3 million to the country. Pigs slaughtered in 2015/16 contributed 2.1% to the total gross value of agricultural production and 4.5% to the gross value of animal products, whereas, fowls, cattle and calves and sheep and goats slaughtered contributed 33.1%, 26.2% and 5.6% respectively towards the gross value of animal products (DAFF, 2017) further illustrating the small size of the South African pig industry.

Even though the South African pig industry is the smallest industry amongst cattle, poultry and sheep and goats (Table 2.1) it has the greatest potential for growth and is displaying this potential with an increase of 0.05% since 2010. The potential for growth that the pig industry has is important as the population in South Africa is currently 56.7 million and is expected to increase to 63.4 million by 2028 (FAOSTAT, 2017) therefore increasing profits will not be the only factor of importance to consider when improving the efficiency of meat production by maximising the output of each pig through increased slaughter weights but also providing a source of protein that could help feed the population. This potential for growth is also reflected in the BFAP (2016) report because according to the report, chicken and pork consumption is expected to exceed that of beef and sheep over the next decade. The BFAP (2016) report predicts a 37% increase in pork consumption from the base period (2013 – 2015) to 2025 while beef, chicken and sheep meat consumption is expected to increase by only 6%, 29% and 10%, respectively.

Table 2.1 and Figure 2.1 show how pig numbers have remained relatively constant; in 2000 the number of pigs was 1.6 million and has decreased to 1.5 million pigs in 2016. From 2000 to 2016 the number of pigs slaughtered a year has increased from 1.8 million to 3 million. The meat produced a year has increased from 106 900 tonnes in 2000 to 242 900 tonnes in 2016 (DAFF, 2017). This increase in meat production is because of increased slaughter weights (Figure 2.2) which is due to the selection of production traits in breeding programs and is a result of the selection of reproduction traits such as number born alive and number weaned. Pork consumption per capita has increased from 2.6 kg/year in 2000 to 4.8 kg/year in 2016 unlike sheep and goats which have declined from 3.6 kg/year in 2000 to 3.5 kg/year in 2016 (Table 2.1).

Table 2.1 Numbers of species alive, slaughtered and per capita consumption for 2000 and 2016 (Adapted from DAFF, 2017 unless stated otherwise)

Species	Number alive (million)		Number slaughtered (million)		Per capita consumption (kg/year)	
	2000	2016	2000	2016	2000	2016
Cattle	13.5	13.4	2.2	3.6	12.7	20.9
Pigs	1.7	1.5	1.9	3.0	2.6	4.8
Sheep and goats	25.9	22.3	5.9	6.9	3.6	3.5
Chickens	126.0*	172.8*	520.0*	1082.5*	21.5	40.0

*Figure is from FAOSTAT, 2017

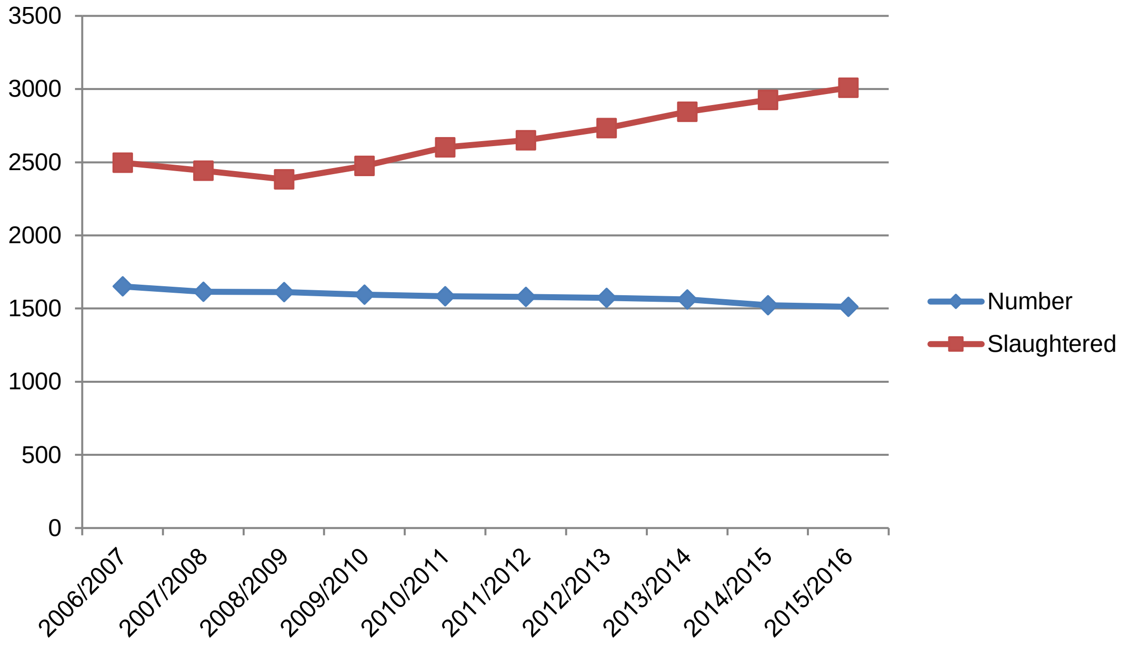

Figure 2.1 Number of live pigs and number of pigs slaughtered (1000) from 2006 to 2016 (Adapted from DAFF, 2017)

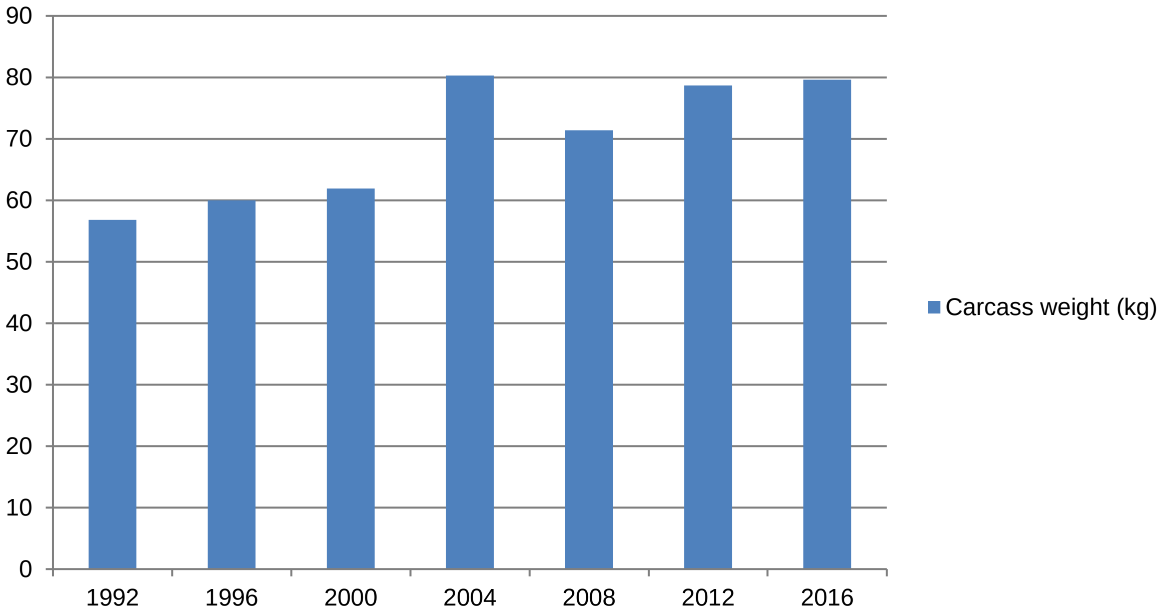

Figure 2.2 Pig carcass weights (kg) from 1992 to 2016 (Adapted from FAOSTAT, 2017)

Figure 2.3 illustrates that the consumption of pork over the past ten years has fluctuated but has remained above the amount of pork produced in the country, making South Africa a net importer of pork. Further illustrating the potential for growth that the South African pig industry has.

Davids *et al.* (2014) expressed that for pork consumption to keep increasing the industry needs to supply the consumer with an end product that is of a high quality and is affordable although the survey conducted by Oyewumi & Jooste (2006) showed the South African population prefer value-added pork products over fresh pork and pre-prepared foods even though the latter are cheaper options. Therefore Oyewumi & Jooste (2006) along with Davids *et al.* (2014) concluded that economic factors as well as non-economic factors influence pork consumption in South Africa and worldwide. These economic factors include the size and structure of the population, the consumer's income and the price of pork in relation to other meats while the non-economic factors are food safety, convenience, animal welfare, environmental concerns and health (Davids *et al.*, 2014).

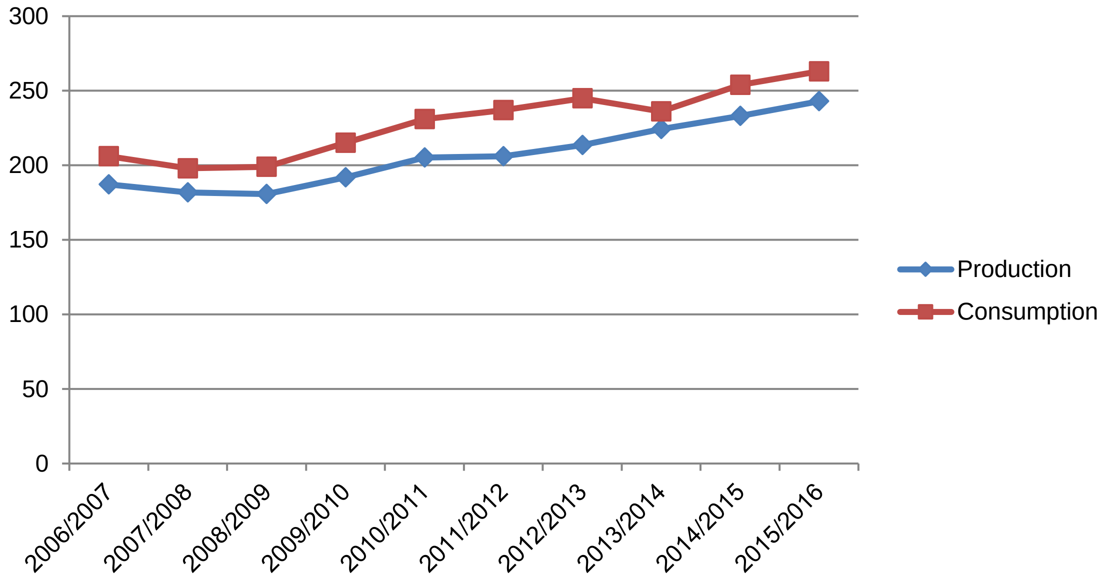

Figure 2.3 Pork production and consumption (1000 tonnes) from 2006 to 2016 (Adapted from DAFF, 2017)

Pig marketing channels for producers are public auctions where pigs require movement permits and identification (in the form of an ear tattoo). The price received depends on what the bidders are prepared to pay. Abattoirs, processors, speculators or local communities are other possible channels for producers to sell their animals to with the price offered, distance, availability and potential of the market being deciding factors (NDA, 2010). The market for pork is split into fresh meat (45%) and processed pork (55%). This split agrees with the survey conducted by Oyewumi & Jooste (2006) as it was shown that value-added pork products are favoured over fresh pork in South Africa. Roughly 70% of pigs produced are marketed on a contract basis with processors, this ensures that processors receive a constant supply of pigs that fulfil their production quotas and that the quality of the pigs delivered are of a certain standard that is consistent. The producer is guaranteed a stable negotiated price for an agreed period of time which helps to protect against daily variations in market price (Volker & Group, 2011).

The Government Notice No. R. 55 of 2015 has not stipulated distinct mass classes and corresponding carcass mass ranges but pigs are generally divided up, in agreement by the pig industry, into porkers and baconers and are further divided up for carcass auctions into the mass classes V, W, X, Y and Z where V and W are considered as porkers (< 60 kg) and X, Y and Z are considered as baconers (60 to 90 kg). In the previous grading system, carcass auctions had four mass classes, namely W, X, Y and Z where W had a mass range of 70.1 to 90.0 kg, X had a mass range of 56.0 to 70.0 kg, Y had a mass range of 40.1 to 55.0 kg and Z had a mass range of 20.1 to 40.0 kg (Bruwer, 1992). The W and X mass classes were considered as baconers and the Y and Z mass classes were considered as porkers. Pigs can also be divided up for contract sales into porkers (< 60 kg), light baconers (60 to 80 kg) and heavy baconers (81 to 90 kg) (NDA, 2010).

2.2.2 Pork value chain

A demand chain is a process that is consumer driven where the wants of the consumer are realised. A product meeting these demands is developed. A supply chain is a process that is production driven where raw materials are processed into products and then supplied to consumers. A value chain incorporates the principles of both a demand and supply chain and according to Spies (2011) creates a system that is able to predict possible future consumer demands and then satisfy those consumers' wants swiftly and efficiently, while making a profit and using a system that is sustainable. The South African pork value chain is vertically integrated at different levels of the value chain making it difficult to define or illustrate a straight forward plan that represents the entire pig industry. Companies work at different levels of the value chain to decrease input costs and ultimately decrease the cost of the final product.

The value chain covers input suppliers, primary breeders, pig producers (farrowing to finishing), abattoirs, processors, wholesalers, retailers, restaurants and butcheries and lastly the consumer. Input suppliers to pig producers are feed and nutritional companies, housing suppliers, equipment suppliers and pharmaceutical companies. The South African animal feed industry is divided into two sectors; a formal sector which is represented by the Animal Feeds Manufacturing Association (AFMA) and an informal sector that is represented by producers who mix feed themselves. Amongst the commercial pig producers 60 to 70% mix their own feed rations. This has the benefit of the diet being specific to the producers needs and to ensure that the dietary requirements for each stage of growth are met. The pig industry contributed to 4.1% of the total feed sales in 2015/2016 which is an increase of 1.3% since 2010/2011 (AFMA, 2016). It has become the general industry norm to assume that the feed cost could account for approximately 70 to 75% of the total cost of pig production, the fluctuations could be caused by factors such as interest rates.

Genetic material can be acquired from two breeding companies, Topigs Norsvin and Kanhym Estates, and 19 stud breeders. Therefore, it could be expected that variation between carcasses is low as limited genetic material sources would promote uniformity with less genetic diversity being seen across the pig population in South Africa. In a review by Notter (1999) it was mentioned that if the end products of animal production are standardized the genetic diversity within that animal population would be low as producers would shift breeding goals, which in this case would be similar, to produce animals that would fit the consumers and markets wants. Whereas, if the end products were diversified the genetic diversity within the animal population would be high as different breeding goals would be used to target different end products. So, the findings that majority of the pig carcasses are classified as either P or O (Hugo & Roodt, 2015; Soji *et al.*, 2015) could be in agreement with the previous statement or it could show that the end products are standardised (consumers want leaner meat).

Pig producers commonly run farrowing to finishing units on one premise where gilts and sows are artificially inseminated (AI) or given to the boar, with the earlier being the popular practice, sows farrow, piglets are weaned at 21 – 28 days, placed into grower houses from 70 days of age and then placed in finisher houses until slaughter, depending on the number of diets that would be productively efficient for the producer and the producer’s farming system. There are 150 abattoirs that are specialised to slaughter pigs out of 285 red meat abattoirs in South Africa and an estimated 4000 commercial pig farmers and 100 small hold farmers (DAFF, 2015), therefore forcing the producer to take the price offered by the abattoir.

At the processor level value is added to the product before it is sold to the retailer. In South Africa, two processing companies account for 80% of the market (Enterprise Foods and Eskort), here contracts are drawn up with producers to ensure the consistency of the quality of the pigs received by the processor, the producer is able to be a shareholder in the processing company therefore giving the producer the incentive to produce pigs with a standard of quality desired by the processing company. It also allows the producer to make an investment in state-of-the-art technology to help improve production (Davids *et al.*, 2014).

The pig industry is continuously evolving and expanding to meet the meat market and consumer demands, which change on a regular basis, to remain profitable (Davids *et al.*, 2014) and to consult the concerns surrounding the environment by shifting towards more sustainable practices of farming to minimize the agricultural ‘carbon footprint’ (Thornton, 2010). For these changes to occur the makeup of the pig has had to change along with the implementation of different systems. One such system is Pork 360, which is a quality assurance and traceability programme in South Africa. It is designed to give retailers and consumers peace of mind that pig producers and abattoirs are adhering to health and food safety standards to ensure that good quality meat is delivered, and that environment, welfare and biosecurity standards are being met. This is done by monitoring all procedures on the farms by auditing the farms on 12 objectives, this in turn can help producers increase profits by identifying sectors that could to be improved; decrease wastage and identify methods to increase production (Pork 360, 2018). The 12 objectives audited are:

1. Access control
2. Sanitary and hygiene requirements
3. Employees
4. Medication and vaccines management
5. Pest control
6. Waste management
7. Feeding and feed quality
8. Transport
9. Housing
10. Maintenance
11. Management and care
12. Measuring and monitoring

Studies have shown that modern genotypes are able to be slaughtered at heavier masses without significant effects on growth performance, lean meat yield or meat quality characteristics (Cisneros *et al.*, 1996). Due to the carcass yield increases and the improvement in the meat to bone ratio (Oliver *et al.*, 1993) the benefit of decreasing overhead costs along the value chain could also be seen, provided the payment system prefers leaner carcasses (Affentranger *et al.*, 1996).

2.3 Carcass Classification and Grading Systems

Carcass classification is a list of criteria which helps describe the composition and physical attributes of a carcass to prospective buyers thereby providing the buyer/consumer with a choice between different carcasses whereas carcass grading places carcasses into different categories based on value for pricing purposes and give a perceived indication of the meat quality (AHDB Industry Consulting, 2008; Webb, 2015). In short, carcass classification and grading systems were devised to describe carcass characteristics to facilitate trade (Polkinghorne & Thompson, 2010). Furthermore, carcass classification systems class carcasses together based on certain carcass features that have been decided upon; carcasses in the same class are similar in composition and quality. This decreases the amount of variation between carcasses and produces more consistent meat products (Webb, 2015).

The economic value of a pig carcass is determined by its mass, amount of subcutaneous fat and its LM% content (Irshad *et al.*, 2013). Accurate, simple and easy to apply carcass classification and grading systems should be applied which suit the current needs of the industry in order to relay the composition of a carcass to the pig value chain. A further reason for the carcass classification/grading systems to be applied quickly and efficiently is because the measurements are done on a moving slaughter line.

Carcass classification/grading systems have been established to create a form of communication that is understood throughout the supply chain to describe the quality and yield of a carcass. According to the report compiled by the Agriculture and Horticulture Development Board (AHDB) Industry Consulting (2008) carcass classification/grading systems should aid in facilitating trade to improve transaction efficiency for buyers’ specifications to be met. Consumer preferences can be communicated to and met by producers by supplying an increased monetary incentive for desirable stock and a discount for stock that is less desired which in turn will promote the improvement of livestock breeds, efficient animal production and carcass quality. Carcass classification/grading systems enable set prices for meat to be stated allowing producers, processors and consumers to buy and/or produce selectively according to economic standings and through better market transparency. Also, export markets can be developed.

2.3.1 European classification system

The EUROP pig carcass classification system (EU Reg No. 1308/2013) was introduced to the European Union in 1984 (Rotaru, 2015) and requires that abattoirs register with the Pig Carcase

Grading Scheme who has set out rules which need to be followed concerning how to dress, weigh and grade carcases. Dressing of the carcass can be done following the EU specifications or for UK abattoirs can be done following the UK specification. The EU specification states that the following needs to be removed from the carcass before it is weighed (Rural Payments Agency, 2014):

- Tongue
- Bristles (hair)
- Hooves
- Genital organs
- Flare fat
- Kidney
- Diaphragm

The UK specification differs in that the kidney, flare fat and diaphragm are left in the carcass and the tongue is optional as to whether it remains or not in the carcass. The carcasses are weighed on a scale within 45 minutes after slaughter and the actual measurement is recorded, no rounding off. Deductions are removed from the carcass weight based on how the carcass is presented (Table 2.2).

Table 2.2 The adjustment made to weight according the carcass that is presented (Adapted from Rural Payments Agency, 2014)

Carcass presentation	Deduction made
Carcass with kidneys, flare fat and diaphragm	- < 56 kg deduct 0.7 kg - 56.5 – 74.5 kg deduct 1.1 kg - ≥ 74.6 kg deduct 1.6 kg
Carcass with tongue	- Deduct 0.3 kg
Weighed >45 minutes after slaughter	- Deduct 0.1 % for each additional 15 minutes

The carcasses are visually inspected to identify carcasses with any faults such as deformities, blemishes, pigmented, coarse skin, soft fat, pale muscles and partially condemned (according to classification documents) and will be recorded as ‘Z’. Young boars will be recorded and carcasses with poor conformation will be recorded as ‘C’ (MLCSL, 2017)

The carcasses are graded by a classifier who uses one of five instruments to determine the backfat thickness and calculate the LM% of the carcass:

- Intrascope
- Fat-O-Meater
- Hennessy Grading Probe
- CSB Ultra-Meater
- AutoFom

The accuracy of the calibration for each instrument needs to be approved by the EU Commission (Olsen *et al.*, 2007).

The carcass is then given a class according to the corresponding LM% (Table 2.3) which is then stamped on to the carcass and recorded.

Table 2.3 The class and corresponding lean meat % of the EUROP pig carcass grading system (Adapted from EU Reg No. 1308/2013)

Class	Lean meat %
S	> 60
E	55 – 60
U	50 – 55
R	45 – 50
O	40 – 45
P	< 40

2.3.2 Australian grading system

The Australian pig carcass grading system follows descriptions/rules set out by the Aus-Meat Language which has been established to assist customers in accurately ordering the meat product that is desired. The descriptions have been designed to be used by each section in the meat value chain, for example the producer, the abattoir, boning rooms, wholesalers and food service organisations (Aus-Meat® Limited). For the standard carcase trim definition; the definition of a Pigmeat carcase is the body of a slaughtered porcine animal, and is not a sucker pork and has skin on, after:

- Bleeding
- Removal of all the internal digestive, respiratory, excretory, reproductive and circulatory organs
- Minimum trimming as required by meat inspection service for carcase to be passed fit for human consumption

And the removal of the:

- Hair and scurf
- Hooves of the foretrotters and of the hindtrotters
- Testes and penis
- Ears, eyelids/lashes, facial hair and tongue
- Kidneys and kidney fat

Pig carcasses will first go through a carcase trim, of which there are 24 trim combinations that the abattoir can follow, there are 24 options for carcasses ≤ 60 kg (Table 2.4) and 24 options for carcasses > 60 kg (Table 2.5). Aus-Meat accredited abattoirs can choose the best trim for a carcass. However, the operator is required to record the weight of the carcass according to the Standard Carcase Definition for example Trim No. 3 as each trim has a conversion factor which will be used to calculate the final weight of the carcass:

Scale weight (kg) x conversion factor = Standard Carcase Weight (kg)

Table 2.4 Standard Carcase Conversion Factor Grid for WCM 60 kg and under (Adapted from Aus-Meat® Limited)

Trim number	Head	Flares	Foretrotters	Hindtrotters	Max* Scale Weight (kg)	Conversion Factor
1	On	In	On	On	60.0	1.000
2	On	Out	On	On	59.0	1.012
3	On	In	Off	On	59.5	1.011
4	On	In	On	Off	59.5	1.011
5	On	Out	Off	On	58.5	1.023
6	On	Out	On	Off	58.5	1.023
7	On	In	Off	Off	59.0	1.022
8	On	Out	Off	Off	58.0	1.035
9	Off	In	On	On	56.0	1.078
10	Off	Out	On	On	55.0	1.092
11	Off	In	Off	On	55.5	1.091
12	Off	In	On	Off	55.5	1.091
13	Off	Out	Off	On	54.5	1.105
14	Off	Out	On	Off	54.5	1.105
15	Off	In	Off	Off	55.0	1.104
16	Off	Out	Off	Off	54.0	1.120
17	Skull out	In	On	On	57.0	1.057
18	Skull out	Out	On	On	56.5	1.071
19	Skull out	In	Off	On	56.5	1.070
20	Skull out	In	On	Off	56.5	1.070
21	Skull out	Out	Off	On	56.0	1.083
22	Skull out	Out	On	Off	56.0	1.083
23	Skull out	In	Off	Off	56.0	1.082
24	Skull out	Out	Off	Off	55.0	1.096

*Maximum weight for which conversion factors apply

Table 2.5 Standard Carcase Conversion Factor Grid for WCM over 60 kg (Adapted from Aus-Meat® Limited)

Trim number	Head	Flares	Foretrotters	Hindtrotters	Min* Scale Weight (kg)	Conversion Factor
1	On	In	On	On	60.1	1.000
2	On	Out	On	On	59.1	1.014
3	On	In	Off	On	59.6	1.009
4	On	In	On	Off	59.6	1.009
5	On	Out	Off	On	58.6	1.023
6	On	Out	On	Off	58.6	1.023
7	On	In	Off	Off	59.1	1.019
8	On	Out	Off	Off	58.1	1.033
9	Off	In	On	On	56.1	1.073
10	Off	Out	On	On	55.1	1.089
11	Off	In	Off	On	55.6	1.084
12	Off	In	On	Off	55.6	1.084
13	Off	Out	Off	On	54.6	1.100
14	Off	Out	On	Off	54.6	1.100
15	Off	In	Off	Off	55.1	1.095
16	Off	Out	Off	Off	54.1	1.110
17	Skull out	In	On	On	57.1	1.051
18	Skull out	Out	On	On	56.6	1.066
19	Skull out	In	Off	On	56.6	1.061
20	Skull out	In	On	Off	56.6	1.061
21	Skull out	Out	Off	On	56.1	1.076
22	Skull out	Out	On	Off	56.1	1.076
23	Skull out	In	Off	Off	56.1	1.071
24	Skull out	Out	Off	Off	55.1	1.087

*Minimum weight for which conversion factors apply

The pig carcasses are further divided up into basic categories and alternative categories of which the descriptions can be seen in Table 2.6. The secondary sex characteristics are defined by:

- Tusks
- Scutum or shield on the forequarter
- Strong sexual odour
- Thickness of skin
- Pronounced protractor muscle

Table 2.6 Australian pig meat categories (Adapted from Aus-Meat® Limited)

Basic categories	
Pork “P”	Female (gilt), Barrow or entire male pigs: • Female show no evidence of milk secretion • Males show no evidence of secondary sex characteristics
Sow Pork “SP”	Female pig with milk secretion
Boar Pork “BP”	Male pigs showing signs of secondary sex characteristics
Alternative categories	
Sucker Pork “SUK”	Pigs weighing up to 35 kg (WCM)
Gilt Pork “GP”	Female pig showing no evidence of milk secretion
Gilt Light Pork “GLP”	Female pig weighing up to 60 kg (WCM) and showing no evidence of milk secretion
Gilt Heavy Pork “GHP”	Female pig weighing more than 60 kg (WCM) and showing no evidence of milk secretion
Barrow Pork “BAP”	Barrow male pig showing no signs of secondary sex characteristics
Barrow Light Pork “BLP”	Barrow male pig weighing less than 60 kg (WCM) and showing no evidence of secondary sex characteristics
Barrow Heavy Pork “BAHP”	Barrow male pig weighing more than 60 kg (WCM) and showing no evidence of secondary sex characteristics
Male Light Pork “MLP”	Entire male pig weighing less than 60 kg (WCM) and showing no evidence of secondary sex characteristics
Male Heavy Pork “MHP”	Entire male pig weighing more than 60 kg (WCM) and showing no evidence of secondary sex characteristics

Pig carcasses that weigh 25 kg or more are further classified according to their WCM (kg) and Fat (mm) at the P2 site (Table 2.7).

Table 2.7 Australian pig carcass weight and fat classification grid (Adapted from Aus-Meat® Limited)

Weight Class	WCM (kg)	Fat class ciphers (mm)					
		0	1	2	3	4	5
A	25.1 – 35	< 7	7	8 – 9	10 – 12	13 – 17	18+
B	35.1 – 40	< 7	7	8 – 10	11 – 13	14 – 18	19+
C	40.1 – 45	≤ 7	8	9 – 11	12 – 14	15 – 19	20+
D	45.1 – 50	≤ 7	8 – 9	10 – 12	13 – 15	16 – 20	21+
E	50.1 – 55	< 7	8 – 10	11 – 13	14 – 16	17 – 21	22+
F	55.1 – 60	< 7	8 – 11	12 – 14	15 – 17	18 – 22	23+
G	60.1 – 65	≤ 7	8 – 12	13 – 15	16 – 18	19 – 23	24+
H	65.1 – 70	≤ 7	8 – 13	14 – 16	17 – 18	19 – 24	25+
I	70.1 – 75	< 7	8 – 14	15 – 18	19 – 20	21 – 25	26+
J	75.1 – 80	< 7	8 – 15	16 – 18	19 – 21	22 – 26	27+
K	80.1 – 85	≤ 7	8 – 16	17 – 19	20 – 22	23 – 27	28+
L	85.1 – 90	≤ 7	8 – 17	18 – 20	21 – 23	24 – 28	29+
M	90.1 +	≤ 7	8 – 18	19 – 21	22 – 24	25 – 29	30+

2.3.3 United States grading system

The United States Standards for Grades of Pork Carcasses had been revised and the updated version was introduced in 1985. The pork carcass grade standards allow for the division of pig carcasses into class, which is the sex condition of the animal at the time of slaughter and into grade, which states the quality and yield of lean cuts for a carcass. Five different classes of pig carcasses are distinguished between, namely, barrow, gilt, sow, stag and boar. Grading is only provided for barrows, gilts and sows.

Grading of barrow and gilt carcasses has two considerations to take into account:

1. Quality of the lean and fat tissue
2. Expected lean yield from each of the primal cuts: ham, loin, picnic shoulder and Boston butt

The quality of the lean is measured using two scores (Acceptable and Unacceptable) by viewing a major muscle (such as the loin muscle at the 10th rib) where a surface cut was made (if a surface cut is not possible the quality of the lean is judged indirectly on the firmness of the fat and lean), amount of feathering between the ribs and the colour of the lean. Barrow and gilt carcasses with unacceptable quality lean or with soft and/or oily fat are graded U.S. Utility. The barrow and gilt carcasses which are deemed to have acceptable lean quality and acceptable belly thickness will be given one of four grades (Table 2.8) based on the amount of LM% of the four primal cuts.

Table 2.8 Grades for barrows and gilts in the USDA system of grading pig carcasses (Adapted from United States Department of Agriculture, 1985)

Class	Yield (LM%)	Back fat thickness (inches)
U.S. No. 1	> 60.4	< 1.00
U.S. No. 2	57.4 – 60.3	1.00 – 1.24
U.S. No. 3	54.4 – 57.3	1.25 – 1.49
U.S. No. 4	< 54.4	> 1.49

The degree of muscling, which is a subjective evaluation, is also taken into consideration with barrow and gilt carcasses and there are three degrees of muscling identified; thick (superior), average and thin (inferior). Carcasses with average muscling will be graded according to back fat thickness at the last rib, carcasses with thin muscling will be graded one grade lower than according to the backfat thickness at the last rib and carcasses with thick muscling with be graded one grade higher than according to the backfat thickness at the last rib (Table 2.8).

Grade (barrow or gilt) = (4.0 x fat thickness at last rib in inches) (1.0 x muscling score)

Where the muscling score is as follows:
1 = thin
2 = average
3 = thick

The standards of the grades for sows are dependent upon the differences between yield of fat cuts and lean cuts of the primal cuts and the difference in quality of cuts. Cuts are used to provide sows with grades because the yields of cuts from carcasses with the same fat thickness are approximately the same even if the carcasses are from a wide range of masses.

The U.S. No. 1 grade carcass has the minimum amount of fat to produce cuts of acceptable palatability and its lean cuts usually equal 48% or more than the carcass mass. The grades U.S. No. 2 and 3 have lean cuts that average 45 to 48% and below 45% of the carcass mass, respectively and therefore have more fat than the U.S. No. 1 (Table 2.9).

The medium grade carcass has a low amount of fat that is linked to poor palatability and the fat lacks firmness. The cull grade carcass has less fat which is soft and has poor palatability. The fat thickness ranges for each of the sow grades is shown in Table 2.9 of which average back fat thicknesses are used.

Table 2.9 Grades for sows in the USDA system of grading pig carcasses (Adapted from United States Department of Agriculture, 1985)

Class	Average back fat thickness* (inches)	% Carcass mass of lean cuts
U.S. No. 1	1.5 – 1.9	> 48
U.S. No. 2	1.9 – 2.3	45 – 48
U.S. No. 3	> 2.3	< 45
Medium	1.1 – 1.5	**
Cull	< 1.1	***

*Average of three measurements, skin included, made opposite first and last ribs and the last lumbar vertebrae
**A % carcass mass of lean cuts value was not specified but was described as being moderately high
***A % carcass mass of lean cuts value was not specified but was described as being high

2.3.4 South African grading system

In the review by Webb (2015) it was explained that from 1944 to 1992, South Africa used a grading system which has since been replaced by a carcass classification system in order to promote better quality meat products which satisfy the consumer's preferences and to keep that quality at a consistent level. The pig carcass grading system made use of eight grades; Suckling pig, Super, Grade 1, Grade 2, Grade 3, Sausage pig, Rough 1 and Rough 2 (Government Notice No. R. 2120 of 1985) (Table 2.10). Table 2.10 shows the grades and their corresponding conformation score, cold carcass mass and back fat thickness measurements except for the grades, Grade 3 and Rough 2. According to the Government Notice No. R. 2120 of 1985 a pig carcass shall be graded as Grade 3 when it:

- Has a mass of > 55 kg (excluding boars)
- Has fat that is excessively oily in appearance
- Is a sow or is visibly pregnant
- Has received a damage class of 3
- Has a backfat thickness that exceeds the maximum back fat thickness for the corresponding cold carcass mass described for Grade 2.

A pig carcass would have been graded as Sausage if it was a barrow that did not display any signs of late castration or if it was a sow. The carcass of a boar or barrow, that showed signs of late castration, that was between 55 – 90 kg and could have been graded as either Super or Grade 1 would be graded as Rough 1. If a carcass met the standards of a specific grade but had any of the following problems, it was unattractive in appearance, not well developed or had black seed or dark hair in the skin it would have been given the grade lower than the one it met the standards of (for example a carcass who meets the standards for grade Super but is unattractive in appearance would receive the grade Grade 1). The grade Rough 2 was given to a carcass that could not meet the standards of the other grades.

Table 2.10 Grades for pig carcasses with the corresponding conformation score, cold carcass mass (kg) and back fat thicknesses (mm) (Adapted from Government Notice No. R. 2120 of 1985)

Grade	Conformation score	Cold carcass mass (kg)	Back fat thickness (mm)
Sucking pig	2 – 5	< 21	*
Super	3 – 5	21 – 40	5 – 10
		41 – 55	5 – 13
		56 – 70	5 – 17
		71 – 90	5 – 20
Grade 1	3 – 5	21 – 40	0 – 12
		41 – 55	0 – 16
		56 – 70	0 – 22
		71 – 90	0 – 26
Grade 2	2 – 5	21 – 40	0 – 15
		41 – 55	0 – 19
		56 – 70	0 – 25
		71 – 90	0 – 30
Grade 3	*	*	*
Sausage pig	2 – 5	> 90	*
Rough 1	3 – 5	56 – 90	*
Rough 2	*	*	*

*Values are not specified

The grading system raised concerns in the pig industry due to the following main reasons; ‘overfatness of pig carcasses, inaccuracy of the Intrascope, the uneven distribution of fat over the carcass causing less reliable grading, the use of the P2-fat measurement and carcass mass as the main criteria in the pig carcass grading system and discrimination against boar carcasses’ (Bruwer, 1992). Bruwer (1992) found that the amount of variation within a grade covered a wide range of fat thickness; range of fat thickness for all porkers, for porkers of the grade Super and for baconers of the grade Super was 4 to 28 mm, 5 to 13 mm and 6 to 20 mm, respectively. The average fat thickness of all porkers, porkers of the grade Super and baconers of the grade Super was 13.9 mm, 11.5 mm and 16 mm, respectively. This highlighted the lack of consistency regarding quality of the products customers were required to choose from. The grading system did not offer any incentives for producers to produce the leaner pigs that the consumer prefers.

2.4 South African Pig Carcass Classification System

2.4.1 Background

Bruwer (1992) conducted a study to determine which carcass parameters could accurately predict the LM% of a carcass and which could easily be applied to a carcass classification system by taking measurements of the carcass parameters using the Intrascope, HGP and callipers. The site on the carcass that results in the most accurate estimate of LM% was also determined.

The study focused on fat and muscle thickness, body measurements, genotype and gender as being possible predictors of LM% of a carcass. Boars, barrows and gilts of four different known genetic backgrounds were raised in a controlled environment until live masses of 53, 68, 87 and 110 kg were reached at which point the pigs were slaughtered. Warm carcass mass, fat thickness at various locations (Figure 2.4) taken 45, 60 and 80 mm from dorsal midline using both the HGP and Intrascope (as one of the problems the industry had with the grading system, as mentioned before, was the concern of the inaccuracy of the Intrascope to measure fat thickness measured at the last rib 60 mm from the dorsal midline) and muscle thickness at the same locations using the HGP were recorded. After 24 hours the fat thickness measurements were repeated, and callipers were used to record the midline measurements. One shoulder, one midback and three loin fat thickness measurements were recorded along with the length of the carcass, the length of the ham and the length and depth of the eye muscle at the last rib. The right side of the carcass was jointed into six cuts; each cut was dissected into lean, subcutaneous fat and bone to determine the composition of the carcass and each cut. Various statistical procedures such as averages, standard deviations, analysis of variances, regression analysis and stepwise regression analysis were carried out on the data recorded. Harvey's model 1 was used to test if genotype or gender influenced the prediction equations.

The results of the simple linear regression analyses showed that the best fat thickness (mm) measurement to use to predict LM% was taken between the 2nd and 3rd last ribs, 45 mm from the dorsal midline using the Intrascope (RSD = 2.19 and $R^2 = 0.60$) and the HGP (RSD = 2.33 and $R^2 = 0.55$). However, the best muscle thickness measurement to use to predict LM% taken with the HGP was taken between the 5th and 6th last ribs, 45 mm from the dorsal midline (RSD = 3.33 and $R^2 = 0.08$) but is not as accurate as either of the Intrascope or HGP's fat thickness (mm) measurements in predicting LM% and therefore should not be used alone. It was concluded that the best point to measure fat thickness to predict LM% was 45 mm from the dorsal midline between the 2nd and 3rd last ribs for both instruments and that the Intrascope's fat measurement was 0.14% more accurate than the HGP's fat measurement in predicting LM%. The study by Hambrock (2005) agreed that the site between the 2nd and 3rd last ribs is the best location to determine an accurate estimate of LM%.

The results of the stepwise regression analysis showed that including three fat thickness (mm) measurements taken with the HGP or two fat thickness (mm) measurements taken with the Intrascope in the prediction equation the accuracy would increase by 2%. Although the increase in accuracy would be beneficial it would be impractical and time consuming to take more than one fat thickness measurement on a moving slaughter line. Therefore, it was decided that it is not feasible to include more than one fat thickness (mm) measurement in the LM% prediction equations.

Genotype and sex showed significant differences ($P < 0.05$) when predicting LM% using the HGP, but the interaction of genotype and sex was not significant. The Intrascope had similar results and it was therefore decided to exclude genotype and sex from both prediction equations. Including WCM (kg) in the regression equations did not improve the accuracy of the prediction of LM% and was excluded from the final prediction equations for both HGP and Intrascope. Like Bruwer (1992), Sather *et al.* (1991b) and Goenaga *et al.* (2008) found that carcass weight and gender improved the prediction of lean slightly when using the HGP therefore agreeing that carcass weight and gender could be left out of the equation with little overall economic significance. Sather *et al.* (1991b) study resulted in no effect on RSD or the accuracy of the prediction of lean of a carcass when WCM (kg) was included.

The following prediction equations were formulated during the study and are currently being used to predict the LM% of a pig carcass:

HGP: $\text{LM\%} = 72.5114 - (0.4618X_1) + (0.0547X_2)$; (RSD = 1.23% and $R^2 = 0.71$)

Where:
X_1 = fat thickness measured between the 2nd and 3rd last ribs, 45 mm from the dorsal midline of the carcass
X_2 = muscle thickness measured at the same position

Intrascope: $\text{LM\%} = 74.4367 - (0.4023X_1)$; (RSD = 1.25% and $R^2 = 0.69$)

Where:
X_1 = fat thickness measured between the 2nd and 3rd last ribs, 45 mm from the dorsal midline of the carcass

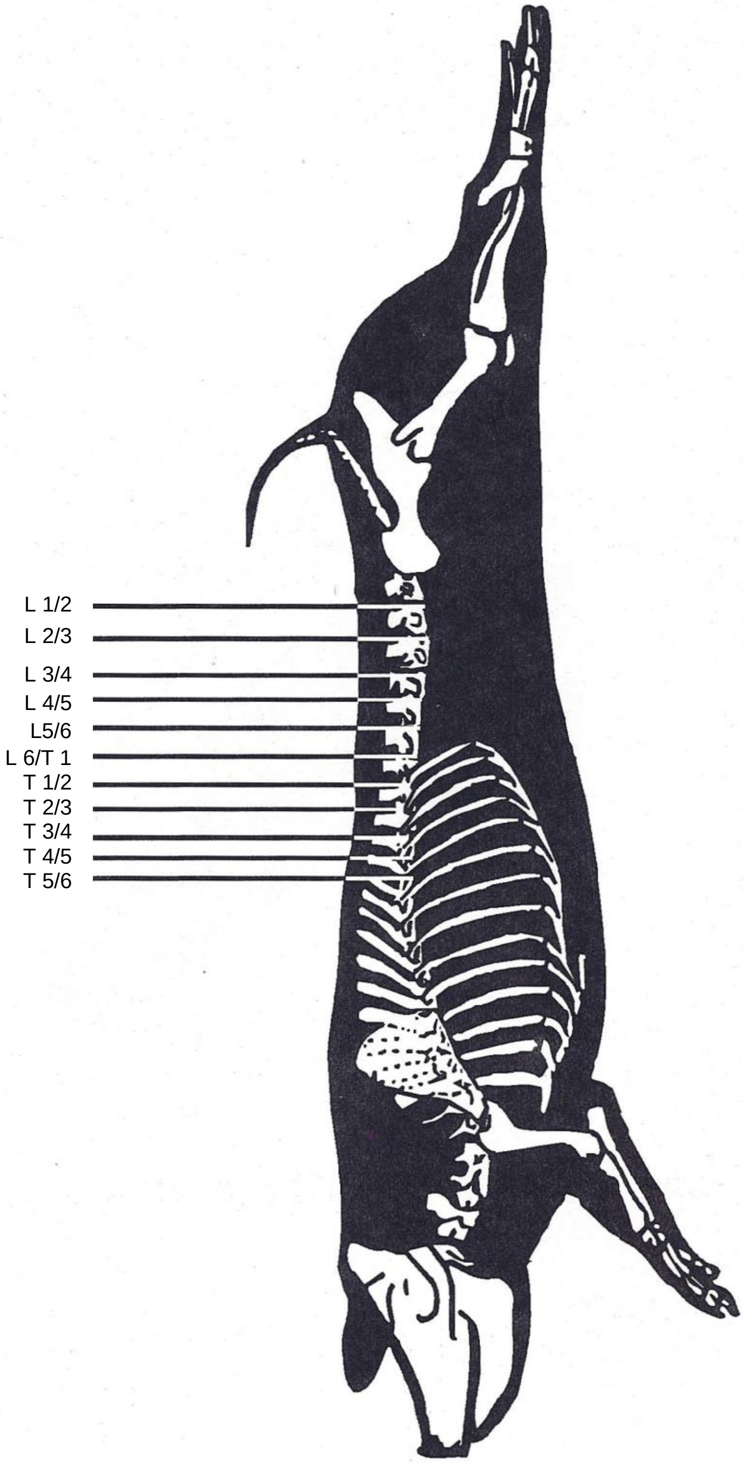

Figure 2.4 Locations of fat thickness measurements recorded (From Bruwer, 1992)

2.4.2 Current regulations for classifying pig carcasses in South Africa

The regulations regarding the classification and marketing of meat intended for sale in the Republic of South Africa in terms of the Government Notice No. R. 55 of 2015 described the classification of pig carcass characteristics as follows:

Pig carcasses shall be classified on the day of slaughter as one of nine classes; “Sucking pig”, “Class P”, “Class O”, “Class R”, “Class C”, “Class U”, “Class S”, “Sausage pig” or “Rough” and the classification shall be done on the whole carcass or on a side. The classes and the corresponding LM%, measured fat thickness (mm) and mass ranges are shown in Table 2.11.

The LM% of the carcass is calculated after the fat thickness and muscle thickness have been measured by either the HGP or Intrascope while the carcass is in a hanging position using the prediction equation (as seen above) suited to the device used. The resulting prediction of LM% will be rounded to the last integer before the carcass is classified. A pig carcass shall be classified as a “Rough” when:

- The conformation class is 1 (Table 2.11)
- The appearance is poor due to poor breeding characteristics
- The carcass is emaciated
- Appearance of skin is noticeably thick and rough
- Fat appears excessively oily

Table 2.11 Classes for pig carcasses and the corresponding calculated LM%, fat thickness (mm) and mass ranges (kg) (adapted from Government Notice No. R. 55 of 2015)

Class	Calculated LM%	Fat thickness measured* (mm)	Mass range (kg)
Sucking pig	**	**	≤ 20.0
P	≥ 70	1 to 12	20.1 – 100
O	68 to 69	> 12 to 17	20.1 – 100
R	66 to 67	> 17 to 22	20.1 – 100
C	64 to 65	> 22 to 27	20.1 – 100
U	62 to 63	> 27 to 32	20.1 – 100
S	≤ 61	> 32	20.1 – 100
Sausage pig	**	**	≥ 100.1
Rough	**	**	***

*Fat thickness measured by either the Intrascope or HGP
**Lean meat % or fat thickness (mm) is not specified for these classes
***Mass range (kg) is not specified for these classes

Each pig carcass is also given a conformation score which is a visual assessment conducted by the classifier and is described in Table 2.12. The extent of damage to a carcass is ranked on a scale of one to three as follows:

- Class 1 – slightly damaged
- Class 2 – moderately damaged
- Class 3 – severely damaged

Table 2.12 Conformation classifications of bovine, sheep, goat and pig carcasses (adapted from Government Notice No. R. 55 of 2015)

Description of carcass in terms of conformation	Conformation class
Very flat	1
Flat	2
Medium	3
Round	4
Very round	5

Carcasses are marked with stamps for easy identification of the conformation, damage, masculinity (boars and barrows, which show signs of late castration, shall be marked) and class, which are in different colour inks and have different placements on the carcass depending on the corresponding score of each characteristic (Table 2.13). It is important that the abattoir identification code is visible on both sides of the carcass in purple ink.

Meat classifiers are provided by an independent company such as IMQAS (International Meat Quality Assurance Systems), SAMIS (South African Meat Industry Services) and AFS (Agency for Food Safety), who ensure that the correct training procedures are followed for the meat classifier to be qualified in the classifying and marking of carcasses according to the regulations set forth by the Government Notice No. R. 55 of 2015. This ensures that the meat classifier has no association with the abattoir and avoids the services from being prejudiced (Klingbiel & Burger, 2014). Meat classifiers arrive at the abattoir in the morning before the slaughtering process begins to check that the ink is clean and that there is enough for the stamps and that the probe and scale work and are linked to the computer system. The classifier is stationed at the end of the slaughter line, where the scale is located, on a raised platform.

Table 2.13 Stamp markings placed on different pig carcasses (adapted from Government Notice No. R. 55 of 2015)

Carcass characteristics	Class	Stamp mark	Ink colour	Placement of stamp on carcass
Conformation	1	1	Green	One side
	2	2		
	3	3		
	4	4		
	5	5		
Damage	1	1	Brown	Indicate damaged area
	2	2	Red	
	3	3	Black	
Masculinity	Male	M/D	Black	Each side
Sucking pig	Sucking pig	S	Purple	Forehead
Percentage meat	P	P	Purple	Each side
	O	O		
	R	R		
	C	C		
	U	U		
	S	S		
Sausage pig	Sausage pig	W	Purple	Each buttock
Rough	Rough	RU	Black	Each side

2.5 Concerns surrounding the South African Pig Carcass Classification System

Since 2009 concerns regarding the South African carcass classification system have arisen. These concerns have developed from the changes that had been made to improve livestock production efficiency through improved genotypes, better feeding plans and use of growth promotants. Production systems have been shown to influence growth and carcass composition. Abattoirs are not standardized therefore making post mortem practices differ between abattoirs, for example the use of electrical stimulation. The communique had on the beef and lamb/mutton meat carcass classification system by the Red Meat Industry Forum (RMIF) in 2016 illustrates these advancements by highlighting that beef carcasses have increased in mass from 210 kg in 1993 to 266 kg in 2003, that growth promotants are more widely used in both an extensive and intensive setting, that carcasses have increased in lean content therefore resulting in decreased fat content and that processing techniques of abattoirs and retailers have changed. In comparison to pigs, Figure 2.2 has displayed that pig carcasses have also increased in weight; 56.8 kg in 1992 to 79.6 kg in 2016. These factors affect the meat quality causing variation within a class to increase in terms of meat quality and resulting in the consumer not being guaranteed of the quality of the meat purchased. However, the Red Meat Industry in South Africa has stated that the carcass classification systems are used to describe specific characteristics of the carcass and is not used for quality assurance (RMIF, 2016).

Another issue raised by Soji *et al.* (2015b) was that communal and small-scale farmers prefer not to market their livestock through abattoirs as the red meat classification system prefers the carcass characteristics of exotic breeds over indigenous breeds therefore denying the producer a premium price for their animals. With these communal and small-scale farmers selling their animals through alternative channels, food health safety may be jeopardized as contaminated or sick animals may be introduced into the food chain. Therefore Soji *et al.* (2015b) recommended that research and development efforts be initiated to overcome the marketing constraints faced by communal and small-scale farmers, and so that formal marketing of communal livestock can be established.

Quality is not a parameter that is considered or measured in the PORCUS carcass classification system, making it a descriptive tool used to determine the value of a carcass based on a few carcass characteristics which are relayed to the middleman and not the consumer (Soji & Muchenje, 2017). Thereby also putting the transparency of the PORCUS carcass classification system under question.

A cheap and quick way of recording the quality of a carcass is by determining the age of the animal, as seen with the other red meat carcass classification systems where age is determined by the number of teeth present. As increased age has been linked to increased toughness of the meat (Shorthose & Harris, 1990; Schönfeldt & Strydom, 2011). Physiological age of the animal is linked to tenderness of the meat produced. Casey & du Toit (2015) suggested, based on research done by Coetzee & Casey (2009) where it was concluded that despite the genotype or level of nutrition, puberty was achieved at a certain level of body fat, that the dentition of a pig could be used to identify its physiological age (Table 2.14) and therefore, with research, be introduced as a quality parameter in a classification system.

Table 2.14 Eruption of pig teeth at different ages and associated physiological age reference (Adapted from Muylle, n.d.; Casey & du Toit, 2015)

Teeth	Age	Physiological age reference
Di_1	3 – 4 weeks	Pre-pubertal
Di_2	2 – 3 months	Pre-pubertal
Di_3	Before birth	Pre-pubertal
Dc	Before birth	Pre-pubertal
Dp_2	4 – 6 weeks	Pre-pubertal
Dp_3	1.5 months	Pre-pubertal
Dp_4	1 – 5 weeks	Pre-pubertal
P_1	5 months	Pubertal changes
M_1	4 – 6 months	Pubertal changes
C	6 – 10 months	Early adolescence
M_2	8 – 12 months	Early adolescence
I_3	8 – 10 months	Adolescence
I_1	12 – 15 months	Adolescence
P_2	12 – 15 months	Adolescence
P_3	12 – 15 months	Adolescence
P_4	12 – 15 months	Adolescence
M_3	12 – 18 months	Adolescence
I_2	16 – 20 months	Approaching adulthood

Although, research has also shown that due to advancements made in the field of nutrition with regard to the use of growth promotants or with the advancements made in technology, for example electrical stimulation, age of the animal may no longer be a reliable way of predicting quality of the meat in terms of tenderness. A study conducted by Soji & Muchenje (2016) analysed cattle carcasses of different genotypes, and it was found that within genotype the meat quality of B- (1 to 6 incisors) and C-class (7 to 8 incisors) carcasses were the same.

New developments are under way in the hopes to find an accurate, easy to apply and reliable way to estimate quality such as the study conducted by Moloto *et al.* (2015) where proteomics was looked at as a possible way to help identify protein markers that could be associated with meat quality attributes; Warner Bratzler shear force, sarcomere length, myofibril fragmentation and calpain system, water holding capacity and drip loss.

Also, the quality of the fat is not taken into consideration in the PORCUS carcass classification system as a study by Hugo & Roodt (2015) shows that the quality of the fat in the preferred fat classes in South Africa (P and O) are below international standards and that only pigs in the R, C, U and S classes are more likely to have a fat quality that is perceived as good. Researchers have explained that nutrition, age, BW, gender, breed, genotype and use of hormones can influence the composition of fat (Cameron & Enser, 1991; Bruwer, 1992; Rehfeldt *et al.*, 1994; Bosch *et al.*, 2012 Wood *et al.*, 2013). For example, due to the selection for leaner genotypes the fatty acid profile of fat in pigs has shifted to one that contains more PUFA (Wood *et al.*, 2008). This will influence the technological cutting properties of the meat as splitting of the fat from the underlying muscle will occur more frequently, the fat is softer, has an oily appearance and has a decreased shelf life causing losses for the processing industry (Hugo & Roodt, 2007). Work done by Sheard *et al.* (2000) found PUFA in the diet to have no significant effect on the flavour or on the shelf life of pig meat. Therefore, Hugo & Roodt (2015) suggested that two pig carcass classification systems be put in place; one for the processing industry and one for the fresh meat market.

Although adding a meat quality parameter into a classification system is a concern for some, others have stated that it would cost too much to implement in South Africa but if a cost-effective method that was easy to apply to a moving slaughter line was developed, all abattoir practices would need to become standardized as pre-slaughter and post-slaughter handling practices can influence meat quality. Therefore, making it unfair to penalise producers for unfavourable meat quality if they are not the only party who could be responsible for the meat quality at the end (Bruwer, 1992).

Conformation score is a visual evaluation of the build and shape of a carcass; how well formed and blocky the fore- and hindquarters are. Conformation score is positively correlated to the lean to bone ratio and muscle thickness in mixed breed populations (Kempster *et al.*, 1982). Kempster *et al.* (1982) had some concerns that problems could arise with the use of a conformation score such as, different countries could allot a different numbering system which would make comparing different studies difficult, more emphasis could be placed on different parts of the body for example the hind quarters and because it is a visual assessment error could be introduced by the assessor. Although none of these concerns are reasons for questioning the use of conformation score in the South African carcass classification systems instead the existence of less variability between carcasses is a cause for concern especially for sheep (RMIF, 2016). But it is still considered useful as some consumers buy in bulk and will visually select a carcass that will meet the standards that they require by use of the conformation of the carcass (SAMIC, 2006).

Majority of carcasses fall in the P and O classes as these classes have preferred leanness and therefore receive a higher monetary value which has led to the carcass classification system being used more as grading system than a classification system (Webb, 2015).

There is speculation that the amount of variation within a class has increased due to the advances made in improving breeds, production systems, feedstuffs and growth enhancing technologies (Webb, 2015).

Although, the class cannot be placed on the packaging of the final product as this would then make it a grading system as some classes would be preferred over others and measuring quality in the abattoir is considered too expensive currently to be placed within the South African carcass classification system, other methods of benefiting the consumer should be explored. Schönfeldt & Hall (2015) suggested implementing unique branding for meat with various qualities which could target different preferences of consumers therefore promoting the sale of more meat.

As previously stated, various researchers have advised that prediction equations should be revised on a regular basis to ensure that the accuracy of the prediction of LM% is maintained as changes regarding advancements made in all aspects of animal production could then be accounted for. One of the advancements, mentioned earlier, is that modern genotypes are able to be taken to heavier masses without forfeiting the lean yield produced (Cisneros *et al.*, 1996) and it can be seen in the research conducted by Hugo & Roodt (2015). Where the maximum WCM of all the pigs classified to PORCUS was 97.5 kg. This may introduce bias as Bruwer (1992) formulated the LM% prediction equations using carcasses weighing ≤ 90 kg. Sather *et al.* (1991a) stated that although breed bias is small it enforces the fact that prediction equations should be re-evaluated on a regular basis while pigs are getting leaner.

Hambrock (2005) found the prediction equation for the HGP by Bruwer (1992) to overestimate LM% when comparing them to the 2005 study's HGP equation but discussed that this may have resulted from different methodologies being used and that when the equations from both studies are placed on a graph (test of parallelism) they are almost parallel, with the heavier carcasses having a smaller difference between the two equations indicating that the equation by Bruwer (1992) can sufficiently predict LM% of carcasses weighing ≥ 100 kg. However, Siebrits *et al.* (2012) found the heavier carcasses to have greater deviations when estimating LM% with the equations devised by Bruwer (1992).

2.6 Factors influencing carcass composition and quality

Carcass composition varies between species, between breeds, within breeds and differs with regards to the carcass parameters; weight, total body fat and percentages of lean and bone. These carcass parameters are influenced by genetics, physiological age, gender, nutrition, the environment and their interactions (Wagner *et al.*, 1999; Irshad *et al.*, 2013). Deposition of adipose tissue at various anatomical locations is affected by intrinsic factors, such as age, body weight, gender and genotype, and by extrinsic (environmental) factors such as feeding regimen, temperature, castration and the use of exogenous hormones (Kouba & Sellier, 2011).

2.6.1 Genetics

Genetics plays a fundamental role in species differentiation and is responsible for the differences seen within species and between individuals of the same breed. Breeds mature at different rates with some breeds being regarded as a late-maturing type, for example the Landrace, and some as an early-maturing type, for example the Meishan breed (Irshad *et al.*, 2013). These different types have shown to cause variation within different compositional characteristics throughout growth to slaughter (Fisher *et al.*, 2003). Breeds deposit fat and build muscle in different body depots and generally leaner genotypes have higher amounts of intermuscular fat to total body fat (Kouba *et al.*, 1999; Irshad *et al.*, 2013) for example the Duroc pig breed has more intermuscular fat relative to subcutaneous fat than other breeds (Wood *et al.*, 2008).

The term breed has become somewhat redundant regarding pig breeds as slaughter pigs are seldom purebreds, but rather a cross between several breeds or are a synthetic line from a genetic company (Causeur *et al.*, 2006). With the synthetic lines, the sire lines are used to improve paternal traits such as rate and efficiency of gain, meat quality and carcass yield while the dam lines are used to improve maternal traits such as fertility, milk production, maintenance efficiency and mothering ability (Bourdon, 2000)

Bruwer (1992) found fat thickness to have a trend of decreasing from the cranial end towards the caudal end until the point of the 1st and 2nd thoracic vertebrae where it starts to increase again towards the caudal end. Faucitano *et al.* (2004) found intramuscular fat along the *longissimus* muscle for barrows and gilts to decrease from the 7th thoracic vertebrae until the last thoracic vertebrae and then increase until the 4th lumbar vertebrae.

The heritability, defined as 'the proportion of the total variance that is attributable to differences of breeding values' (Falconer & Mackay, 1996), of carcass composition traits is usually moderately to highly inherited (Table 2.15) which is why these traits are in selection programs and which have shown success by producing the leaner genotypes seen in today's modern pig breeds. Fix *et al.* (2010) conducted a study to determine the differences in lean growth performance of pigs from 1980 and 2005 in which it was found that pigs from 1980 had higher ($P < 0.01$) backfat depths and smaller ($P < 0.01$) eye muscle areas (at the 10th rib) at a LW of 95 kg than pigs from 2005. Pigs from 2005 had better ($P < 0.01$) lean ADG (291 g/d) than pigs from 1980 (227 g/d).

Table 2.15 Heritability (h^2) of carcass traits

Traits	h^2	Reference
Carcass fat depth (mm)	0.45 ± 0.14	Nguyen & McPhee, 2005
Ultrasound backfat depth (mm)	0.45 ± 0.07	Miar *et al.*, 2014
Dressing percentage	0.30	Visser & Hofmeyr, 2014
Intra-muscular fat	0.5 – 0.61	Visser & Hofmeyr, 2014
Loin muscle area	0.45 ± 0.02; 0.47	Suzuki *et al.*, 2005; Visser & Hofmeyr, 2014
Carcass length	0.56	Visser & Hofmeyr, 2014

Selecting for lower backfat thickness could result in correlated responses in other fat depots (Kolstad, 2001) and could result in changes in the amounts of saturated fatty acids (SFA; decreased), monounsaturated fatty acids (MUFA; decreased) and polyunsaturated fatty acids (PUFA; increased) (Wood *et al.*, 2008). The study by Lopes *et al.*, (2014) showed that the backfat thickness measured at the P_2 level for lean type pigs was lower ($P < 0.001$) than when compared to pigs of a fat type (14.7 ± 0.972 and 28.0 ± 1.33 mm, respectively) and concluded that genotype does influence subcutaneous fat deposition. However, this result conflicts with Latorre *et al.*, (2003) who found genotype to have no significant ($P > 0.10$) effect on backfat thickness.

Selection for production traits could result in correlated changes in maintenance requirements, for example when comparing the Landrace to the Duroc, the Landrace has an improved lean growth rate but has higher maintenance requirements than the Duroc (Kolstad & Vangen, 1996). Selection for reproduction traits has been successful, for example the study conducted by McPherson *et al.* (2004) produced results that showed that fetal weights at day 110 and 114 of gestation were up to 30% greater than what other researchers had found seven years prior to their study. Although genetics is a cause for variation seen between and within breeds, full genetic potential will not be expressed with restricted feeding.

2.6.2 Age

Physiological age is defined as the stage of development of an individual rather than chronological age in years, months or days. Individuals of the same breed and within the same age group vary in their rate of development with some performing above average and others performing below average (Crampton, 1908). Chronological and physiological age both have an influence on the deposition rate of the different tissues in the body. However, the maximum rate of growth of the tissues that is reached follows a sequence from conception to maturity; the sequence being the nervous system first, followed by the skeleton, muscle and then fat. This differential growth was shown in pigs in a study by McMeekan (1940a) where the growth of the tissues was recorded from birth to 28 weeks of age, where each tissue increased in mean mass as follows; skeleton – 0.24 to 7.40 kg, muscle – 0.39 to 31.65 kg, fat – 0.05 to 34.51 kg and skin – 0.11 to 3.44 kg. This is also displayed in Figure 2.5. Research by Gu *et al.* (1991a) agrees with the previous findings of McMeekan (1940a) that bone and muscle develop first until the peak rate of growth is reached at which point the rate of growth of these tissues slows down and the rate of growth of fat increases. The study by McMeekan (1940a) also found that within each tissue group growth rate and the location of this growth varied. For example, at 16 weeks of age the amount of both intramuscular and subcutaneous fat was greater in the region of the forelimbs than in the loin region, however, at 28 weeks of age the opposite was found. This can also be displayed with the study by Bosch *et al.*, 2012 where intramuscular fat was found to increase linearly with age while subcutaneous backfat thickness and loin thickness increased at a decreasing rate with age, with loin thickness decreasing at a faster rate.

Bosch *et al,* (2012) found that the amount of PUFA in intramuscular fat and subcutaneous backfat decreased with an increase in age. The study conducted by Schönfeldt & Strydom (2011) which aimed at determining the effect of age on the tenderness of cooked beef concluded that age had no effect on collagen content but did affect tenderness and collagen solubility, with both decreasing with age.

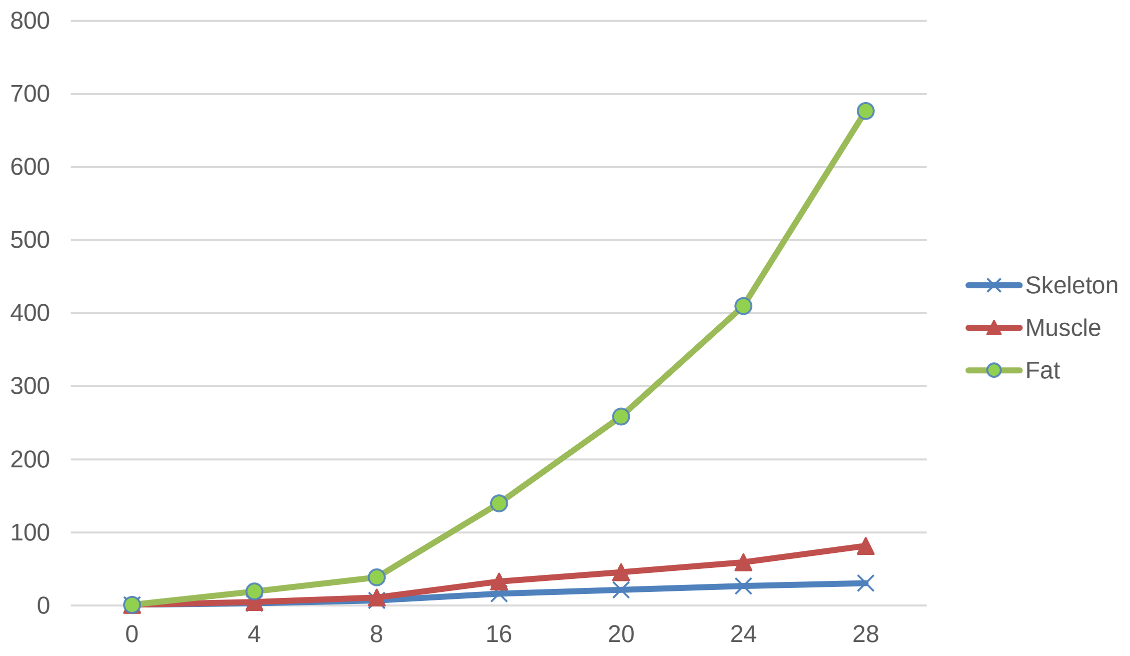

Figure 2.5 Mass of skeleton, muscle and fat as a percentage of mass of tissue at birth from 0 to 28 weeks of age (Adapted from McMeekan, 1940a)

2.6.3 Gender

Intact male carcasses tend to have less fat and are leaner while the opposite is usually true for castrates and female carcasses. Latorre *et al.* (2003) found that carcasses of castrated pigs had a higher ($P < 0.01$) backfat thickness than gilts (23.5 and 20.9 mm, respectively) and had more ($P < 0.01$) fat over the *gluteus medius* muscle than gilts (19.5 and 17.3 mm, respectively). It was also found that gilts had a higher ($P < 0.001$) percentage of total carcass trimmed cut yield of loin than castrates (7.3 and 6.9 %, respectively) but no differences ($P > 0.10$) for hams and shoulders were found. Schiavon *et al.* (2015) found similar results. A study done by Dube *et al.*, (2011) agrees with Latorre *et al.*, (2003) findings that castrates had a higher backfat measurement than did gilts and concluded the difference could be a result of castrates consuming larger ($P < 0.001$) quantities of feed than gilts. Loin eye area in gilts has been shown to be larger ($P < 0.05$) when compared to boars (Beattie *et al.*, 1999) and barrows and that genotype had a significant effect ($P < 0.05$) on this carcass characteristic (Cisneros *et al.*, 1996). Although Dube *et al.* (2011) found gilts to have smaller ($P < 0.01$) eye muscle areas than barrows and concluded that barrows have a higher carcass yield while gilts have better carcass quality. Fat quality tends to be poorer in intact males than barrows and females (Wood *et al.*, 2008).

2.6.4 Body weight

Increasing carcass weight from 70 to 100 kg has been shown to have the following effects on carcass composition characteristics; increased ($P < 0.001$) eye muscle area (cm^2), decreased ($P < 0.001$) lean ($g\ kg^{-1}$) and decreased ($P < 0.001$) lean to fat ratio (Beattie *et al.*, 1999).

Wagner *et al.*, (1999) conducted a study whereby body composition changes were recorded for different weight groups (ranging from 25 to 152 kg LW), genetic populations and between gender (barrows and gilts). They found that weight, genetic population and gender had an effect ($P < 0.001$) on the carcass characteristics backfat thickness (between 10th and 11th rib, ¾ of the lateral distance across the loin muscle; cm), loin muscle area between the 10th and 11th ribs (cm^2) and last rib back fat thickness. It was noted that as the weight group increased the difference between backfat thicknesses for barrows and gilts increased until 152 kg LW where the difference remained the same. From this study done by Wagner *et al.*, (1999) it was concluded that developmental changes for 10th rib fat depth ¾ of the lateral distance across the loin muscle were linear ($P < 0.05$) and the developmental changes for loin muscle area and last rib backfat thickness to be quadratic ($P < 0.05$) with respect to empty body weight.

It has been suggested by Orcutt *et al.* (1990) that in order to have more accurate estimations of % lean, two prediction equations could be beneficial where one is used for carcasses weighing < 100 kg and another equation for carcasses weighing ≥ 100kg.

2.6.5 Nutrition

Nutrition affects the rate of growth as nutrients are partitioned within the body according to a rank of functions. The rank of functions being tissues of vital organs, tissues that are part of a physiological process or a developing foetus receive nutrients first, bone being second, muscle third and fat deposition last (Irshad *et al.*, 2013). A diet that does not fulfil maintenance requirements reverses the order and the body will first utilise its fat reserves followed by the breakdown of muscle tissue and the reabsorbing of nutrients from bone. Different groups of pigs, for example gilts, sows, weaners, growers and finishers, receive diets specified for their phase of growth to ensure their dietary requirements are met and growth is optimised while being efficient. Researchers have found multiple phase feeding programs to be more beneficial than a single-phase feeding program within a group of pigs, as this minimises under- and overfeeding as nutrient requirements decrease with increasing weight while feed consumption increases with weight (van Heugten, 2010). The study by McPherson *et al.* (2004) supports a two-phase feeding program for pregnant gilts because it was found that after day 69 of gestation the fetal accretions of protein and fat increase, resulting in higher requirements for protein and fat by the foetus, therefore increasing the dietary protein requirement of the pregnant gilt.

In a study where piglets received a high or a low plane of nutrition, the piglets at 16 weeks of age on the low plane had body compositions where 19.20% of the body weight was contributed by the skeleton, 53.14% by muscle and 10.32% by fat while the piglets on a high plane of nutrition had body compositions where 12.71% of the BW was contributed by the skeleton, 45.76% by muscle and 30.73% by fat (McMeekan, 1940b). Thereby showing that bone is affected least during prolonged periods of low planes of nutrition and fat being affected the most and that although the low plane pig had a higher muscle % the high plane pig had a higher bone to muscle ratio (high plane = 3.59 and low plane = 2.77) which is an indication of a good quality meat animal.

The study by McMeekan, (1940b) also showed that the various regions of the body developed differently depending on the plane of nutrition received, where the later developing regions such as the body depth, loin and hindquarters will be affected negatively on a low plane of nutrition and would be favoured on a high plane of nutrition. The low plane of nutrition piglets had better developed forequarters, a larger head, a longer face and neck, longer legs and a shorter body which was shallow compared to that of the piglets who received a high plane of nutrition who had well developed hindquarters which were rounded, smaller head, shorter face and neck, shorter legs and a longer, deeper body. After 16 weeks some of the pigs that had received a high plane of nutrition received a low plane of nutrition (H-L) and some that had received a low plane of nutrition received a high plane of nutrition (L-H) until 200 lb LW was reached (McMeekan, 1940c). The H-H reached 200 lb LW in 24 weeks while the L-L took 48 weeks. The H-H and L-H pigs had more fat and less muscle and poorer bone to muscle ratios compared to the H-L and L-L pigs. Therefore, showing that fat will be deposited at a faster rate than muscle in the later stages of development (Evans & Kempster, 1979) provided that sufficient nutrients are supplied and that based on the diet received the body composition of the pig can be changed to meet the requirements of the producer.

Although, pigs destined for the production of meat would not be fed sub-maintenance diets there is concern about the amount of protein in feeds and its effect on the environment (Wood *et al.*, 2013). Due to this concern, low-protein diets have been investigated to determine the effects they would have on performance, carcass composition and on the environment. Researchers have found that a low-protein diet negatively affects feed efficiency, decreases the proportion of loins on carcass weight (Schiavon *et al.*, 2015), has no significant effect on P_2 fat thickness (6.5 cm from dorsal midline at the last rib), increases the amount of intramuscular fat in the *longissimus* muscle and affects the fatty acid composition in the *longissimus* and *semimembranosus* muscles; percentage of oleic acid is increased and that of linoleic acid is decreased (Wood *et al.*, 2013). But, Wood *et al.* (2013) concluded that a diet containing 11% less protein fed to pigs from a LW of 40 to 115 kg could be used to reduce Nitrogen (N) emissions while maintaining a similar level of carcass fat. A low protein as well as a low energy diet has negative effects on reproduction such as delayed follicle development (Coetzee & Casey, 2009). Phase feeding more closely matches the nutrient requirements of the animal resulting in minimal wastages of nutrients by excretion (van Heugten, 2010) and lower levels of N entering the environment.

The fatty acid (FA) composition of adipose tissue is important as it has an effect on meat quality particularly on the quality of the fat and muscle where the texture and ease of separation of fat can be changed and the oxidative stability of muscle can be changed (Wood *et al.*, 2008). The FA composition is dependent on the diet, the amount of fat present and on gender and can determine the nutritional quality of the meat. As backfat thickness increases the saturated FA (SFA) increase and the polyunsaturated FA (PUFA) decrease which has an effect on the melting point of the fat as SFA have a higher melting point than PUFA, making the fat firmer and less likely to separate from the muscle (Wood *et al.*, 1989).

2.6.6 Environment

From the time of the foetus being in the uterus until slaughter weight is reached, the environment has an influence on development and growth and therefore ultimately on carcass composition. Powell & Aberle (1981) found that runts (birth weight = 0.97 ± 0.2 kg) had a higher ($P < 0.05$) percentage of red type II muscle fibers (*semimembranosus* muscle) than littermates that had a higher ($P < 0.05$) birth weight (1.56 ± 0.03 kg), 18.1 ± 0.8% and 13.1 ± 1.2% respectively.

Season has also been shown to influence the composition of a pig carcass, one such study reported Landrace pig's performance tested in winter were leaner ($P < 0.001$) than Landrace pigs tested in summer (Dube *et al.*, 2011). Another study by Gajana *et al*. (2013) showed that the incidence of PSE meat was higher during Autumn (68% of carcasses) and the incidence of DFD meat was higher during Winter (32% of carcasses).

A study by Lucht (2010), although not showing the effect on carcass composition, showed that age at first service was affected by the season in which the gilt was born, with gilts born in autumn being younger at age at first service than gilts born in either spring ($P = 0.0008$) or winter ($P < 0.0001$).

2.6.7 Treatment

Treatment effects, such as the use of ractopamine hydrochloride (RAC) as a growth stimulant or performing immunocastration, could potentially cause a change in carcass composition.

Ractopamine hydrochloride is a feed additive used to improve the growth performance of pigs through improved feed efficiency, increased rate of weight gain and increased carcass leanness. Although, RAC does have improved growth benefits the benefits are better seen when a diet of lower quality is used as seen with Hinson *et al.* (2012) study where two control groups were compared to RAC fed pigs. There was a negative control which received a diet containing 13.13% crude protein (CP) and 0.64% standard ileal digestible lysine (SID Lys) and a positive control which received a diet containing 17.77% CP and 0.94 SID Lys. The results indicate that the estimated carcass % lean for the negative control group was lower ($P = 0.003$) than RAC treated pigs and that although the positive control group was also lower than RAC fed pigs, it was not significant ($P = 0.811$).

Immunocastration is used as an alternative to surgical castration because it helps reduce the incidence of boar taint by preventing the build-up of skatole and androstenone in the fat and is believed to help improve meat quality. Also, immunocastrated males (IM) are less aggressive compared to entire males and do not display sexual behaviours thereby improving welfare and management. Immunocastration causes less stress to the animal than surgical castration, which is also considered to have negative health effects, and with the consumers growing concern for welfare this is an added benefit. Immunocastration is an active immunization against the hormones gonadotropin-releasing hormone (GnRH) or luteinizing hormone (LH) which helps to regulate reproductive function (Zamaratskaia & Rasmussen, 2015). Research has found immunocastration to have little influence on meat quality characteristics, one such study by Needham & Hoffman (2015) showed that the percentage of cooking loss was less ($P < 0.05$) for IM (30.59 ± 0.21) than for entire males (31.33 ± 0.20). Gispert *et al.* (2010) compared carcass characteristics of entire males (EM), surgically castrated males (CM), IM and females (FE) and found that fat thickness over the *gluteus medius* muscle increased ($P < 0.05$) in the following order, CM > IM > FE > EM and that fat depth over the loin area was similar between IM and CM and concluded that EM are leaner than IM.

Other research has been focused on determining the effect of RAC on IM such as the study conducted by Rikard-Bell *et al.* (2009) where the results showed RAC treated IM to have a higher ($P < 0.006$) half carcass % lean than IM who were not fed RAC, 70.2 and 64.4%, respectively. It was also found that RAC treated IM had a higher ($P < 0.006$) half carcass % lean than RAC treated gilts, 70.2 and 67.0%, respectively. Lowe *et al.* (2016) found carcass characteristics to differ between RAC treated CM, RAC treated IM and RAC treated gilts where back fat depths ($P < 0.05$) between the 10th and 11th ribs were 2.80, 2.35 and 2.06 cm respectively.

2.6.8 Pre-slaughter handling

Pre-slaughter handling procedures, which include loading and off-loading of the animals, the transport conditions, lairage conditions, the length of fasting times and the stunning methods used, and post-slaughter carcass management such as electrical stimulation and chilling methods, can adversely affect the composition and quality of the carcass.

Pre-slaughter handling procedures place the animals under stress which can cause physiological imbalances to occur resulting in DFD or PSE meat ultimately affecting meat quality and consumer perception (Guàrdia *et al.*, 2005; Vermeulen *et al.*, 2015). Stress is not the only factor to contribute to these conditions however, breed, sex and species are contributing factors too. Incorrect handling procedures can result in an increase in the incidence of DFD, PSE, bruising, damage and broken bones leading to loss of value of the carcass.

Dark, firm and dry (DFD) meat is a condition caused from glycogen depletion which affects the quality of the meat and is often associated with the pre- and post-slaughter procedures (Nguyen *et al.*, 2006). Dark, firm and dry (DFD) meat often occurs when animals have been exposed to chronic or long-term stress and is characterised by having high pH values (> 6, 12 to 48 hours after slaughter), high water holding capacity (WHC) and is dark in colour (reflects less light) (van der Wal *et al.*, 1988; Adzitey & Nurul, 2011). Glycogen stores are depleted with little lactic acid being formed resulting in a high pH. This condition does not occur as often in pig meat as it does in other red meat.

Pig meat is more likely to be of the condition pale, soft and exudative (PSE) which often occurs when animals have been exposed to acute or short-term stress and is characterised by low pH values (< 6, 45 minutes after slaughter) abnormal colour, has a soft consistency and has poor water holding capacity (van der Wal *et al.*, 1988; Adzitey & Nurul, 2011). Glycogen in the muscle after slaughter is converted to lactic acid at a faster rate resulting in a lower pH at a higher body temperature causing the denaturation of proteins and lower WHC.

2.7 Predicting lean yield of a carcass

It is important to have an accurate and reliable way of estimating carcass composition because carcass classification and grading systems focus on determining backfat thickness, muscle thickness, WCM and LM% when determining the value of a carcass, as shown with the classification and grading systems discussed above. The LM% of a carcass is measured objectively on the moving slaughter line (Font i Furnols & Gispert, 2009).

Non-invasive techniques of estimating carcass LM% are important as damaged carcasses cannot be sold for a premium. Invasive techniques such as physical dissections are expensive, time consuming and damaging to the carcass. Therefore, researchers have studied various methods, instruments and technologies to obtain prediction equations that would calculate an estimation of carcass lean that would best suit their pig industry's requirements.

Instruments used to measure characteristics of carcass composition differ in the technology that they offer, price, size and accuracy (Causeur *et al.*, 2006). The various instruments that have been studied are optical probes, such as the Intrascope, HGP, Fat-O-Meater® and Destron®, ultrasound, video image analysis, electromagnetic scanning, bioelectrical impedance, computerised X-ray tomography and nuclear magnetic resonance. Variability within a method of measurement still arises due to the following reasons (Causeur *et al.*, 2006):

- The operator
- The equipment used
- Calibration of the equipment
- The environment
- Slaughter process
- Amount of time passed between measurements

Eye muscle length and depth measurements have been shown to be inferior to fat thickness measurements when predicting LM% of a carcass; Bruwer (1992) found that the muscle thickness measured between the 5th and 6th last ribs 45 mm from the dorsal midline was the best predictor of LM% compared to all the other muscle thickness measurements taken as it had a low R^2 value of 0.08 and a RSD of 3.33.

Sather *et al.* (1991b) reported that using both the HGP fat and muscle measurements along with the measurement of the eye muscle area made by the Aloka SSD-210DXII Echo Camera, which is a real-time ultrasound device, to predict the lean content of a carcass, the R^2 value could be improved from 0.58 to 0.66. They further reported that these results were evidence that eye muscle area can explain a portion of the variance in carcass composition.

Various studies have shown that LM% prediction equations used across genders and genotypes usually underestimate fat-free lean mass of lean genotypes and overestimate fat-free lean mass of fatter genotypes when a single technology (optical probe or electromagnetic scanning) is used (Hicks *et al.*, 1998).

2.8 Correlations between carcass parameters and percentage lean

Correlation between fat-free lean mass (kg) and loin eye area at 10th rib (cm^2) is 0.74 and with WCM is 0.70 (Hicks *et al.*, 1998). Buck (1963) determined the correlations between % lean and % bone, % lean and average back fat and between % lean and eye muscle area at three different weights (150, 200 and 260 lb) for hogs and gilts and concluded that a carcass with a high % lean can be associated with higher % bone, larger eye muscle area and less back fat.

Table 2.16 Correlations between carcass parameters and % lean

Traits	r (RSD)	Reference
Fat-free lean (kg) and loin eye area at 10th rib (cm^2)	0.74	Hicks *et al.*, 1998
Backfat 4cm from midline at last rib (C) and %(muscle and loss)	-0.87 (2.07)	Joblin, 1966
Eye muscle depth at last rib and %(muscle and loss)	0.63 (3.24)	Joblin, 1966
Eye muscle area at last rib (EMA) and %(muscle and loss)	0.86 (2.15)	Joblin, 1966
EMA/C and %(muscle and loss)	0.90 (1.83)	Joblin, 1966

2.9 Carcass grading probes used in South Africa

The probes commonly used in South African abattoirs to measure fat thickness and muscle depth, which are used to predict the LM% of a carcass, are the HGP and the Intrascope. These optical probes work on the principle that adipose tissue as well as muscle tissue will reflect light differently. The accuracy of the readings of the probes will vary between operators, the probes used and the probes calibration (Olsen *et al.*, 2007). Both probes take measurements between the 2nd and 3rd last ribs, 45 mm from the dorsal midline while the carcass is in a hanging position.

2.9.1 Hennessy Grading Probe

The HGP is an electronic, optical, hand held, robust grading probe that is linked to a computer system which measures both fat thickness and muscle depth by use of reflectance spectroscopy. The cutting blade on the tip of the probe cuts through the carcass allowing for the insertion of the probe needle, which contains a light emitting diode and a photo sensitive diode. The intensity of the light reflected to the photo sensitive diode makes it possible to distinguish between adipose tissue and muscle tissue. The probe is then able to measure the distance travelled by the probe needle from which fat and muscle thickness are recorded and calculates LM% using the computer program (Klingbiel & Burger, 2014).

Sather *et al.* (1989) found the HGP to underestimate lean content of a carcass as carcass weight increased and that by including carcass weight into the prediction equation it decreased the RSD by 0.06. The HGP has been found to overestimate ($P < 0.001$) the carcass lean of barrows and underestimate ($P < 0.05$) carcass lean of gilts (Sather *et al.*, 1991b). The HGP also underestimated ($P < 0.0001$) lean yield of a leaner breed and overestimated ($P < 0.0001$) lean yield of a fatter breed (Sather *et al.*, 1991b). However, research by Bruwer (1992) showed that the lower the LM% is in a carcass the more accurately the HGP prediction equation can predict LM% of a carcass. And further research by Hambrock (2005) may be in agreement as the study found that both the HGP and the Intrascope are still able to accurately predict LM% of the leaner modern genotypes.

2.9.2 Intrascope

The Intrascope is an optical, hand held measuring device used to measure fat thickness only. It also works on the changes of light reflectance once the blade penetrates the carcass but makes use of a mirror system. The classifier is required to determine between fat and muscle tissue when looking through the viewfinder and then read the fat measurement on the calibrated scroll (Daumas, 2001; Klingbiel & Burger, 2014).

The Intrascope is cost effective but may not manage to keep up with the slaughter line and is therefore preferred in smaller abattoirs (Daumas, 2001). The HGP was found to be more accurate ($R^2 = 0.69$) in predicting LM% than the Intrascope ($R^2 = 0.62$) but only when muscle thickness was included in the equation (Hambrock, 2005). Hambrock (2005) found that the inclusion of WCM in his study's LM% equation for the Intrascope improved the R^2 value from 0.62 to 0.72.

2.10 Hypothesis

Part 1: Analysis of the variance of data sourced at a commercial abattoir

1. H_0: No significant differences exist between WCM and Fat across the entire data set, within gender, within mass category, within class and within mass cluster.
   H_a: Significant differences exist between WCM and Fat across the entire data set, within gender, within mass category, within class and within mass cluster.

2. H_0: A predictor cannot be identified.
   H_a: A predictor can be identified.

3. H_0: No significant differences exist between WCM and Fat within producer.
   H_a: Significant differences exist between WCM and Fat within producer.

4. H_0: The South African Pig Carcass Classification system can accommodate all ranges of pig carcasses and from all types of producers (commercial and communal).
   H_a: The South African Pig Carcass Classification system cannot accommodate all ranges of pig carcasses and from all types of producers (commercial and communal).

Part 2: Analysis of the variance of the data collected and measured on selected carcasses provided by a commercial abattoir

1. H_0: Warm carcass mass and Fat can be reliable predictors of EMA and % lean.
   H_a: Warm carcass mass and Fat cannot be reliable predictors of EMA and % lean.

2. H_0: The legislated lean prediction equation is required.
   H_a: The legislated lean prediction equation is not required.

CHAPTER 3
MATERIALS AND METHODS

The analysis was done in two parts where Part 1 was conducted on data received from a commercial abattoir that contained information on the pig carcasses classified according to the South African Pig Carcass Classification system, described in the Government Notice No. R. 55 of 2015, and included the origins of the pig marketed. Part 2 was conducted on information collected from selected carcasses according to a sampling matrix from the same commercial abattoir.

3.1 Part 1

A data set of 65 792 classified pig carcasses was provided by Chamdor Meat Packers (Pty) Ltd abattoir, Krugersdorp, in terms of the Ethics of External Data agreement with the University of Pretoria. The ethics approval reference was EC160519-031, dated 3 June 2016. The data set was for a period of 8 months (2 November 2015 to 30 June 2016).

Chamdor Meat Packers (Pty) Ltd was selected as a data source because a wide range of pigs are slaughtered which provides a good representation of the pig population in South Africa. The pigs came from specific producers and speculative agents who buy pigs from various producers including small-scale farmers. The data was from 56 suppliers to the abattoir and were designated "producer" in the analyses. Of these 56 producers, 15 producers, excluding speculative agents, who had supplied 200 and more pigs over the period, were selected to test for a "producer" effect on the classes, carcass mass and variances.

The data received provided the following information on each carcass:

- serial number,
- batch number,
- producer,
- agent,
- class,
- warm carcass mass in kilograms (WCM),
- cold carcass mass in kilograms (CCM, calculated at 97% of WCM),
- back fat thickness in millimetres (Fat) measured at the point 45 mm lateral from the carcass midline between the 2nd and 3rd last ribs with a Hennessy Grading Probe (HGP),
- conformation (CFM; on a scale of 1 to 5),
- damage (class 1 to 3),
- gender (no differentiation between pre-slaughter treatments of males; castrated males were not distinguished).

Warm carcass mass (WCM; kg) was measured on the moving slaughter line at Chamdor Meat Packers (Pty) Ltd with a scale at the same point where the classifier uses the HGP to identify the backfat measurements after which the corresponding class is then stamped in purple on both sides of the carcass. The carcass is also visually assessed to allocate a conformation score which is stamped in green on one side. All measurements taken at this point along with the other information stated above are recorded on the computer system.

The carcasses were then transferred to a cold room at an average of 3°C and an air flow rate of 0.5 ms^{-1}. The CCM was not measured again, but the standard practice at Chamdor Meat Packers (Pty) Ltd was to deduct 3% from the WCM.

The data was received in Microsoft Excel format and needed to be reorganised or "cleaned up" in order for SAS® (Statistical Analysis System, 2017) program to properly identify all the variables. This included making sure that all the same producers had their names spelt the same and that blank rows and rows that repeated the headings were deleted.

The data was analysed using the MEANS procedure, GLM procedure (linear and quadratic) of which the statistical models are shown below and the CORR procedure of SAS® (Statistical Analysis System, 2017) to determine the relationships between Fat, WCM and gender. Table 3.1.1 shows the wide range of WCM (kg) and Fat (mm) across the entire data set and the data set divided into males and females.

Table 3.1.1 Range of carcass information in the data set

Gender	WCM (kg)				Fat (mm)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
All	74.1	32.9	4.2	345.8	13.3	5.2	1.4	95.0
Male	66.1	18.0	4.2	345.8	12.1	3.2	1.6	80.0
Female	82.5	41.9	4.8	317.0	14.6	6.5	1.4	95.0

The linear statistical model applied was:

$$Y = \beta_0 + \beta_1 X + \varepsilon$$

Where:
β_0 = intercept
β_1 = parameter estimate for independent variable
X = independent variable
ε = residual error

The quadratic statistical model applied was:

$$Y = \beta_0 + \beta_1 X + \beta_2 X^2 + \varepsilon$$

Where:
β_0 = intercept
β_1 = parameter estimate for independent variable
β_2 = parameter estimate for independent variable
X = independent variable
X^2 = independent variable
ε = residual error

The MEANS procedure was conducted across all data, across boars, across sows, within each mass category (Table 3.1.2), within each class, for example BC, in order to produce the mean, standard deviation, minimum and maximum WCM and Fat.

The GLM procedure was run across the entire data set, across boars, across sows, within mass categories and within class; with the dependent variable being fat thickness (mm) and the independent variable being WCM (kg). As mass classes and the corresponding carcass mass ranges have not been standardized and set out in the Government Notice No. R. 55 of 2015 the industry has made an agreement to use the mass classes and the corresponding carcass mass ranges shown in Table 3.1.3. These differ from the mass categories tested in this study which were estimated, for illustrative purposes, based on the information provided in the data set received and are shown in Table 3.1.2.

Table 3.1.2 Estimates of the mass categories and the corresponding mass ranges (kg)

Mass category	Mass range (kg)
Porker	20.1 – 61.6
Cutter	56.3 – 75.4
Baconer	64.8 – 82.4
Heavy baconer	73.2 – 103.2

Table 3.1.3 Mass classes used by agreement by the industry for contract sales and the corresponding mass ranges (kg) (Adapted from NDA, 2010)

Mass classes	Mass range (kg)
Porker	< 60
Light Baconers	60 – 80
Heavy Baconers	81 – 90
Sausager	> 90

The WCM (kg) range over the entire data set was narrowed down into smaller mass ranges for this study. The WCM (kg) range, 4.2 to 345.8 kg, was divided into 10 kg mass clusters (28 mass clusters in total) as the industry places carcasses into narrower mass classes to decrease the amount of variation between carcasses within the same class (Table 3.1.3). Therefore, by narrowing the ranges down further for this study the extent of the amount of variation seen within fat thickness (mm) that is explained by WCM (kg) can be examined. Also, the wide range of WCM (Table 3.1.1) seen across the entire data set could result in a high coefficient of variation (CV).

Table 3.1.4 The WCM (kg) range per mass cluster

Cluster	WCM (kg)
1	4.2 - 9
2	10 - 19
3	20 - 29
4	30 - 39
5	40 - 49
6	50 - 59
7	60 - 69
8	70 - 79
9	80 - 89
10	90 - 99
11	100
12	110
13	120
14	130
15	140
16	150
17	160
18	170
19	180
20	190
21	200
22	210
23	220
24	230
25	240
26	250
27	260
28	>270

The MEANS procedure was applied within each mass cluster and between boars and sows within each mass cluster.

The GLM procedure was applied within each cluster and within cluster 4 to 9 combined with the dependent variable being fat thickness and independent variable being WCM.

The CORR procedure was used to analyse the relationship between fat thickness and WCM within each cluster, between boars and sows within each cluster and between boars and sows within clusters 4 to 9 combined. Mass clusters 4 to 9 were combined as 84.9% of the carcasses in the data set were accounted for within this range (30 to 89 kg) (Table 3.1.4).

The extent of producer effect was determined by selecting producers who had 200 carcasses or more. In total, 15 producers were selected and renamed with a letter (A to O) to keep the producer's name confidential. The MEANS procedure, GLM procedure and CORR procedure were applied for all selected producers pooled and for each individual selected producer to determine the relationship between fat thickness and WCM.

Statistical differences were considered at an alpha level of 0.05.

After the first run of the data through SAS it was noticed that carcass information for four pigs could have possibly been entered incorrectly and were removed from the data set, making the new total 65 788 entries. The four pigs had carcass information removed for the following reasons:

- Gender was recorded as 'P' instead of 'B' or 'S'
- Fat thickness of 109 mm and another of 212 mm
- A carcass recorded as class 'BO' had a WCM of 179 kg

The results of the data analysis were used to help create a sampling matrix for Part 2.

The data set received from Chamdor Meat Packers (Pty) Ltd is archived on the computer system at House 1 on the Experimental Farm on the LC de Villiers Sportsground of the University of Pretoria.

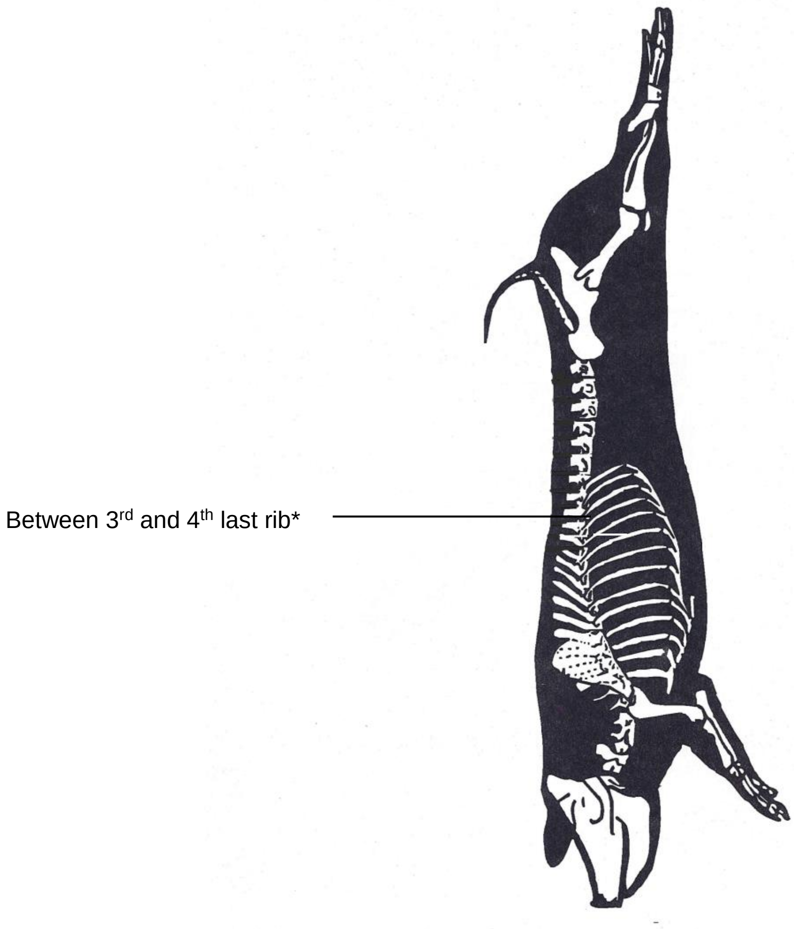

Figure 3.1.1 Diagram of a pig carcass depicting the location the HGP was used to measure fat thickness (mm) (Adapted from Bruwer, 1992)

*The HGP is used 45 mm lateral from the carcass midline between the 2nd and 3rd last ribs when a carcass has 13 ribs but when the carcass has 14 ribs as in the case of the figure above the measurement should be taken between the 3rd and 4th last ribs (Klingbiel & Burger, 2014).

3.2 Part 2

Chamdor Meat Packers (Pty) Ltd supplied the pig carcasses for this study, the carcasses were bought according to the market price of the class that the carcass was classified as and were sold back as roughs.

The sampling matrix that was created from the analysis of the data of Part 1, where a significant linear relationship between Fat (mm) and WCM (kg) was found, had six mass clusters (Table 3.1.3).

The six mass clusters were:

- cluster 3 (20 to 29 kg),
- cluster 5 (40 to 49 kg),
- cluster 7 (60 to 69 kg),
- cluster 9 (80 to 89 kg),
- cluster 11 (100 to 109 kg),
- cluster 13 (120 to 129 kg)

The data analysis from Part 1 showed no significant differences between genders but for scientific purposes the selection included a minimum of six carcasses per gender. The sampling matrix would include six clusters each with twelve carcasses to give a total of 72 carcasses.

The sampling matrix was later adapted to accommodate the shortage of carcasses within certain mass clusters. No carcasses were available in cluster 3, too few carcasses were available for cluster 11 (for both male and female carcasses) and for cluster 13 too few female carcasses and no male carcasses were available.

The new sampling matrix comprised of ten mass clusters (Table 3.2.1). Extra carcasses that were outside of these mass cluster ranges were also used and an eleventh cluster was decided upon (Table 3.2.1). Data was collected from a total of 89 carcasses, however two of these carcasses were damaged and had had the damaged portions removed which would have affected the mass of the carcass and were therefore excluded from the analysis.

Table 3.2.1 Mass ranges and number of carcasses per cluster for males and females

Cluster	Mass Ranges (kg)	n of male carcasses	n of female carcasses	Total n of carcasses
	20 – 29	0	0	0
1	30 – 39	2	3	5
2	40 – 49	6	6	12
3	50 – 59	4	8	12
4	60 – 69	6	6	12
5	70 – 79	6	7	13
6	80 – 89	6	6	12
7	90 – 99	2	2	4
8	100 – 109	1	2	3
9	110 – 119	0	5	5
10	120 – 129	0	4	4
11	130 – 189	0	5	5

The 89 selected carcasses went through the same on-floor slaughter line process as all the carcasses slaughtered at the abattoir, where serial number, batch, producer, agent, Fat from the HGP, WCM, CCM, class, CFM, damage and gender were recorded on a computer system. The carcasses were placed in a cold room at an average of 3˚C with an air flow of 0.5 ms^{-1}.

The selected cold carcasses remained in the cold room on the premises of Chamdor Meat Packers (Pty) Ltd while extended from the hip joint in a hanging position during the procedure of recording the measurements where each carcass was cut transversely with a boning knife and saw at the point where the HGP fat thickness reading is taken (45 mm lateral from the carcass midline between the 2nd and 3rd last ribs, Figure 3.1.1) to expose the *Longissimus dorsi* muscle (eye-muscle).

A calliper was used to measure the fat and skin thickness (C) in millimetres of the carcasses at the same point the HGP was used (Figure 3.2.1). The green mark the assistant of the classifier placed in order for the classifier to identify the correct location for the HGP to record a fat thickness and muscle depth reading was used to identify where the calliper should be placed to take a fat thickness and muscle depth measurement. The skin thickness was measured as the Government Notice No. R. 55 of 2015 defined fat thickness as 'the thickness of the back fat including the skin'. The depth (A) and length (B) of the eye-muscle was measured using a calliper as shown in Figure 3.2.1.

A 5 by 5 mm grid that was printed on a transparent sheet was placed on top of the exposed transverse section of the eye-muscle (Figure 3.2.1), a photo was taken using a smart phone and the eye-muscle was traced. The tracing was later used to calculate the area of the eye-muscle in cm^2.

The data was analysed using the MEANS, CORR and GLM procedures of SAS® (Statistical Analysis System, 2017) to determine the relationship between:

- WCM and Fat [with either the fat thickness measured by the calliper (Sfat) or the recorded HGP Fat (HGPFat)],
- WCM and depth of the eye-muscle (EMD),
- WCM and length of the eye-muscle (EML),
- WCM and eye-muscle area (EMA),
- Sfat and EMD,
- Sfat and EML,
- Sfat and EMA,
- HGPFat and EMD,
- HGPFat and EML
- HGPFat and EMA.

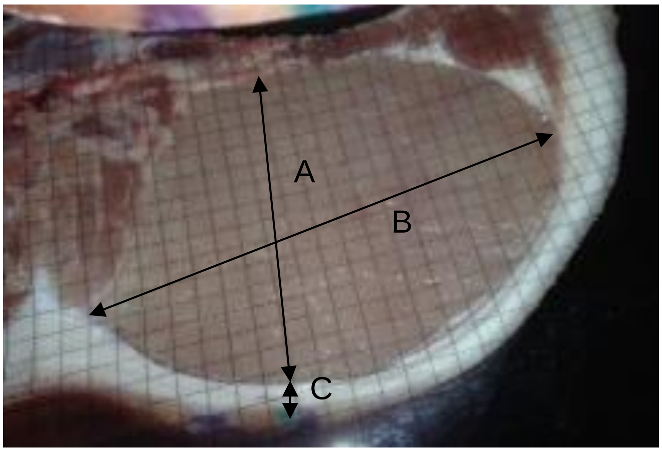

Figure 3.2.1 Transverse section through the right *Longissimus dorsi* muscle between the 2nd and 3rd last ribs where depth (A), length (B) and fat thickness (C) were measured.

The data collected and recorded on the selected carcasses from Chamdor Meat Packers (Pty) Ltd is archived at House 1 on the Experimental Farm on LC de Villiers Sportsgrounds of the University of Pretoria.

CHAPTER 4
RESULTS

4.1 Part 1

4.1.1 All data pooled

Table 4.1.1 shows that the mean WCM and Fat are 74.08 ± 32.93 kg and 13.33 ± 5.18 mm, respectively. There is a wide range for both WCM, 4.2 to 345.8 kg, and Fat, 1.4 to 95 mm. Both of these wide ranges could be attributable to the high coefficient of variation (CV = 28.36) seen for WCM and Fat in Table 4.1.2.

Table 4.1.2 shows that 47% of the variation seen within Fat can be explained by WCM (R^2 = 0.47) and is significant ($P < 0.0001$), both linearly and quadratically although the quadratic variable did not improve the R^2 value. The Pearson's correlation coefficient (r) for Fat and WCM over the entire data set showed that there is a strong positive association between the two parameters (r = 0.68) and that it is highly significant ($P < 0.0001$). The positive association can also be seen in Table 4.1.5 with a_1 = 0.11 and 0.10, for the linear and quadratic models respectively.

Table 4.1.1 The means, standard deviations, minimum and maximum values for warm carcass mass (WCM; kg) and back fat thickness (Fat; mm) over the entire data set

Variable	n	Mean	SD	Min	Max
WCM (kg)	65 788	74.1	32.9	4.2	345.8
Fat (mm)	65 788	13.3	5.2	1.4	95.0

Table 4.1.2 The GLM Procedure for back fat thickness (Fat; mm) and warm carcass mass (WCM; kg) across whole data set

GLM Procedure	n	F value	R^2	CV	Pr > F
Linear	65 788	57847	0.47	28.36	0.0001
Quadratic	65 788	28941	0.47	28.36	0.0001

From Table 4.1.3 it can be seen that there are more male (M) carcasses than female (F) carcasses (M = 33 851 and F = 31 938). The means for WCM and Fat for males is 66.13 ± 18.02 kg and 12.14 ± 3.15 mm, respectively, and for females it was 82.49 ± 41.86 kg and 14.59 ± 6.46 mm, respectively (Table 4.1.3). The WCM and Fat ranges still appear to be wide with males having ranges of 4.2 to 345.8 kg (WCM) and 1.6 to 80 mm (Fat) and females having ranges of 4.8 to 317 kg (WCM) and 1.4 to 95 mm (Fat).

Table 4.1.3 The means, standard deviations, minimum and maximum values for WCM (kg) and fat (mm) over the entire data set between males and females

Gender	n	WCM (kg)				Fat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
Male	33 851	66.1	18.0	4.2	345.8	12.1	3.2	1.6	80.0
Female	31 937	82.5	41.9	4.8	317.0	14.6	6.5	1.4	95.0

Table 4.1.4 shows that the relationship between back Fat and WCM is stronger for females (R^2 = 0.46) than it is for males (R^2 = 0.36) and is significant linearly for both males and females ($P < 0.0001$), however the CV is also higher for females (CV = 32.46) than for males (CV = 20.78).

Table 4.1.4 The GLM Procedure for fat (mm) and WCM (kg) between males and females

Gender	n	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
Male	33 851	18 833	0.36	20.78	0.0001	9418	0.36	20.78	0.1425
Female	31 937	27 475	0.46	32.46	0.0001	13 751	0.46	32.45	0.0001

Table 4.1.5 illustrates the data above (Table 4.1.4) as if it were in equation form, both linear and quadratic. The quadratic variable only improved the equation for the boars, but it was not significant (P = 0.1425). Although, the other quadratic equations were not an improvement, the data for all information pooled and for sows fitted a quadratic line (P < 0.0001).

Table 4.1.5 GLM Procedure for Fat (mm) and WCM (kg) and the linear and quadratic variables for all data and between males and females

Data	n	x	x^2	a_1	a_2	b	R^2	CV	Pr > F
All data	65 788	WCM		0.11		5.35	0.47	28.36	0.0001
			WCM*WCM	0.10	0.000	5.67	0.47	28.36	0.0001
Boars	33 851	WCM		0.10		5.23	0.36	20.78	0.0001
			WCM*WCM	0.11	-0.000	5.13	0.36	20.78	0.1425
Sows	31 937	WCM		0.10		5.93	0.46	32.46	0.0001
			WCM*WCM	0.09	0.000	6.42	0.46	32.45	0.0001

x = independent variable in the linear model; x^2 = independent variable in the quadratic model; a_1 = linear independent variable estimate, a_2 = quadratic independent variable estimate; b = intercept

4.1.2 Sausagers

The mean WCM for males and females classified as Sausagers are 148.2 ± 48.9 kg and 165.2 ± 35.2 kg, respectively (Table 4.1.6). The mean Fat for males and females classified as Sausagers are 20.9 ± 11.2 mm and 22.9 ± 10.2 mm, respectively. The male and female carcasses classified as Sausagers have narrower WCM ranges than seen in Table 4.1.3 with males having a range from 102.2 to 345.8 kg and with females having a range from 101.0 to 317.0 kg. The Fat ranges remain wide with males with a range from 5.2 to 80.0 mm and females with a range from 5.2 to 95.0 mm.

Figure 4.1.1 shows that there were 20 males and 177 females with Fat less than 10 mm (cluster 1). There are 215 males and 2261 females with Fat less than 20 mm.

Dividing the Fat range for males into 10 mm clusters (Figure 4.1.1):

- 80 are between 20 and 30 mm (cluster 3),
- 30 are between 30 and 40 mm (cluster 4),
- 12 are between 40 and 50 mm (cluster 5),
- 7 are between 50 and 60 mm (cluster 6),
- 1 is between 60 and 70 mm (cluster 7),
- 3 have Fat of 80.0 mm

Dividing the Fat range for females into 10 mm clusters (Figure 4.1.1):

- 1975 are between 20 and 30 mm,
- 617 are between 30 and 40 mm,
- 156 are between 40 and 50 mm,
- 72 are between 50 and 60 mm,
- 15 are between 60 and 70 mm,
- 14 are between 70 and 80 mm (cluster 8),
- 24 are between 80 and 90 mm (cluster 9),
- 4 are between 90 and 95 mm

Table 4.1.6 Number of carcasses per gender, means, standard deviations, minimum and maximum values for WCM (kg) and Fat (mm) of carcasses that are classified as Sausagers

Gender	n	WCM (kg)				Fat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
Boar	348	148.2	48.9	102.2	345.8	20.9	11.2	5.2	80.0
Sow	5138	165.2	35.2	101.0	317.0	22.9	10.2	5.2	95.0

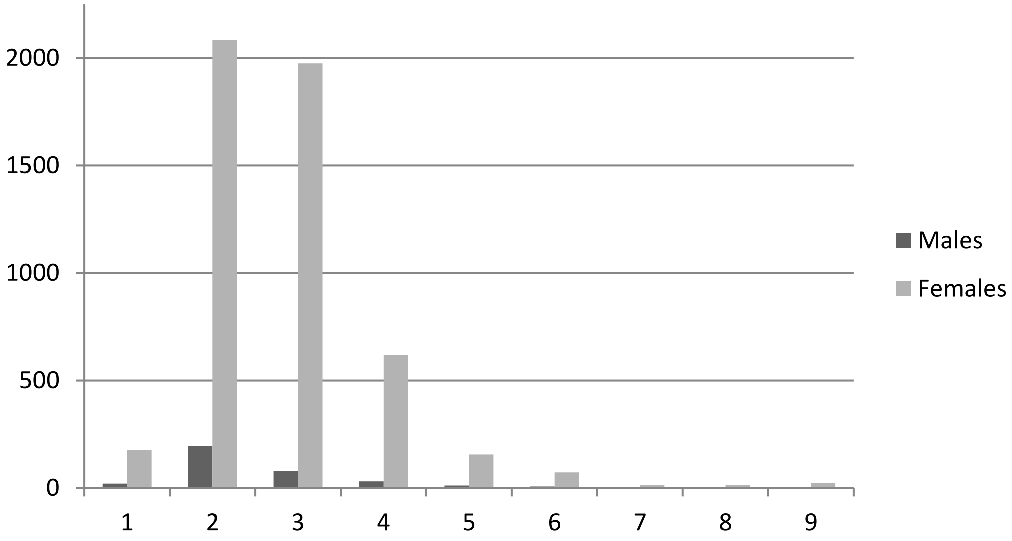

Figure 4.1.1 Number of males and females per 10 mm Fat clusters (1 to 9) within the Sausager class

Table 4.1.7 shows that the variation seen in Fat of pigs classified as Sausagers that is explained by WCM in males is 9% ($R^2 = 0.09$) and in females is 15% ($R^2 = 0.15$) and both have high CV values, 50.78 and 40.96 respectively. This could be because of the wide range of Fat and narrower WCM ranges (Table 4.1.6). The quadratic equation improved the R^2 value for both males and females by 0.01, changing the R^2 value to 0.10 for males and to 0.16 for females while it decreased the CV values to 50.69 and 40.37 for males and females, respectively.

Table 4.1.7 GLM Procedure: Fat (mm) and WCM (kg) of carcasses classified as Sausagers

Gender	n	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
Male	348	37.33	0.09	50.78	0.0001	19.86	0.10	50.69	0.7046
Female	5138	911.68	0.15	40.96	0.0001	545.08	0.16	40.37	0.0001

4.1.3 Mass Categories

Table 4.1.8 shows that the data set was divided up into the four mass categories (Porker, Cutter, Baconer and Heavy Baconer) the pig industry uses to further divide the LM% classes (P, O, R, C, U and S). Baconers constitute 31.7% of the carcasses classified, Porkers 28.7%, Cutters 22.7% and Heavy Baconers 16.9%.

The mean WCM values for the mass categories are 47.3 ± 7.2 kg for Porkers, 61.8 ± 3.0 kg for Cutters, 74.3 ± 4.3 kg for Baconers and 88.7 ± 4.8 kg for Heavy Baconers. The mean Fat values for the mass categories are 10.5 ± 2.8 mm for Porkers, 11.7 ± 2.6 mm for Cutters, 13.2 ± 2.5 mm for Baconers and 15.7 ± 3.2 mm for Heavy Baconers (Table 4.1.8).

The Fat ranges are wider for Porkers, Cutters and Heavy Baconers than for Baconers (Table 4.1.8). The Porkers had a Fat range of 1.4 to 80.0 mm. Within the Porkers group there were three carcasses, with Fat of 60.0 mm, 80.0 mm and 60.0 mm, which fell outside the Fat range (1.4 to 40.0

mm) that 17226 Porker carcasses were in. A similar scenario occurred with the Cutters group where two carcasses had 70.0 and 90.0 mm Fat, excluding these two carcasses the Fat range would be 1.6 to 39.0 mm instead of 1.6 to 90 mm. By removing two carcasses with Fat of 60.0 and 80.4 mm from the Heavy Baconers group the range would be 2.0 to 46.0 mm instead of 2.0 to 80.4 mm. These outlier carcasses with the thicker Fat are all female.

No clear distinction is made for the mass categories within the Government Notice No. R. 55 of 2015 which can be seen as the mass categories' (Table 4.1.8) mass ranges overlap each other with overlaps of:

- 5.3 kg between the Porkers and Cutters,
- 10.6 kg between Cutters and Baconers,
- 9.2 kg between Baconers and Heavy Baconers

Within the Porker and Cutter overlap range (56.3 to 61.6 kg) there are 462 Porkers and 6671 Cutters, within the Cutters and Baconers overlap range (64.8 to 75.4 kg) there are 3049 Cutters and 11220 Baconers and within the Baconers and Heavy Baconers overlap range (73.2 to 82.4 kg) there are 10828 Baconers and 138 Heavy Baconers.

Table 4.1.8 Number of carcasses per weight category and means, standard deviation, minimum and maximum values per mass category for WCM (kg) and Fat (mm)

Mass category	n	WCM (kg)				Fat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
Porker	17 229	47.3	7.2	20.8	61.6	10.5	2.8	1.4	80.0
Cutter	13 619	61.8	3.0	56.3	75.4	11.7	2.6	1.6	90.0
Baconer	18 995	74.3	4.3	64.8	82.4	13.2	2.5	1.8	46.0
Heavy Baconer	10 154	88.7	4.8	73.2	103.2	15.7	3.2	2.0	80.4

Table 4.1.9 displays low R^2 values for the relationship between Fat and WCM for Porkers, Cutters, Baconers and Heavy Baconers; the values being 0.016 (CV = 26.53), 0.015 (CV = 22.03), 0.072 (CV = 18.11) and 0.040 (CV = 20.15), respectively, and all were significant ($P < 0.0001$). The low R^2 values could be from the overlap of the mass categories as seen above. The CV value is the lowest for Baconers (CV = 18.11) and is the highest for Porkers (CV = 26.53). The high CV seen for Porkers could be because there is a 40.8 kg difference between the minimum (20.8 kg) and maximum (61.6 kg) WCM while Cutters, Baconers and Heavy Baconers have a difference of 19.1, 17.6 and 30.0 kg, respectively, between minimum and maximum WCM (Table 4.1.8). Overall the low R^2 and high CV values could be attributed to the wide Fat ranges and wide WCM ranges for Porkers (range of 40.8 kg) and for Heavy Baconers (range of 30.0 kg).

The quadratic variables for the mass categories Porkers and Heavy Baconers increased the R^2 values to 0.017 (CV = 26.52) and 0.041 (CV = 20.15), respectively and were both significant (P = 0.0064 for Porkers and 0.0012 for Heavy Baconers). The quadratic variable for Cutters (P = 0.9208) and Baconers (P = 0.5613) were not significant.

Table 4.1.9 The GLM Procedure: Fat (mm) and WCM (kg) within mass categories

Mass category	Linear			Quadratic		
	R^2	CV	Pr > F	R^2	CV	Pr > F
Porker	0.016	26.53	0.0001	0.017	26.52	0.0064
Cutter	0.015	22.03	0.0001	0.015	22.04	0.9208
Baconer	0.072	18.11	0.0001	0.072	18.10	0.5613
Heavy Baconer	0.040	20.15	0.0001	0.041	20.15	0.0012

Tables 4.1.10 and 4.1.11 show that there were more males than females classified according to PORCUS, with males accounting for 55.6% of the carcasses and females accounting for 44.4%. Males had lower maximum Fat than females (Table 4.1.10 and 4.1.11), with males having a high maximum

Fat of 46.0 mm for the Heavy Baconers mass category and females having 90.0 mm for the Cutters mass category.

The mean WCM and Fat for the mass categories for males and females were similar (Table 4.1.10 and 4.1.11). The mean WCM values for males were 47.3 ± 7.3 kg for Porkers, 61.9 ± 2.9 kg for Cutters, 74.1 ± 4.3 kg for Baconers and 88.2 ± 4.7 kg for Heavy Baconers (Table 4.1.10). The mean Fat values for males were 10.3 ± 2.5 mm for Porkers, 11.4 ± 2.0 mm for Cutters, 12.8 ± 2.2 mm for Baconers and 15.1 ± 2.6 mm for Heavy Baconers (Table 4.1.10). Most male carcasses (34.1%) fell under the Baconer mass category, with 28.5% under the Porker mass category, 23.8% under the Cutter mass category and 13.6% under the Heavy Baconer mass category (Table 4.1.10).

Table 4.1.10 Number of male carcasses per mass category and means, standard deviations, minimum and maximum values for WCM (kg) and Fat (mm) for males

Mass Category	n	WCM (kg)				Fat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
Porker	9502	47.3	7.3	20.8	61.6	10.3	2.5	4.0	40.0
Cutter	7951	61.9	2.9	56.4	75.4	11.4	2.0	1.6	28.0
Baconer	11 382	74.1	4.3	64.8	82.4	12.8	2.2	1.8	35.0
Heavy Baconer	4520	88.2	4.7	76.6	103.0	15.1	2.6	7.6	46.0

Most of the female carcasses are Porkers (29.0%) with 21.3% being Cutters, 28.6% being Baconers and 21.1% being Heavy Baconers (Table 4.1.11). The mean WCM values for females are 47.3 ± 7.1 kg for Porkers, 61.7 ± 3.0 kg for Cutters, 74.5 ± 4.3 kg for Baconers and 89.2 ± 4.9 kg for Heavy Baconers. The mean Fat values for females are 10.8 ± 3.2 mm for Porkers, 12.1 ± 2.9 mm for Cutters, 13.6 ± 2.8 mm for Baconers and 16.2 ± 3.6 mm for Heavy Baconers. Females show a more even spread across the mass categories regarding number of carcasses.

Table 4.1.11 Number of female carcasses per mass category and means, standard deviations, minimum and maximum values for WCM (kg) and Fat (mm) for females

Mass Category	n	WCM (kg)				Fat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
Porker	7727	47.3	7.1	20.8	59.0	10.8	3.2	1.4	80.0
Cutter	5669	61.7	3.0	56.3	71.2	12.1	2.9	6.0	90.0
Baconer	7613	74.5	4.3	65.2	82.4	13.6	2.8	1.8	46.0
Heavy Baconer	5634	89.2	4.9	73.2	103.2	16.2	3.6	2.0	80.4

Table 4.1.12 shows the R^2 values for Porkers, Cutters, Baconers and Heavy Baconers are 0.025, 0.017, 0.085 and 0.052, respectively, for males which are all significant ($P < 0.0001$). The CV values for Porkers, Cutters, Baconers and Heavy Baconers are 23.59, 20.23, 16.18 and 17.07, respectively (Table 4.1.12). The R^2 values are higher and the CV values are lower than when males and females are combined (Table 4.1.9). The quadratic variable for Porkers ($P = 0.3203$), Cutters ($P = 0.6333$), Baconers ($P = 0.1914$) and Heavy Baconers ($P = 0.3343$) are not significant and the R^2 values remained the same except for Porkers where the R^2 value increased to 0.026. The CV values changed for Porkers (CV = 23.578), Cutters (CV = 20.233) and Heavy Baconers (CV = 0.3343) and remained the same for Baconers.

Table 4.1.12 The GLM Procedure: Fat (mm) and WCM (kg) within mass categories for males

Mass category	Linear			Quadratic		
	R^2	CV	Pr > F	R^2	CV	Pr > F
Porker	0.025	23.586	0.0001	0.026	23.578	0.3203
Cutter	0.017	20.232	0.0001	0.017	20.233	0.6333
Baconer	0.085	16.175	0.0001	0.085	16.175	0.1914
Heavy Baconer	0.052	17.072	0.0001	0.052	17.073	0.3343

Table 4.1.13 shows the R^2 values for Porkers, Cutters, Baconers and Heavy Baconers are 0.009, 0.015, 0.057 and 0.028, respectively, for females and are all significant ($P < 0.0001$). The CV values for Porkers, Cutters, Baconers and Heavy Baconers are 29.23, 23.59, 19.96 and 21.68, respectively (Table 4.1.13). The R^2 values are lower and the CV values are higher, like with the males, than when males and females are combined (Table 4.1.9). The quadratic variable for Porkers ($P = 0.0022$) and for Heavy Baconers ($P = 0.0080$) is significant while for Cutters ($P = 0.7260$) and Baconers ($P = 0.0638$) it is not significant. The quadratic variable increased all the R^2 values and decreased the CV values, Porkers ($R^2 = 0.011$ and CV = 29.205), Cutters ($R^2 = 0.016$ and CV = 23.587), Baconers ($R^2 = 0.058$ and CV = 19.951) and Heavy Baconers ($R^2 = 0.029$ and CV = 21.673).

Table 4.1.13 The GLM Procedure: Fat (mm) and WCM (kg) within mass categories for females

Mass category	Linear			Quadratic		
	R^2	CV	Pr > F	R^2	CV	Pr > F
Porker	0.009	29.234	0.0001	0.011	29.205	0.0022
Cutter	0.015	23.585	0.0001	0.016	23.587	0.7260
Baconer	0.057	19.957	0.0001	0.058	19.951	0.0638
Heavy Baconer	0.028	21.681	0.0001	0.029	21.673	0.0080

4.1.4 Carcasses classified according to PORCUS fat classes

Table 4.1.14 also shows that more males than females are classified according to PORCUS. The means for WCM and Fat are similar for males and females. Male and females have a similar range of minimum to maximum WCM, the male's range covers 82.2 kg while the female's range covers 82.4 kg. The same cannot be said for the minimum and maximum Fat range as the male's range covers 44.4 mm and female's range covers 88.6 mm.

Table 4.1.14 Number of carcasses per gender and means, standard deviation, minimum and maximum values per gender for WCM (kg) and Fat (mm), for carcasses classified according to PORCUS

Gender	n	WCM (kg)				Fat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
Male	33 355	65.5	14.8	20.8	103.0	12.1	2.8	1.6	46.0
Female	26 643	67.0	16.3	20.8	103.2	13.0	3.7	1.4	90.0

Table 4.1.15 illustrates that both linear and quadratic values are significant ($P < 0.0001$). Although the quadratic line is a better fit (R^2 values = 0.336 and 0.299 for males and females, respectively) it is only a slight improvement to the linear model (R^2 values = 0.320 and 0.288 for males and females, respectively). The linear CV values for males (CV = 19.343) and females (CV = 23.704) are lower than the CV values of the entire data set divided into males and females, which were 20.78 for males and 32.46 for females (Table 4.1.4) but an improvement in the R^2 values was not seen. There was a 17.2% decrease in the R^2 values from the pooled females to the females classified according to PORCUS and a decrease of 4% from the pooled males to the males classified according to PORCUS.

Table 4.1.15 The GLM Procedure: Fat (mm) and WCM (kg) between males and females of carcasses that are classified according to PORCUS

Gender	Linear			Quadratic		
	R^2	CV	Pr > F	R^2	CV	Pr > F
Male	0.320	19.343	0.0001	0.336	19.109	0.0001
Female	0.288	23.704	0.0001	0.299	23.499	0.0001

4.1.5 Within classes

Table 4.1.16 shows that the five classes with the most carcasses are PP with 21.9%, BO with 17.2%, CP with 14.8%, BP with 12.8% and HO with 10.8% of the carcasses. Overall, the P and O classes constitute 51.7% and 41.1% respectively of the carcasses classified. The mean Fat for all classes are given in Table 4.1.16 and fall within the Fat ranges specified by the Government Notice No. R. 55 of 2015, however some of the minimum and maximum Fat values fall outside the ranges set out by the Government Notice No. R. 55 of 2015. The SD values for Fat for all classes are given in Table 4.1.16 are the highest for class CS and PS with SD = 22.3 and 12.0, respectively. The mean, SD and minimum and maximum values for WCM for all classes are shown in Table 4.1.16.

Table 4.1.16 Number of carcasses, the means, standard deviation, minimum and maximum values of WCM (kg) and Fat (mm) per class

Class	n	WCM (kg)				Fat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
PP	13 161	47.3	7.2	20.8	61.6	9.4	1.3	1.4	13.8
CP	8904	61.6	2.9	56.4	75.4	10.4	0.9	1.6	14.4
BP	7653	73.1	4.1	64.8	82.4	10.9	0.9	1.8	15.6
HP	1309	87.9	4.8	77.2	103.0	11.3	0.9	2.0	14.0
PO	3543	47.8	7.2	20.8	56.6	13.4	0.7	9.0	24.6
CO	4342	62.3	2.9	56.3	68.4	13.6	0.8	8.2	20.0
BO	10 327	74.9	4.2	65.2	82.4	14.2	0.8	10.0	20.0
HO	6455	88.4	4.7	76.6	103.0	14.9	0.9	12.0	22.6
PR	426	45.4	7.9	20.8	56.6	18.6	0.9	17.6	22.0
CR	303	62.2	3.1	56.8	67.0	18.5	0.9	17.6	22.2
BR	899	76.2	4.0	67.0	82.4	18.6	0.9	17.6	22.2
HR	2155	89.9	4.9	73.2	103.2	19.1	0.9	15.8	22.4
PC	58	46.9	8.9	22.2	56.6	24.5	0.7	22.8	26.0
CC	51	61.6	3.1	56.8	67.0	24.6	0.7	22.8	26.2
BC	69	74.6	4.3	67.2	82.4	24.7	0.9	22.8	27.2
HC	159	92.2	5.2	82.2	103.0	24.7	0.7	22.8	26.8
PU	21	43.9	8.1	24.2	56.4	29.5	0.8	27.8	31.0
CU	12	61.1	2.5	57.0	65.8	29.2	0.6	28.0	30.0
BU	26	74.1	4.7	67.6	82.2	29.4	0.9	27.8	32.0
HU	37	92.2	5.8	82.8	102.6	29.3	1.1	27.6	32.0
PS	20	45.9	8.9	24.2	56.2	40.5	12.0	33.0	80.0
CS	7	60.0	3.6	56.8	65.6	48.6	22.3	33.8	90.0
BS	22	77.7	3.7	67.2	82.0	35.8	4.1	32.8	46.0
HS	39	91.3	6.1	82.6	102.0	38.4	8.6	32.8	80.4

The highly significant ($P < 0.0001$) relationships between Fat and WCM within class are for class PP ($R^2 = 0.151$ and CV = 12.4), CP ($R^2 = 0.041$ and CV = 9.3), BP ($R^2 = 0.039$ and CV = 7.6), HP ($R^2 = 0.015$ and CV = 8.4), CO ($R^2 = 0.012$ and CV = 5.6), BO ($R^2 = 0.093$ and CV = 5.7), HO ($R^2 = 0.071$ and CV = 5.8), HR ($R^2 = 0.015$ and CV = 5.1) (Table 4.1.17). The relationship between Fat and WCM for class PO (P = 0.0022), BR (P = 0.0005) and HC (P = 0.0209) were significant and had R^2 values of 0.003 (CV = 5.109), 0.013 (CV = 4.709) and 0.034 (CV = 2.869), respectively (Table 4.1.17). The quadratic variable for class PP (P = 0.0007), CP (P = 0.0006), PO (P = 0.0050), HR (P = 0.0053) and HS (P = 0.0210) were significant and had R^2 values of 0.152 (CV = 12.414), 0.042 (CV = 9.340), 0.005 (CV = 5.103), 0.018 (CV = 5.109) and 0.139 (CV = 21.454), respectively.

Table 4.1.17 The GLM Procedure: Fat (mm) and WCM (kg) within classes

Class	Linear			Quadratic		
	R^2	CV	Pr > F	R^2	CV	Pr > F
PP	0.151	12.415	0.0001	0.152	12.414	0.0007
CP	0.041	9.344	0.0001	0.042	9.340	0.0006
BP	0.039	7.649	0.0001	0.040	7.650	0.3823
HP	0.015	8.354	0.0001	0.019	8.344	0.0562
PO	0.003	5.109	0.0022	0.005	5.103	0.0050
CO	0.012	5.604	0.0001	0.012	5.605	0.7251
BO	0.093	5.655	0.0001	0.093	5.655	0.8627
HO	0.071	5.769	0.0001	0.075	5.755	0.0001
PR	0.001	5.109	0.5580	0.001	5.114	0.7275
CR	0.003	4.987	0.3322	0.004	4.993	0.5964
BR	0.013	4.709	0.0005	0.014	4.710	0.4797
HR	0.015	5.117	0.0001	0.018	5.109	0.0053
PC	0.019	2.655	0.3061	0.024	2.671	0.5054
CC	0.014	2.980	0.4098	0.019	3.003	0.6071
BC	0.001	3.512	0.7954	0.030	3.487	0.1668
HC	0.034	2.869	0.0209	0.036	2.876	0.4904
PU	0.016	2.631	0.5822	0.098	2.589	0.2508
CU	0.163	2.077	0.1927	0.212	2.125	0.4948
BU	0.009	2.988	0.6443	0.015	3.043	0.7029
HU	0.057	3.659	0.1556	0.063	3.699	0.6540
PS	0.042	29.864	0.3869	0.292	26.424	0.0212
CS	0.019	45.172	0.3253	0.226	49.432	0.6862
BS	0.008	11.586	0.6959	0.030	11.752	0.5244
HS	0.001	22.804	0.8456	0.139	21.454	0.0210

For the male carcasses that are classified according to PORCUS the five classes with the most carcasses are PP, BO, CP, BP and HO with 22.5%, 17.8%, 16.7%, 15.2% and 9.3% of the carcasses (Table 4.1.18). The mean, SD and minimum and maximum values for WCM and Fat for males in each class are given in Table 4.1.18.

The female carcasses classified according to PORCUS had the following five classes with the most carcasses PP, BO, HO, CP and BP which had 21.3%, 16.5%, 12.5%, 12.5% and 9.7%, respectively, of the carcasses (Table 4.1.19). The mean, SD, minimum and maximum values for WCM and Fat for females of each class are shown in Table 4.1.19.

Males and females per class are; P class: 18819 males and 12208 females, O class: 13093 males and 11574 females, R class: 1312 males and 2471 females, C class: 100 males and 237 females, U class: 22 males and 74 females, S class: 8 males and 80 females (Table 4.1.18 and 4.1.19).

Most of the R^2 values for male carcasses classified according to PORCUS are low apart from class PU, HU and PS which have R^2 values of 0.355 (CV = 2.562 and P = 0.1583), 0.236 (CV = 3.003 and P = 0.2221) and 0.929 (CV = 2.169 and P = 0.1718), respectively; however, these values are not significant (Table 4.1.20). The classes in which Fat variation is explained ($P < 0.0001$) by WCM are PP (R^2 = 0.151 and CV =12.6), CP (R^2 = 0.043 and CV = 9.6), BP (R^2 = 0.049 and CV = 7.7), CO (R^2 = 0.007 and CV = 5.5), BO (R^2 = 0.083 and CV = 5.7) and HO (R^2 = 0.071 and CV = 5.7) (Table 4.1.20). The relationship between Fat and WCM was also significant for class BR (R^2 = 0.012, CV = 4.643 and P = 0.0392) and HR (R^2 = 0.008, CV = 4.880 and P = 0.0226). The quadratic variable was highly significant ($P < 0.0001$) for one class, HO where R^2 was 0.070 and the CV was 5.7 and for class PP (R^2 = 0.154, CV = 12.143 and P = 0.0499), CP (R^2 = 0.051, CV = 8.629 and P = 0.0002), PS (R^2 = 0.288, CV = 28.629 and P = 0.0373) and HS (R^2 = 0.152, CV = 22.304 and P = 0.0235) was significant (Table 4.1.20).

Table 4.1.18 Number of male carcasses and means, standard deviation, minimum and maximum values of WCM (kg) and Fat (mm) per class

Class	n	WCM (kg)				Fat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
PP	7498	47.3	7.3	20.8	61.6	9.3	1.3	4.0	13.8
CP	5573	61.8	2.9	56.4	75.4	10.3	1.0	1.6	12.4
BP	5065	73.1	4.1	64.8	82.4	10.9	0.9	1.8	15.6
HP	683	87.3	4.4	77.2	102	11.4	0.7	7.6	12.8
PO	1801	47.6	7.2	20.8	56.6	13.3	0.7	9.0	24.6
CO	2241	62.3	2.9	56.8	67.8	13.5	0.7	10.0	17.2
BO	5935	74.8	4.2	65.2	82.4	14.1	0.8	10.0	17.2
HO	3116	88.1	4.6	76.6	103	14.8	0.9	12.0	17.2
PR	175	45.9	8.3	21.2	56.6	18.5	0.9	17.6	22.0
CR	121	62.1	3.2	56.8	67.0	18.6	0.9	17.6	22.0
BR	352	76.4	3.8	67.0	82.4	18.6	0.9	17.6	22.0
HR	664	89.6	5.1	78.4	103.0	19.1	0.9	17.6	22.0
PC	18	45.5	10.1	22.2	55.4	24.4	0.8	22.8	25.6
CC	14	61.3	3.3	56.8	66.0	24.4	0.7	23.6	26.0
BC	23	74.5	4.4	68.0	82.2	24.6	0.9	22.8	26.6
HC	45	91.5	5.4	82.8	103.0	24.6	0.6	23.6	25.6
PU	7	48.3	5.3	42.2	56.4	29.3	0.9	27.8	30.4
CU	1	62.0		62.0	62.0	28.0		28.0	28.0
BU	6	73.1	3.1	68.6	75.8	29.3	0.6	28.6	30.0
HU	8	93.4	6.2	85.6	102.6	29.3	0.9	28.0	31.0
PS	3	47.1	8.9	36.8	52.4	37.6	2.1	35.8	40.0
CS	0								
BS	1	78.0		78.0	78.0	35.0		35	35.0
HS	4	97.9	3.3	93.4	101.2	38.8	5.1	34	46.0

Table 4.1.19 Number of female carcasses and means, standard deviation, minimum and maximum values of WCM (kg) and Fat (mm) per class

Class	n	WCM (kg)				Fat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
PP	5663	47.2	7.0	20.8	59.0	9.4	1.3	1.4	12.4
CP	3331	61.4	2.9	56.8	71.2	10.5	0.9	6.0	14.4
BP	2588	73.3	4.1	64.4	82.4	11.0	0.8	1.8	12.4
HP	626	88.5	5.1	80.6	103.0	11.2	1.2	2.0	14.0
PO	1742	48.0	7.1	21.6	56.6	13.4	0.7	11.2	17.2
CO	2101	62.2	2.9	56.3	68.4	13.7	0.8	8.2	20.0
BO	4392	75.0	4.3	65.2	82.4	14.3	0.8	12.0	20.0
HO	3339	88.7	4.7	80.8	103.0	15.1	0.9	12.6	22.6
PR	251	45.0	7.7	20.8	56.6	18.6	0.9	17.6	22.0
CR	182	62.3	3.1	56.8	67.0	18.5	0.9	17.6	22.2
BR	547	76.1	4.2	67.2	82.4	18.6	0.9	17.6	22.2
HR	1491	90.0	4.9	73.2	103.2	19.2	1.0	15.8	22.4
PC	40	47.8	8.3	27.6	56.6	24.6	0.6	23.7	26.0
CC	37	61.7	3.1	56.8	67.0	24.6	0.7	22.8	26.2
BC	46	74.7	4.3	67.2	82.4	24.7	0.8	23.0	27.2
HC	114	92.5	5.1	82.2	102.0	24.7	0.8	22.8	26.8
PU	14	41.8	8.5	24.2	52.8	29.5	0.7	28.0	31.0
CU	11	60.9	2.6	57.0	65.8	29.3	0.5	28.4	30.0
BU	20	74.4	5.2	67.6	82.2	29.4	0.9	27.8	32.0
HU	29	91.8	5.7	82.8	102.0	29.3	1.1	27.6	32.0
PS	17	45.7	9.3	24.2	56.2	41.0	13.0	33.0	80.0
CS	7	60.0	3.6	56.8	65.6	48.6	22.3	33.8	90.0
BS	21	77.7	3.8	67.2	82.0	35.9	4.2	32.8	46.0
HS	35	90.5	5.9	82.6	102.0	38.3	9.0	32.8	80.4

Table 4.1.20 The GLM Procedure: Fat (mm) and WCM (kg) within classes for males

Class	Linear			Quadratic		
	R^2	CV	Pr> F	R^2	CV	Pr> F
PP	0.151	12.584	0.0001	0.151	12.584	0.0103
CP	0.043	9.652	0.0001	0.043	9.651	0.0863
BP	0.049	7.729	0.0001	0.049	7.730	0.7620
HP	0.004	6.143	0.1049	0.005	6.144	0.3400
PO	0.002	5.086	0.0813	0.007	5.073	0.0030
CO	0.007	5.471	0.0001	0.007	5.472	0.6355
BO	0.083	5.688	0.0001	0.083	5.689	0.8977
HO	0.071	5.692	0.0001	0.073	5.687	0.0026
PR	0.0001	4.818	0.8532	0.001	4.829	0.6852
CR	0.003	5.324	0.5644	0.006	5.336	0.5210
BR	0.012	4.643	0.0392	0.025	4.619	0.0368
HR	0.008	4.880	0.0226	0.019	4.858	0.0059
PC	0.149	3.061	0.1142	0.157	3.146	0.5773
CC	0.052	2.956	0.4314	0.103	3.004	0.4551
BC	0.068	3.921	0.2295	0.110	3.926	0.3583
HC	0.010	2.433	0.5077	0.033	2.433	0.3140
PU	0.355	2.562	0.1583	0.369	2.832	0.8190
CU	0			0		
BU	0.057	2.022	0.6474	0.654	1.416	0.1072
HU	0.236	3.003	0.2221	0.286	3.179	0.5583
PS	0.929	2.169	0.1718	1		
CS						
BS				0		
HS	0.104	15.331	0.6780	0.547	15.412	0.5014

The quadratic variables for class PP ($P = 0.0103$), CP ($P = 0.0863$), PO ($P = 0.0030$), HO ($P = 0.0026$), BR ($P = 0.0368$) and HR ($P = 0.0059$) were significant with the corresponding R^2 values being 0.151 ($CV = 12.584$), 0.043 ($CV = 9.651$), 0.007 ($CV = 5.073$), 0.025 ($CV = 0.0368$) and 0.019 ($CV = 4.858$) (Table 4.1.20).

High R^2 values as seen in Table 4.1.20 are not seen in Table 4.1.21. The classes in which Fat variation is explained ($P < 0.0001$) by WCM for female carcasses (Table 4.1.21) are PP ($R^2 = 0.200$ and $CV = 12.14$), CP ($R^2 = 0.048$ and $CV = 8.6$), BP ($R^2 = 0.023$ and $CV = 7.4$), HP ($R^2 = 0.048$ and $CV = 10.1$), CO ($R^2 = 0.019$ and $CV = 5.7$), BO ($R^2 = 0.106$ and $CV = 5.6$), HO ($R^2 = 0.063$ and $CV = 5.7$) and HR ($R^2 = 0.018$ and $CV = 5.2$). The relationship between Fat and WCM in class PO ($R^2 = 0.004$, $CV = 5.132$ and $P = 0.0113$), BR ($R^2 = 0.014$, $CV = 4.757$ and $P = 0.0048$) and HC ($R^2 = 0.042$, $CV = 3.034$ and $P = 0.0277$) are significant.

Table 4.1.21 The GLM Procedure: Fat (mm) and WCM (kg) within classes for females

Class	Linear			Quadratic		
	R^2	CV	Pr> F	R^2	CV	Pr> F
PP	0.200	12.144	0.0001	0.154	12.143	0.0499
CP	0.048	8.644	0.0001	0.051	8.629	0.0002
BP	0.023	7.439	0.0001	0.023	7.439	0.3957
HP	0.048	10.102	0.0001	0.048	10.108	0.7473
PO	0.004	5.132	0.0113	0.005	5.132	0.3475
CO	0.019	5.709	0.0001	0.019	5.711	0.9934
BO	0.106	5.558	0.0001	0.106	5.558	0.7713
HO	0.063	5.748	0.0001	0.070	5.728	0.0001
PR	0.003	5.311	0.3895	0.005	5.316	0.5005
CR	0.003	4.779	0.4286	0.004	4.792	0.9213
BR	0.014	4.757	0.0048	0.015	4.759	0.4765
HR	0.018	5.214	0.0001	0.019	5.213	0.1484
PC	0.0003	2.425	0.9167	0.004	2.453	0.7146
CC	0.005	3.037	0.6871	0.028	3.046	0.3717
BC	0.011	3.288	0.4866	0.024	3.304	0.4422
HC	0.042	3.034	0.0277	0.043	3.047	0.7763
PU	0.004	2.602	0.8282	0.006	2.715	0.8661
CU	0.173	1.764	0.2027	0.364	1.641	0.1688
BU	0.007	3.309	0.7185	0.009	3.403	0.8771
HU	0.036	3.899	0.3258	0.051	3.942	0.5377
PS	0.037	32.158	0.4592	0.288	28.629	0.0373
CS	0.192	45.172	0.3253	0.226	49.432	0.6862
BS	0.008	11.862	0.7056	0.033	12.033	0.5123
HS	0.003	23.814	0.7729	0.152	22.304	0.0235

4.1.6 Mass clusters

The WCM range was narrowed down into 10 kg mass clusters (Table 3.1.3). From Table 4.1.22 the mass clusters with the most carcasses are clusters 7, 8, 6 and 9 with each cluster representing 20.0%, 19.5%, 18.1% and 13.4% of the carcasses, respectively. The range 30 to 89 kg (cluster 4 to 9) accounted for 84.9% of the carcasses, 40 to 99 kg (cluster 5 to 10) accounted for 86.8% of the carcasses and 30 to 99 kg (cluster 4 to 10) accounted for 89.9% of the carcasses.

Pearson's correlation coefficient (r) between WCM and Fat for cluster 4 to 9 is 0.51, cluster 5 to 10 is 0.55 and cluster 4 to 13 is 0.56. Pearson's correlation coefficient (r) for individual mass clusters are lower with the highly significant ($P < 0.0001$) ones being clusters 5, 6, 7, 8, 9 and 10 with r values of 0.06, 0.09, 0.11, 0.18, 0.17 and 0.08, respectively. Clusters 1 ($P = 0.0074$), 2 ($P = 0.0029$), 19 ($P = 0.0118$) and 21 ($P = 0.0241$) have significant r values, the r values being 0.3131, 0.2025, 0.0739 and 0.1234, respectively. The mean, SD, minimum and maximum values for WCM and Fat per mass cluster are shown in Table 4.1.22.

The relationship between Fat and WCM within mass cluster is low (Table 4.1.23). The R^2 value is the highest for cluster 1 where R^2 is 0.0900 (CV = 44.22 and $P = 0.0074$), it is followed by clusters 2, 8, 9, 28, 21 and 7 with R^2 values of 0.0400 (CV = 62.35 and $P = 0.0029$), 0.0317 (CV = 18.03 and $P < 0.001$), 0.0309 (CV = 18.95 and $P < 0.0001$), 0.0244 (CV = 48.47 and $P = 0.4991$), 0.0152 (CV = 32.93 and $P = 0.0241$) and 0.0115 (CV = 20.08 and $P < 0.0001$), respectively, mass cluster 28 is not significant. Mass clusters 5 ($R^2 = 0.0038$, CV = 25.91 and $P < 0.0001$), 6 ($R^2 = 0.0089$, CV = 23.90 and $P < 0.0001$) and 10 ($R^2 = 0.0061$, CV = 20.78 and $P < 0.0001$) had low R^2 values and are highly significant.

Table 4.1.22 Number of carcasses, Pearson's correlation coefficient (r) for WCM and Fat, means, standard deviations, minimum and maximum values for Fat (mm) and WCM (kg) per mass cluster

Cluster	n	r	Pr > F	WCM (kg)				Fat (mm)			
				Mean	SD	Min	Max	Mean	SD	Min	Max
1	72	0.3131	0.0074	7.9	1.3	4.2	9.8	4.4	2.0	2.8	15.0
2	215	0.2025	0.0029	14.6	2.7	10.0	19.8	8.6	5.5	3.0	28.0
3	536	0.0080	0.8529	26.1	2.7	20.0	29.8	9.8	4.3	3.8	60.0
4	2063	0.0239	0.2773	36.3	2.7	30.0	39.8	10.0	3.4	4.0	60.0
5	7059	0.0617	0.0001	45.5	2.8	40.0	49.8	10.4	2.7	1.4	38.0
6	11 892	0.0954	0.0001	55.2	2.9	50.0	59.8	11.0	2.6	1.8	90.0
7	13 180	0.1071	0.0001	64.9	2.9	60.0	69.8	11.9	2.4	1.6	39.0
8	12 848	0.1781	0.0001	74.8	2.9	70.0	79.8	13.2	2.4	1.8	46.0
9	8811	0.1757	0.0001	84.5	2.8	80.0	89.9	14.9	2.9	5.2	80.4
10	3344	0.0782	0.0001	93.6	2.7	90.0	99.8	16.4	3.4	2.0	46.0
11	654	0.0738	0.0592	103.9	2.8	100.0	109.8	17.5	6.8	5.0	90.0
12	340	0.0163	0.7653	114.9	3.0	110.0	119.8	18.2	8.2	5.2	80.0
13	437	0.0613	0.2013	125.1	2.9	120.0	129.8	19.9	9.0	5.2	78.0
14	455	0.0906	0.0535	135.2	2.9	130.0	139.8	20.7	8.3	5.2	80.0
15	535	0.0105	0.8090	144.9	2.8	140.0	149.8	21.3	10.3	5.6	92.0
16	517	-0.0335	0.4478	155.1	2.9	150.0	159.8	21.9	10.9	6.0	88.0
17	489	0.0050	0.6123	164.6	2.8	160.0	169.8	21.1	8.1	5.2	70.0
18	492	-0.0189	0.6755	174.7	2.9	170.0	179.8	22.3	9.7	7.0	83.0
19	449	0.0739	0.0118	184.7	2.9	180.0	189.8	22.7	8.9	7.6	95.0
20	405	0.0546	0.2727	194.7	2.8	190.0	199.8	24.6	8.8	7.6	88.0
21	334	0.1234	0.0241	204.5	2.9	200.0	209.8	25.9	8.6	7.0	93.8
22	246	-0.0009	0.9886	214.5	2.9	210.0	219.8	29.5	14.7	9.0	70.6
23	165	0.0929	0.2353	224.3	2.9	220.0	229.8	33.1	12.4	15.8	84.0
24	117	-0.0160	0.8640	234.5	2.9	230.0	239.8	32.9	9.9	13.2	82.0
25	67	0.0589	0.6361	244.6	3.0	240.0	249.8	35.5	9.5	14.4	60.0
26	35	-0.0361	0.8370	254.2	2.7	250.2	259.6	39.4	13.5	18.8	88.8
27	12	-0.0787	0.8078	264.7	3.3	260.0	269.4	40.6	9.5	27.6	59.2
28	21	0.1562	0.4991	290.6	24.1	270.0	345.8	44.5	21.3	15.4	80.0

Figure 4.1.2 shows how the R^2 values over the mass range 30.0 to 149.9 kg increase until cluster 9 at which point the R^2 values decline until cluster 12 and then improve until cluster 14, which is further illustrated with the polynomial trend line fitted to the values. The low R^2 value for cluster 12 could be an anomaly. Pearson's correlation coefficient (r) values from Table 4.1.22 display a similar pattern.

Table 4.1.24 shows that the majority of the male carcasses are grouped towards the lighter mass clusters with clusters 4 to 10 (30 to 99 kg) being the target area which contains 32952 carcasses (97.3% of male carcasses). The mean, SD, minimum and maximum WCM and Fat values for males are shown in Table 4.1.24.

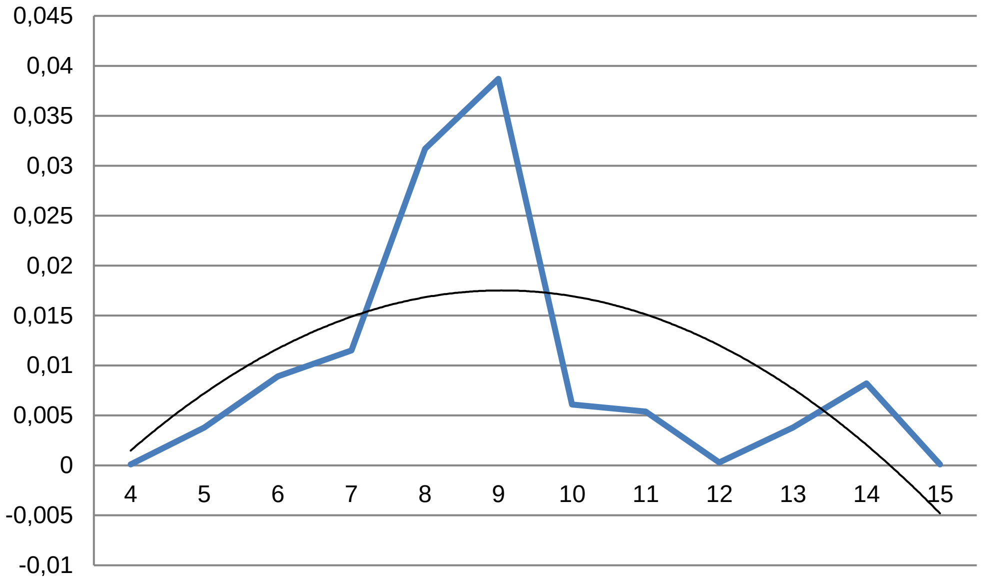

Figure 4.1.2 The coefficient of determination (R^2) values for mass clusters 4 to 15 across all data with a polynomial trend line fitted to the values

Table 4.1.23 GLM procedure for Fat (mm) and WCM (kg) per mass cluster

Cluster	F value	R^2	CV	Pr > F
1	7.61	0.0900	44.22	0.0074
2	9.11	0.0400	62.35	0.0029
3	0.03	0.0001	43.59	0.8529
4	1.18	0.0006	34.42	0.2773
5	27.00	0.0038	25.91	0.0001
6	107.24	0.0089	23.90	0.0001
7	152.83	0.0115	20.08	0.0001
8	420.63	0.0317	18.03	0.0001
9	280.59	0.0309	18.95	0.0001
10	20.56	0.0061	20.78	0.0001
11	3.57	0.0054	38.99	0.0592
12	0.09	0.0003	45.18	0.7653
13	1.64	0.0038	45.13	0.2013
14	3.75	0.0082	39.97	0.0535
15	0.06	0.0001	48.14	0.8090
16	0.58	0.0011	49.73	0.4478
17	0.01	0.0001	38.22	0.9123
18	0.18	0.0004	43.56	0.6755
19	2.45	0.0055	39.47	0.1181
20	1.21	0.0029	35.69	0.2727
21	5.14	0.0152	32.93	0.0241
22	0.00	0.0000	50.14	0.9886
23	1.42	0.0086	37.43	0.2353
24	0.03	0.0003	30.35	0.8640
25	0.23	0.0035	26.97	0.6361
26	0.04	0.0013	34.79	0.8370
27	0.06	0.0062	24.39	0.8078
28	0.47	0.0244	48.47	0.4991

Table 4.1.24 Number of carcasses, means, standard deviations, minimum and maximum values per mass cluster for WCM (kg) and Fat (mm) within males

Cluster	n	WCM (kg)				Fat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
1	29	8.1	1.3	4.2	9.8	4.3	2.4	2.8	15.0
2	102	14.4	2.8	10.0	19.8	8.4	4.9	3.0	25.0
3	303	26.0	2.6	20.0	29.8	9.4	3.3	4.0	25.4
4	1143	36.2	2.7	30.0	39.8	9.6	2.9	4.0	40.0
5	3853	45.4	2.8	40.0	49.8	10.2	2.4	5.8	30.4
6	6660	55.3	2.8	50.0	59.8	10.8	2.2	1.8	37.0
7	7911	65.0	2.9	60.0	69.8	11.7	2.3	1.6	39.0
8	7705	74.7	2.9	70.0	79.8	12.9	2.2	7.0	35.0
9	4368	84.2	2.8	80.0	89.8	14.5	2.3	8.0	29.0
10	1312	93.4	2.7	90.0	99.8	15.8	2.9	8.0	46.0
11	227	103.6	2.8	100.0	109.8	17.2	5.4	7.0	48.8
12	34	113.5	2.3	110.2	118.6	19.3	6.7	7.0	36.8
13	31	124.8	2.8	120.2	129.2	21.5	10.8	5.2	50.0
14	19	135.5	3.1	130.0	139.8	21.3	10.9	9.0	50.0
15	6	143.8	3.4	140.8	149.2	20.8	5.5	14.0	28.6
16	18	154.8	2.8	150.8	159.6	23.0	16.9	6.0	80.0
17	17	166.5	3.3	160.2	169.8	21.1	11.7	5.2	44.0
18	20	174.4	2.9	170.2	179.4	21.2	18.2	8.0	79.6
19	13	184.9	2.9	180.2	189.6	20.9	13.3	7.6	55.0
20	21	193.6	2.5	190.6	199.4	21.3	8.8	7.6	42.0
21	16	205.5	2.8	200.4	209.4	24.1	8.4	7.0	38.6
22	9	214.3	2.9	210.2	219.0	22.7	13.5	9.0	50.0
23	9	222.7	2.6	220.0	228.0	29.4	11.0	17.0	50.0
24	9	233.6	1.4	231.2	235.4	27.3	13.2	13.2	55.0
25	6	246.4	3.1	241.2	249.8	29.3	14.5	14.4	54.0
26	1	255.6		255.6	255.6	18.8		18.8	18.8
27	1	266.4		266.4	266.4	40.4		40.4	40.4
28	8	304	30.9	271.8	345.8	36.5	20.1	17.6	80.0

The female carcasses are more evenly spread over all the mass clusters (Table 4.1.25) when comparing it to the male carcasses in Table 4.1.24 where 82.2% of the female carcasses are grouped within clusters 4 to 10. The mean, SD, minimum and maximum values for WCM and Fat within mass cluster for females is shown in Table 4.1.25.

Table 4.1.26 shows that for males mass clusters 1 (R^2 =0.16, CV = 51.64 and $P = 0.0327$), 5 ($R^2 = 0.007$, CV = 23.67 and $P < 0.0001$), 6 ($R^2 = 0.009$, CV = 20.23 and $P < 0.0001$), 7 ($R^2 = 0.01$, CV = 19.35 and $P < 0.0001$), 8 ($R^2 = 0.04$, CV = 16.34 and $P < 0.0001$), 9 ($R^2 = 0.04$, CV = 15.67 and $P < 0.0001$) and 10 ($R^2 = 0.008$, CV = 18.82 and $P = 0.0012$) there is a significant relationship between Fat and WCM. The female mass clusters 2 ($R^2 = 0.06$, CV = 65.73 and $P = 0.0113$), 5 ($R^2 = 0.001$, CV = 28.06 and $P = 0.0299$), 6 ($R^2 = 0.01$, CV = 27.24 and $P < 0.001$), 7 ($R^2 = 0.01$, CV = 20.39 and $P < 0.0001$), 8 ($R^2 = 0.03$, CV = 19.71 and $P < 0.0001$), 9 ($R^2 = 0.02$, CV = 20.93 and $P < 0.0001$) and 10 ($R^2 = 0.004$, CV = 21.50 and $P = 0.0043$) have a significant relationship between Fat and WCM. The other mass clusters for males and females are not significant.

Table 4.1.25 Number of carcasses, means, standard deviations, minimum and maximum values per mass cluster for WCM (kg) and Fat (mm) within females

Cluster	n	WCM (kg)				Fat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
1	43	7.9	1.3	4.8	9.8	4.5	1.8	3.0	13.0
2	113	14.7	2.6	10.0	19.8	8.8	5.9	3.0	28.0
3	233	26.1	2.7	20.0	29.8	10.3	5.3	3.8	60.0
4	920	36.3	2.7	30.0	39.8	10.5	3.9	5.0	60.0
5	3206	45.6	2.8	40.0	49.8	10.6	2.9	1.4	38.0
6	5232	55.1	2.9	50.0	59.8	11.3	3.1	3.0	90.0
7	5269	64.8	2.9	60.0	69.8	12.4	2.6	4.0	39.0
8	5143	74.9	2.9	70.0	79.8	13.7	2.7	1.8	46.0
9	4443	84.7	2.8	80.0	89.9	15.5	3.3	5.2	80.4
10	2032	93.7	2.7	90.0	99.8	16.8	3.6	2.0	40.0
11	427	104.2	2.8	100.0	109.8	17.7	7.5	5.0	90.0
12	306	115.0	3.0	110.0	119.8	18.1	8.4	5.2	80.0
13	406	125.1	2.9	120.0	129.8	19.9	8.9	5.2	78.0
14	436	135.2	2.9	130.0	139.8	20.7	8.2	5.2	80.0
15	529	144.9	2.8	140.0	149.8	21.3	10.3	5.6	92.0
16	499	155.1	2.9	150.0	159.8	21.9	10.7	7.6	88.0
17	472	164.6	2.8	160.0	169.8	21.1	7.9	5.2	70.0
18	472	174.7	2.9	170.0	179.8	22.3	9.2	7.0	83.0
19	436	184.7	2.9	180.0	189.8	22.8	8.8	9.0	95.0
20	384	194.8	2.8	190.0	199.8	24.8	8.7	12.8	88.0
21	318	204.5	2.9	200.0	209.8	25.9	8.6	9.2	93.8
22	237	214.5	2.9	210.0	219.8	29.7	14.8	12.8	70.6
23	156	224.4	2.9	220.0	229.8	33.3	14.5	15.8	84.0
24	108	234.5	2.9	230.0	239.8	33.4	9.6	16.8	82.0
25	61	244.4	2.9	240.0	249.8	36.1	8.8	21.0	60.0
26	34	254.2	2.7	250.2	259.6	40.0	13.2	21.0	88.8
27	11	264.5	3.4	260.0	269.4	40.7	9.9	27.6	59.2
28	13	282.4	14.8	270.0	317.0	49.4	21.2	15.4	80.0

Table 4.1.26 Pearson’s correlation coefficient (r) and GLM procedure for Fat (mm) and WCM (kg) per mass cluster for males and females

Cluster	Males					Females				
	r	F value	R^2	CV	Pr > F	r	F value	R^2	CV	Pr > F
1	0.39*	5.07	0.16	51.64	0.0327	0.26	2.97	0.07	39.34	0.0925
2	0.16	2.57	0.03	58.31	0.1120	0.24*	6.64	0.06	65.73	0.0113
3	-0.02	0.09	0.0003	34.76	0.7610	0.02	0.14	0.0006	51.17	0.7054
4	0.001	0	0.0000	30.10	0.9646	0.04	1.55	0.002	37.83	0.2136
5	0.08**	26.97	0.007	23.67	0.0001	0.04*	4.72	0.001	28.06	0.0299
6	0.09**	61.19	0.009	20.23	0.0001	0.10**	54.76	0.01	27.24	0.0001
7	0.12**	112.9	0.01	19.35	0.0001	0.11**	62.14	0.01	20.39	0.0001
8	0.19**	282.52	0.04	16.34	0.0001	0.16**	137.98	0.03	19.71	0.0001
9	0.19**	161.85	0.04	15.67	0.0001	0.15**	100.64	0.02	20.93	0.0001
10	0.09*	10.54	0.008	18.82	0.0012	0.06	8.17	0.004	21.50	0.0043
11	0.13	3.85	0.02	31.02	0.0509	0.05	1.05	0.002	42.46	0.3054
12	0.09	0.31	0.009	35.07	0.5816	-0.02	0.09	0.0003	46.33	0.7650
13	0.14	0.62	0.02	50.69	0.4376	0.06	1.24	0.003	44.68	0.2653
14	0.32	1.92	0.10	50.26	0.1842	0.08	2.58	0.006	39.48	0.1089
15	0.17	0.11	0.03	28.98	0.7517	0.01	0.05	0.0001	48.33	0.8303
16	0.02	0	0.0003	75.81	0.9447	-0.04	0.64	0.001	48.65	0.4234
17	-0.47	4.15	0.22	50.80	0.0596	0.03	0.50	0.001	37.51	0.4782
18	-0.43	3.99	0.18	79.86	0.0612	0.01	0.08	0.0002	41.25	0.7730
19	0.04	0.01	0.001	66.40	0.9083	0.08	2.54	0.006	38.74	0.1119
20	0.14	0.37	0.02	41.93	0.5485	0.04	0.7	0.002	35.36	0.4023
21	0.18	0.48	0.03	35.63	0.5013	0.12*	5.0	0.02	32.86	0.0261
22	-0.22	0.35	0.05	62.10	0.5743	0.04	0	0.00002	49.74	0.9463
23	0.64	4.94	0.41	30.61	0.0617	0.06	0.61	0.004	37.51	0.4369
24	-0.19	0.28	0.04	50.77	0.6114	-0.02	0.05	0.0005	28.76	0.8159
25	0.44	0.96	0.19	49.78	0.3823	0.05	0.17	0.003	24.59	0.6854
26			0			-0.01	0.01	0.0002	33.57	0.9440
27			0			-0.08	0.06	0.006	25.70	0.8185
28	0.25	0.41	0.06	57.63	0.5453	0.49	3.64	0.25	38.86	0.0830

*significance level $P < 0.05$
**significance level $P < 0.0001$

4.1.7 Mass clusters 4 to 9 combined

Mass clusters 4 to 9 combined accounted for 84.9% of the total number of carcasses and have a mean WCM of 64.7 ± 13.8 kg and a mean Fat of 12.3 ± 3.0 mm (Table 4.1.27). The mass range is fixed at 30.0 to 89.9 kg. The Fat data ranged from 1.4 to 90.0 mm which is similar to Table 4.1.1.

Table 4.1.27 Number of carcasses, means, standard deviations, minimum and maximum values for WCM (kg) and Fat (mm) within mass clusters four to nine combined

n	WCM (kg)				Fat (mm)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
55 854	64.7	13.8	30.0	89.9	12.3	3.0	1.4	90.0

Pearson’s correlation coefficient (r) for Fat and WCM for mass clusters 4 to 9 combined is 0.51 ($P < 0.0001$). Warm carcass mass can explain 26% ($R^2 = 0.26$, CV = 21.43 and $P < 0.0001$) of the variance seen within Fat and when the quadratic variable is added, WCM can explain 27% ($R^2 = 0.27$, CV = 21.4 and $P < 0.0001$) of the variance seen (Table 4.1.28).

Table 4.1.28 Pearson's correlation coefficient (r) and GLM procedure for Fat (mm) and WCM (kg) for mass clusters four to nine combined

GLM procedure	r	F value	R^2	CV	Pr > F
Linear	0.51*	19195.4	0.26	21.43	0.0001
Quadratic		10312.9	0.27	21.23	0.0001

*significance level $P < 0.0001$

In Table 4.1.29 the Pearson's correlation coefficient (r) is higher for males ($r = 0.53$, $P < 0.0001$) in mass clusters 4 to 9 combined than for females ($r = 0.49$, $P < 0.0001$). There are more males ($n = 31641$) than females ($n = 24213$). The WCM range is expected to be the same for males and females as the mass clusters are fixed. The difference between the minimum and maximum Fat values males is 38.4 mm and it is 88.6 mm for females even though the means and SD are similar, males: mean = 11.9 ± 1.6mm, females: mean = 12.7 ± 1.4 mm. This could be because only 5 female carcasses had Fat above 46.0 mm. The 5 carcasses had Fat of 60.0, 70.0, 80.0, 80.4 and 90.0 mm with WCM of 35.0, 56.8, 56.2, 82.6 and 57.6 kg, respectively.

Table 4.1.29 Pearson's correlation coefficient (r), means, standard deviations, minimum and maximum values for WCM (kg) and Fat (mm) within mass clusters four to nine combined between males and females

Gender	n	r	WCM (kg)				Fat (mm)			
			Mean	SD	Min	Max	Mean	SD	Min	Max
Male	31 641	0.53*	64.6	13.4	30.0	89.8	11.9	2.7	1.6	40.0
Female	24 213	0.49*	64.9	14.2	30.0	89.9	12.7	3.4	1.4	90.0

*significance level $P < 0.0001$

The R^2 values in Table 4.1.30 are 0.28 and 0.24 for males (CV = 19.1) and females (CV = 23.4), respectively, and both are significant ($P < 0.0001$). The quadratic variable increases the R^2 values to 0.29 for males and 0.25 for females and decreases the CV values to 18.92 for males and 23.23 for females and was significant ($P < 0.0001$) for both males and females.

Table 4.1.30 The GLM procedure for Fat (mm) and WCM (kg) for mass clusters four to nine combined between males and females

Gender	Linear				Quadratic			
	F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
Male	12327.5	0.28	19.09	0.0001	6572.5	0.29	18.92	0.0001
Female	7722.0	0.24	23.41	0.0001	4106.4	0.25	23.23	0.0001

4.1.8 Producer effect

The mean WCM for the 15 selected producers (designated A to O) is 79.1 ± 31.1 kg while the mean Fat is 13.4 ± 4.3 mm (Table 4.1.31). The mean WCM for the data together is 74.1 kg and the mean Fat is 13.3 mm (Table 4.1.1). Table 4.1.1 shows the WCM range for all the data is 4.2 to 345.8 kg which is similar to Table 4.1.31 which has a WCM range from 10.2 to 345.8 kg and Table 4.1.1 has a Fat range from 1.4 to 95.0 mm which is also similar to the Fat range seen in Table 4.1.31 which is 1.6 to 80.0 mm.

Table 4.1.31 Number of carcasses, Pearson's correlation coefficient (r), means, standard deviations, minimum and maximum values for fifteen selected producers for WCM (kg) and Fat (mm)

n	r	WCM (kg)				Fat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
46490	0.76*	79.1	31.1	10.2	345.8	13.4	4.3	1.6	80.0

*Significance level $P < 0.0001$

Warm carcass mass can explain 57% ($R^2 = 0.57$; linear) and 58% ($R^2 = 0.58$; quadratic) of the variation seen within Fat. Both R^2 values are significant with $P < 0.0001$ (Table 4.1.32). The CV values were 20.9 (linear) and 20.8 (quadratic). This is an improvement from when all the data was pooled together where R^2 was 0.47 and CV was 28.36 (Table 4.1.2).

Table 4.1.32 The GLM Procedure: Fat (mm) and WCM (kg) for fifteen selected producers

GLM Procedure	R^2	CV	Pr> F
Linear	0.57	20.87	0.0001
Quadratic	0.58	20.78	0.0001

Table 4.1.33 shows the mean WCM and Fat for the fifteen producers within class along with the minimum and maximum ranges. Majority of the carcasses are in class BO (19.9%) followed by class BP with 15.5%, class CP with 15.4%, class HO with 13.4% and class PP with 11.8%. Overall, the P and O classes constitute 45.3% and 40.4%, respectively, of the carcasses produced by fifteen producers. The Pearson's correlation coefficient (r) is highest ($P < 0.0001$) for the SAS class (r = 0.53) followed by the PP class (r = 0.45) and then the SAB class (r = 0.44).

Table 4.1.33 Number of carcasses, Pearson's correlation coefficient (r), mean, standard deviation, minimum and maximum values per class for WCM (kg) and Fat (mm) for fifteen producers

Class	n	r	WCM (kg)				Fat (mm)			
			Mean	SD	Min	Max	Mean	SD	Min	Max
PK	8	0.20	15.7	4.6	10.2	20.6	6.3	2.0	3.8	8.8
PP	5464	0.45*	49.5	6.1	21.0	61.6	9.3	1.3	4.0	12.4
CP	7143	0.21*	61.9	2.9	56.4	75.4	10.3	0.9	1.6	12.4
BP	7226	0.21*	73.2	4.1	64.8	82.4	10.9	0.8	1.8	15.6
HP	1224	0.02	87.6	4.5	77.2	102.6	11.4	0.7	6.0	14.0
PO	636	0.12**	51.4	4.6	29.0	56.6	13.3	0.8	11.2	24.6
CO	2661	0.11*	62.8	2.9	56.3	68.4	13.6	0.8	8.2	17.2
BO	9254	0.31*	75.1	4.2	65.2	82.4	14.2	0.8	10.0	20.0
HO	6217	0.28*	88.4	4.6	76.6	103.0	14.9	0.9	12.0	22.6
PR	8	-0.19	51.0	5.5	42.2	56.4	18.4	0.9	17.8	20.0
CR	61	-0.02	63.5	2.9	57.4	67.0	18.3	0.8	17.6	22.0
BR	649	0.16*	76.9	3.7	67.0	82.4	18.6	0.9	17.6	22.2
HR	1993	0.13*	89.8	4.9	73.2	103.2	19.2	0.9	15.8	22.4
PC	1		25.4		25.4	25.4	25.0		25.0	25.0
CC	0									
BC	14	0.42	76.4	3.8	69.6	81.6	24.3	0.7	23.0	25.4
HC	112	0.28**	91.9	5.1	82.2	103.0	24.7	0.7	23.6	26.6
PU	0									
CU	0									
BU	1		79.0		79.0	79.0	29.0		29.0	29.0
HU	5	-0.21	90.8	3.9	85.8	94.8	29.1	0.4	28.6	29.8
PS	0									
CS	0									
BS	0									
HS	0									
SAB	137	0.44*	133.8	51.9	102.2	345.8	16.6	7.3	5.2	80.0
SAS	3676	0.53*	168.3	35.8	103.0	292.2	21.8	7.7	5.2	80.0

*Significance level $P < 0.0001$

**Significance level $P < 0.05$

Low variation (CV < 10) within class for the fifteen producers is displayed in Table 4.1.34 with a trend that decreases from the P fat classes to the S fat classes. Classes SAS, PP and SAB have the highest R^2 values; 0.28, 0.20 and 0.19, respectively.

Table 4.1.34 GLM Procedure: Fat (mm) and WCM (kg) within class for fifteen producers

Class	F value	R^2	CV	Pr > F
PK	0.26	0.04	33.88	0.6299
PP	1393.1	0.20	12.00	0.0001
CP	330.19	0.04	9.30	0.0001
BP	317.59	0.04	7.55	0.0001
HP	0.4	0.0003	6.47	0.5274
PO	9.13	0.01	6.06	0.0026
CO	33.5	0.01	5.57	0.0001
BO	981.67	0.09	5.65	0.0001
HO	519.37	0.08	5.75	0.0001
PR	0.23	0.04	5.62	0.6466
CR	0.02	0.0004	4.57	0.8826
BR	17.84	0.03	4.85	0.0001
HR	32.23	0.02	5.09	0.0001
PC		0		
CC				
BC	2.52	0.17	2.51	0.1384
HC	9.06	0.08	2.60	0.0032
PU				
CU				
BU		0		
HU	0.14	0.04	1.70	0.7335
PS				
CS				
BS				
HS				
SAB	31.62	0.19	39.67	0.0001
SAS	1438.47	0.28	30.07	0.0001

The mean WCM and Fat values can be found in Table 4.1.35 along with the minimum and maximum values. Mass cluster 8 has 25.1% of the carcasses followed by mass clusters 7, 9, 6, 10 and 5 which have 22.4%, 17.9%, 13.6%, 6.7% and 4.5%, respectively. The Pearson's correlation coefficients are low with 0.31 for mass cluster 4 being the highest (Table 4.1.35). It is interesting to note that the Pearson's correlation coefficient is high ($r = 0.24$) for mass cluster 28, although it is not significant, as the Sausagers (SAS and SAB) are also seen to have a high r value in Table 4.1.33.

Table 4.1.35 Number of carcasses, Pearson's correlation coefficient (r), mean, standard deviation, minimum and maximum values for Fat (mm) and WCM (kg) within mass cluster for fifteen producers

Cluster	n	r	WCM (kg)				Fat (mm)			
			Mean	SD	Min	Max	Mean	SD	Min	Max
2	6	-0.11	14.0	4.1	10.2	19.8	5.8	2.1	3.8	8.8
3	57	0.08	26.6	2.7	20.6	29.8	7.6	2.8	5.0	25.0
4	407	0.31*	36.9	2.5	30.0	39.8	8.2	1.5	4.0	13.8
5	2079	0.14*	45.8	2.8	40.0	49.8	9.4	1.7	5.8	20.0
6	6338	0.19*	55.7	2.8	50.0	59.8	10.4	1.7	6.0	24.6
7	10429	0.18*	65.2	2.9	60.0	69.8	11.6	1.8	1.6	24.0
8	11681	0.22*	74.9	2.9	70.0	79.8	13.1	2.1	1.8	29.0
9	8325	0.22*	84.5	2.8	80.0	89.9	14.9	2.4	7.6	29.0
10	3124	0.07*	93.5	2.6	90.0	99.8	16.2	2.8	6.0	29.8
11	472	-0.03	103.6	2.8	100.0	109.8	16.4	3.7	5.2	30.0
12	184	0.01	115.2	2.9	110.0	119.8	15.9	4.5	5.2	27.6
13	272	0.09	125.1	2.9	120.0	129.8	17.9	5.5	5.2	35.0
14	281	0.12**	135.2	2.9	130.0	139.8	19.1	5.8	7.0	39.4
15	380	-0.02	144.8	2.8	140.0	149.8	19.8	6.3	7.6	50.0
16	351	-0.03	155.0	2.9	150.0	159.8	19.7	5.9	7.8	38.4
17	338	0.03	164.6	2.8	160.0	169.8	19.8	6.4	5.2	48.0
18	359	0.01	174.7	2.9	170.0	179.8	20.9	6.9	7.0	56.0
19	331	0.06	184.7	2.9	180.0	189.8	21.4	5.4	8.0	45.8
20	302	0.17**	194.9	2.9	190.0	199.8	23.5	6.3	10.6	47.0
21	259	0.11	204.5	2.9	200.0	209.8	24.6	6.1	9.2	44.0
22	200	0.15**	214.6	2.9	210.0	219.8	27.8	8.1	12.8	70.6
23	127	0.09	224.2	2.8	220.0	229.8	31.4	9.5	15.8	80.0
24	89	0.04	234.7	2.9	230.0	239.8	32.0	8.2	16.8	55.0
25	49	0.08	244.5	3.1	240.0	249.8	34.6	8.4	14.4	60.0
26	27	-0.12	253.9	2.5	250.2	258.8	36.3	10.6	18.8	58.0
27	11	-0.28	264.5	3.4	260.0	269.4	38.9	7.8	27.6	58.0
28	12	0.24	292.4	27.7	271.4	345.8	36.7	16.8	15.4	80.0

*Significance level $P < 0.0001$
**Significance level $P < 0.05$

In Table 4.1.36 the R^2 values are low, ranging from 0 to 0.09, and the CV values are high, ranging from 15.37 to 46.61, for the mass clusters of the fifteen producers.

Dividing the fifteen producers into males and females still results in a high Pearson's correlation coefficient (r), where r = 0.65 (M) and 0.76 (F) (Table 4.1.37). Wide ranges are seen for both males and females for the parameters Fat and WCM (Table 4.1.37) which may have contributed to the high CV values seen in Table 4.1.38. Linearly WCM can explain 42% ($P < 0.0001$) of the variation seen in Fat for males and 58% ($P < 0.0001$) of the variation seen within females. Quadratically, 43% (M; $P < 0.0001$) and 58% (F; $P < 0.0001$) of the variation within Fat can be explained by WCM.

Table 4.1.36 GLM Procedure: Fat (mm) and WCM (kg) within mass cluster for fifteen producers

Cluster	F value	R^2	CV	Pr > F
2	0.05	0.01	41.00	0.8415
3	0.4	0.01	37.39	0.5303
4	42.54	0.09	18.09	0.0001
5	42.5	0.02	17.49	0.0001
6	228.5	0.03	15.95	0.0001
7	348.51	0.03	15.37	0.0001
8	589.96	0.05	15.63	0.0001
9	419.1	0.05	15.89	0.0001
10	16.31	0.01	17.46	0.0001
11	0.46	0	22.22	0.4982
12	0.01	0	28.35	0.9408
13	2.27	0.01	30.44	0.1329
14	4.02	0.01	29.95	0.0458
15	0.17	0	31.69	0.679
16	0.42	0	29.85	0.516
17	0.23	0	32.21	0.6302
18	0.03	0	33.26	0.8692
19	1	0	25.38	0.3175
20	9.01	0.03	26.50	0.0029
21	3.36	0.01	24.66	0.068
22	4.84	0.02	28.72	0.029
23	1.07	0.01	30.16	0.3023
24	0.17	0	25.81	0.681
25	0.27	0.01	24.40	0.6083
26	0.34	0.01	29.49	0.5657
27	0.77	0.08	20.34	0.4038
28	0.59	0.06	46.61	0.459

Table 4.1.37 Number of carcasses, Pearson's correlation coefficient (r), mean, standard deviation, minimum and maximum values for Fat (mm) and WCM (kg) for males and females for fifteen producers

Gender	n	r	WCM (kg)				Fat (mm)			
			Mean	SD	Min	Max	Mean	SD	Min	Max
Male	24606	0.65*	70.4	14.1	10.2	345.8	12.3	2.7	1.6	80.0
Female	21884	0.76*	88.8	40.6	10.6	292.2	14.7	5.3	1.8	80.0

*Significance level P < 0.0001

Table 4.1.38 GLM Procedure: Fat (mm) and WCM (mm) between males and females for fifteen producers

Gender	Linear				Quadratic			
	F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
Male	18044.3	0.42	16.50	0.0001	9359.53	0.43	16.37	0.0001
Female	29803.3	0.58	23.38	0.0001	14944.9	0.58	23.36	0.0001

Table 4.1.39 shows that 97.8% of the male carcasses fall within mass clusters 5 to 10 (40 – 99 kg). Mass clusters 4 to 9 have highly significant (P < 0.0001) Pearson's correlation coefficients which range from 0.12 to 0.32 (Table 4.1.39). The mean, standard deviation, minimum and maximum values for WCM and Fat are shown in Table 4.1.39 for males and Table 4.1.40 for females.

Table 4.1.39 Number of carcasses, Pearson's correlation coefficient (r), mean, standard deviation, minimum and maximum values for WCM (kg) and Fat (mm) within mass clusters for males of the fifteen selected producers

Cluster	n	r	WCM (kg)				Fat (mm)			
			Mean	SD	Min	Max	Mean	SD	Min	Max
2	1		10.2		10.2	10.2	8.8		8.8	8.8
3	31	0.02	26.3	2.8	20.6	29.8	7.7	3.5	5.0	25.0
4	269	0.32*	36.8	2.5	30.2	39.8	8.2	1.7	4.0	13.8
5	1224	0.12*	45.8	2.7	40.0	49.8	9.3	1.7	5.8	18.0
6	3748	0.19*	55.8	2.8	50.0	59.8	10.3	1.7	6.0	24.6
7	6551	0.19*	65.2	2.8	60.0	69.8	11.4	1.8	1.6	21.6
8	7169	0.22*	74.7	2.9	70.0	79.8	12.8	2.0	7.0	25.0
9	4145	0.20*	84.3	2.8	80.0	89.8	14.4	2.2	8.0	25.0
10	1235	0.05	93.3	2.6	90.0	99.8	15.6	2.6	9.0	58.6
11	179	-0.11	103.3	2.6	100.0	109.8	16.0	2.9	7.0	25.6
12	11	0.07	111.8	0.9	110.6	113.2	16.7	4.2	12.0	25.2
13	3	0.66	121.9	0.7	121.2	122.6	12.9	7.2	5.2	19.6
14	1		135.0		135.0	135	9.0		9.0	9.0
15										
16	2	-1	155.2	3.7	152.6	157.8	15.4	3.7	12.8	18.0
17	5	-0.15	165.9	3.0	162.2	169.6	13.0	2.6	11.0	17.6
18	8	-0.29	175.6	2.8	171.2	179.4	12.2	2.8	8.0	15.2
19	5	0.54	187.6	2.6	183.2	189.6	14.2	5.5	8.0	21.8
20	4	0.90	192.2	2.1	190.6	195.2	13.5	4.4	10.6	20.0
21	3	0.99**	206.7	0.4	206.4	207.2	23.8	1.8	22.4	25.8
22	2	1	213.2	0.8	212.6	213.8	20.9	10.9	13.2	28.6
23	1		223.4		223.4	223.4	23.6		23.6	23.6
24	1		232.4		232.4	232.4	17.6		17.6	17.6
25	2	1	247.1	3.8	244.4	249.8	19.8	7.6	14.4	25.2
26	1		255.6		255.6	255.6	18.8		18.8	18.8
27	1		266.4		266.4	266.4	40.4		40.4	40.4
28	4	0.31	324.1	26.5	285.6	345.8	39.2	27.7	21.8	80.0

*Significance level $P < 0.0001$
**Significance level $P < 0.05$

Table 4.1.40 shows that only 81.8% of female carcasses fall within the 5 to 10 mass cluster range which is 16% less than the number of male carcasses within that mass cluster range (Table 4.1.39). Pearson's correlation coefficients are highly significant ($P < 0.0001$) for mass clusters 5 to 9 and range from 0.16 to 0.21.

The R^2 values are low and the CV values are high (CV > 10.0) for Fat and WCM for males and females (Table 4.1.41). An anomaly may have occurred for mass cluster 21 within males as the R^2 value is 0.99, this anomaly is also displayed in Table 4.1.39 where males had a r value of 0.99 between Fat and WCM.

Table 4.1.40 Number of carcasses, Pearson’s correlation coefficient (r), mean, standard deviation, minimum and maximum values for WCM (kg) and Fat (mm) within mass clusters for females of the fifteen selected producers

Cluster	n	r	WCM (kg)				Fat (mm)			
			Mean	SD	Min	Max	Mean	SD	Min	Max
2	5	0.32	14.8	4.1	10.6	19.8	5.2	1.7	3.8	7.2
3	26	0.32	27.0	2.5	20.6	29.8	7.4	1.7	5.0	13.2
4	138	0.26**	37.0	2.5	30.0	39.8	8.3	1.3	6.0	13.0
5	855	0.16*	45.9	2.7	40.0	49.8	9.5	1.7	6.0	20.0
6	2590	0.19*	55.7	2.8	50.0	59.8	10.6	1.7	6.8	20.0
7	3878	0.18*	65.1	2.9	60.0	69.8	11.9	1.9	4.0	24.0
8	4512	0.21*	75.0	2.9	70.0	79.8	13.4	2.2	1.8	29.0
9	4180	0.21*	84.8	2.8	80.0	89.9	15.3	2.5	7.6	29.0
10	1889	0.07**	93.6	2.7	90.0	99.8	16.6	2.9	6.0	29.8
11	293	-0.01	103.8	2.8	100.0	109.8	16.7	4.0	5.2	30.0
12	173	0.02	115.3	2.9	110.0	119.8	15.9	4.5	5.2	27.6
13	269	0.08	125.2	2.9	120.0	129.8	17.9	5.4	5.2	35.0
14	280	0.12**	135.2	2.9	130.0	139.8	19.1	5.7	7.0	39.4
15	380	-0.02	144.8	2.8	140.0	149.8	19.8	6.3	7.6	50.0
16	349	-0.03	155.0	2.9	150.0	159.8	19.7	5.9	7.8	38.4
17	333	0.04	164.5	2.8	160.0	169.8	19.9	6.4	5.2	48.0
18	351	0.02	174.7	2.9	170.0	179.8	21.1	6.9	7.0	56.0
19	326	0.07	184.7	2.9	180.0	189.8	21.5	5.4	9.0	45.8
20	298	0.15**	194.9	2.9	190.0	199.8	23.6	6.2	12.8	47.0
21	256	0.11	204.5	2.9	200.0	209.8	24.6	6.1	9.2	44.0
22	198	0.15**	214.7	2.9	210.0	219.8	27.9	8.0	12.8	70.6
23	126	0.09	224.2	2.8	220.0	229.8	31.5	9.5	15.8	80.0
24	88	0.03	234.7	2.9	230.0	239.8	32.2	8.1	16.8	55.0
25	47	0.13	244.3	3.0	240.0	249.8	35.2	7.9	21.0	60.0
26	26	-0.07	253.8	2.6	250.2	258.8	36.9	10.2	21.0	58.0
27	10	-0.29	264.3	3.5	260.0	269.4	38.8	8.2	27.6	58.0
28	8	0.08	276.6	6.7	271.4	292.2	35.4	10.4	15.4	46.0

*Significance level $P < 0.0001$

**Significance level $P < 0.05$

The WCM and Fat means of the 15 selected producers are shown in Table 4.1.42 and 4.1.43. The WCM range is from 56.8 to 122.8 kg and the Fat range is from 10.7 to 17.8 mm (Table 4.1.42 and 4.1.43). Producer I produces the lightest and leanest pigs with a mean WCM of 56.8 ± 8.8 kg and a mean Fat of 10.7 ± 2.2 mm. The producer with the highest number of carcasses is Producer B with 8168 carcasses and has a mean WCM of 82.6 ± 16.6 kg and a mean Fat of 14.9 ± 3.3 mm. The SD of each producer is low, across all 15 selected producers; the SD range was from 2.2 to 7.7, showing uniformity across Fat.

Table 4.1.41 GLM Procedure: Fat (mm) and WCM (kg) for males and females for fifteen producers

Cluster	Males				Females			
	F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
2		0			0.35	0.11	36.50	0.5943
3	0.01	0	46.27	0.9328	2.7	0.10	22.41	0.1133
4	32.37	0.11	19.39	0.0001	9.84	0.07	15.30	0.0021
5	19.39	0.02	17.54	0.0001	23.19	0.03	17.41	0.0001
6	141.34	0.04	15.87	0.0001	94.58	0.04	15.87	0.0001
7	237.79	0.04	15.17	0.0001	135.5	0.03	15.24	0.0001
8	349.74	0.05	15.29	0.0001	217.17	0.05	15.81	0.0001
9	172.99	0.04	15.12	0.0001	199.33	0.05	16.13	0.0001
10	3.37	0.003	16.76	0.0667	9.73	0.01	17.50	0.0018
11	2.08	0.01	18.26	0.1507	0.04	0	24.09	0.8339
12	0.04	0.004	26.63	0.8468	0.06	0	28.59	0.8123
13	0.76	0.43	59.99	0.5431	1.71	0.01	30.20	0.1927
14		0			4.02	0.01	29.77	0.0458
15					0.17	0	31.69	0.6790
16		1			0.37	0.001	29.83	0.5459
17	0.07	0.02	23.19	0.8089	0.42	0.001	31.97	0.5182
18	0.57	0.09	23.38	0.4778	0.14	0	32.67	0.7086
19	1.29	0.29	37.94	0.3458	1.65	0.005	24.91	0.2000
20	8.76	0.81	17.21	0.0977	6.86	0.02	26.10	0.0093
21	4107	0.99	0.16	0.0099	3.4	0.01	24.78	0.0665
22		1			4.49	0.02	28.58	0.0354
23		0			1.03	0.01	30.14	0.3131
24		0			0.07	0.001	25.38	0.7863
25		1			0.8	0.02	22.41	0.3772
26		0			0.13	0.01	28.01	0.7176
27		0			0.78	0.09	21.49	0.4031
28	0.21	0.09	82.26	0.6895	0.04	0.01	31.51	0.8433

Table 4.1.42 Number of carcasses, means, standard deviations, minimum and maximum values for WCM (kg) and Fat (mm) of fifteen selected producers

Producer	n	WCM (kg)				Fat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
A	992	122.8	60.5	25.2	292.2	17.8	7.7	4.0	58.0
B	8168	82.6	16.6	14.4	256.8	14.9	3.3	4.0	56.0
C	986	59.9	32.4	30.0	188.6	11.2	3.7	5.2	33.2
D	2371	89.9	7.8	42.2	122.0	14.5	2.6	8.0	29.0
E	2107	80.9	24.1	39.0	239.8	12.9	3.4	6.0	50.4
F	2659	64.3	20.6	30.6	228.0	12.1	2.7	6.8	44.0
G	359	111.1	45.9	47.8	232.4	16.8	6.3	5.2	56.0
H	3888	85.7	17.3	26.4	277.6	14.9	3.2	5.8	40.0
I	684	56.8	8.8	32.6	87.4	10.7	2.2	6.0	21.6
J	5049	66.7	35.8	22.2	250.2	11.3	3.6	4.0	43.6
K	7238	76.8	27.9	10.6	334.8	12.7	3.7	1.6	80.0
L	272	85.8	38.4	40.2	330.2	13.9	3.9	6.0	36.0
M	7590	70.4	18.8	10.2	253.8	12.3	3.8	4.0	80.0
N	728	81.9	24.4	52.6	240.4	13.4	3.3	5.2	35.2
O	3399	100.9	56.5	24.0	345.8	15.5	7.1	5.0	58.0

Producer K and M may have culled sows as the mean WCM was 76.8 ± 28.9 kg and 70.4 ± 18.8 kg, respectively, and the mean Fat was 12.7 ± 3.7 mm and 12.3 ± 3.8 mm, respectively. They have maximum WCM values of 334.8 and 253.8 kg, respectively and the maximum Fat values were both 80.0 mm (Table 4.1.42 and 4.1.43).

Table 4.1.43 Number of carcasses, means, standard deviations, minimum and maximum values for WCM (kg) and Fat (mm) of fifteen selected producers ranked by WCM (kg)

Producer	n	WCM (kg)				Fat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
I	684	56.8	8.8	32.6	87.4	10.7	2.2	6.0	21.6
C	986	59.9	32.4	30.0	188.6	11.2	3.7	5.2	33.2
F	2659	64.3	20.6	30.6	228.0	12.1	2.7	6.8	44.0
J	5049	66.7	35.8	22.2	250.2	11.3	3.6	4.0	43.6
M	7590	70.4	18.8	10.2	253.8	12.3	3.8	4.0	80.0
K	7238	76.8	27.9	10.6	334.8	12.7	3.7	1.6	80.0
E	2107	80.9	24.1	39.0	239.8	12.9	3.4	6.0	50.4
N	728	81.9	24.4	52.6	240.4	13.4	3.3	5.2	35.2
B	8168	82.6	16.6	14.4	256.8	14.9	3.3	4.0	56.0
H	3888	85.7	17.3	26.4	277.6	14.9	3.2	5.8	40.0
L	272	85.8	38.4	40.2	330.2	13.9	3.9	6.0	36.0
D	2371	89.9	7.8	42.2	122.0	14.5	2.6	8.0	29.0
O	3399	100.9	56.5	24.0	345.8	15.5	7.1	5.0	58.0
G	359	111.1	45.9	47.8	232.4	16.8	6.3	5.2	56.0
A	992	122.8	60.5	25.2	292.2	17.8	7.7	4.0	58.0

Pearson's correlation coefficient (r) between WCM and Fat for the 15 selected producers range from 0.34 to 0.85 (Table 4.1.44) and are all significant ($P < 0.0001$). The producers with the highest r values are O, A, J, M, C and N and the corresponding r values are 0.85, 0.82, 0.81, 0.79, 0.75 and 0.70. The linear relationship between Fat and WCM is significant ($P < 0.0001$) for all 15 selected producers with producer O having the highest R^2 value of 0.72 (CV = 24.45) and producer D having the lowest R^2 value of 0.12 (CV = 17.11). The R^2 values for producers A, J, M and C are high with the values being 0.66 (CV = 25.02), 0.65 (CV = 19.03), 0.62 (CV = 19.12) and 0.56 (CV = 21.98), respectively. Seven producers (B, D, F, G, H, K and L) have R^2 values that are lower than the R^2 value of all the data pooled together ($R^2 = 0.47$). The quadratic variable for producers A ($R^2 = 0.67$, CV = 24.89 and $P < 0.0001$), B ($R^2 = 0.45$, CV =16.27 and $P < 0.0001$), C ($R^2 = 0.57$, CV = 21.84 and $P = 0.0003$), F ($R^2 = 0.44$, CV = 16.64 and $P < 0.0001$), G ($R^2 = 0.33$, CV = 30.88 and $P = 0.0048$), H ($R^2 = 0.34$, CV = 17.21 and $P < 0.0001$), K ($R^2 = 0.43$, CV = 21.73 and $P < 0.0001$), M ($R^2 = 0.64$, CV = 18.55 and $P < 0.0001$) and O ($R^2 = 0.72$, CV = 24.44 and $P = 0.0458$) are significant.

Table 4.1.44 Pearson's correlation coefficients (r) and GLM procedure for Fat (mm) and WCM (kg) for fifteen selected producers

Producer	r	Linear			Quadratic		
		R^2	CV	Pr > F	R^2	CV	Pr > F
A	0.82	0.66	25.02	0.0001	0.67	24.89	0.0001
B	0.65	0.43	16.55	0.0001	0.45	16.27	0.0001
C	0.75	0.56	21.98	0.0001	0.57	21.84	0.0003
D	0.34	0.12	17.11	0.0001	0.12	17.11	0.3655
E	0.69	0.47	19.14	0.0001	0.47	19.14	0.3733
F	0.65	0.42	16.97	0.0001	0.44	16.64	0.0001
G	0.57	0.32	31.18	0.0001	0.33	30.88	0.0048
H	0.57	0.33	17.36	0.0001	0.34	17.21	0.0001
I	0.62	0.38	15.87	0.0001	0.38	15.85	0.1385
J	0.81	0.65	19.03	0.0001	0.65	19.03	0.0566
K	0.65	0.42	21.83	0.0001	0.43	21.73	0.0001
L	0.62	0.39	21.99	0.0001	0.39	22.03	0.7082
M	0.79	0.62	19.12	0.0001	0.64	18.55	0.0001
N	0.70	0.49	17.43	0.0001	0.49	17.45	0.7628
O	0.85	0.72	24.45	0.0001	0.72	24.44	0.0458

4.2. Part 2

4.2.1 All data

The mean WCM for the data collected on 87 carcasses is 79.0 ± 32.2 kg. Warm carcass mass data ranged from 32.6 to 189.8 kg (Table 4.2.1), as obtained from the abattoir. The mean HGPFat is 14.3 ± 4.9 mm and mean Sfat is 10.7 ± 4.3 mm. The HGPFat was measured using the HGP and the information was provided by the abattoir and the Sfat was measured using callipers. The ranges of the two fat readings are 6.0 to 26.0 mm (HGPFat) and 3.9 to 21.0 mm (Sfat).

The eye muscle measurements are as follows, the means of the EML, EMD and EMA are 9.4 ± 1.2 cm, 5.8 ± 1.1 cm and 39.5 ± 11.1 cm^2, respectively (Table 4.2.1). The ranges for the EML and EMD are 6.9 to 12.9 cm (EML) and 3.1 to 8.3 cm (EMD). The range for the EMA is 12.8 to 58.6 cm^2.

Table 4.2.1 Means, standard deviation, minimum and maximum values for carcass parameters for all data

Parameter	Mean	SD	Min	Max
WCM (kg)	79.0	32.2	32.6	189.8
Sfat (mm)	10.7	4.3	3.9	21.0
HGPFat (mm)	14.3	4.9	6.0	26.0
EML (cm)	9.4	1.2	6.9	12.9
EMD (cm)	5.8	1.1	3.1	8.3
EMA (cm^2)	39.5	11.1	12.8	58.6

Sfat = subcutaneous backfat measured with callipers; HGPFat = backfat measured with Hennessy Grading Probe; EML = eye muscle length; EMD = eye muscle depth and EMA = eye muscle area

The Pearson's correlation coefficients (r) show that the strongest ($P < 0.0001$) relationships are between WCM and EML, WCM and EMA and between WCM and HGPFat with r = 0.64, 0.50 and 0.42, respectively.

Table 4.2.2 Pearson's correlation coefficients between carcass parameters for all data

	Sfat (mm)	HGPFat (mm)	EML (cm)	EMD (cm)	EMA (cm^2)
WCM (kg)	0.31 (0.0033)	0.42 (<.0001)	0.64 (<.0001)	0.26 (0.0159)	0.50 (<.0001)
Sfat (mm)	1		-0.11 (0.3322)	-0.14 (0.1861)	-0.14 (0.2019)
HGPFat (mm)		1	-0.02 (0.8768)	-0.05 (0.6363)	-0.01 (0.9057)

Sfat = subcutaneous backfat measured with callipers; HGPFat = backfat measured with Hennessy Grading Probe; EML = eye muscle length; EMD = eye muscle depth and EMA = eye muscle area

The variance seen within WCM could be explained by EML by 41% ($R^2 = 0.41$ and $P < 0.0001$) and the CV value is 9.82 (Table 4.2.3). The quadratic variable improved the R^2 value between WCM and EML to 0.54 (Table 4.2.3 and Figure 4.2.1) and decreased the CV value to 8.74. Warm carcass mass and Sfat have a low R^2 value (0.09) and a high CV value (38.34), a similar situation is seen with WCM and HGPFat where $R^2 = 0.18$ and CV = 30.95, but the linear relationship between WCM and HGPFat is highly significant ($P < 0.0001$) while the relationship between WCM and Sfat is significant ($P = 0.0033$).

Table 4.2.3 The GLM Procedure: WCM (kg) and other carcass parameters for all data

Parameter	Linear				Quadratic			
	F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
Sfat (mm)	9.16	0.09	38.34	0.0033	4.54	0.09	38.56	0.6020
HGPFat (mm)	18.15	0.18	30.95	0.0001	9.95	0.19	30.84	0.7783
EML (cm)	59.70	0.41	9.82	0.0001	49.21	0.54	8.74	0.0001
EMD (cm)	6.05	0.07	17.56	0.0159	16.71	0.28	15.46	0.0001
EMA (cm^2)	28.46	0.25	24.48	0.0001	34.02	0.45	21.15	0.0001

The linear relationships between WCM and EMA, where $R^2 = 0.25$, CV = 24.48 and $P < 0.0001$ and between WCM and EMD where $R^2 = 0.07$, CV = 17.56 and $P = 0.0159$ are significant. The quadratic relationships between WCM and EMD and WCM and EMA show an improvement in the R^2 values, $R^2 = 0.28$ and $R^2 = 0.45$, respectively and the CV values, CV = 15.46 and CV = 21.15, respectively and are significant ($P < 0.0001$) (Table 4.2.3). This improvement is also demonstrated in Figure 4.2.2 and Figure 4.2.3.

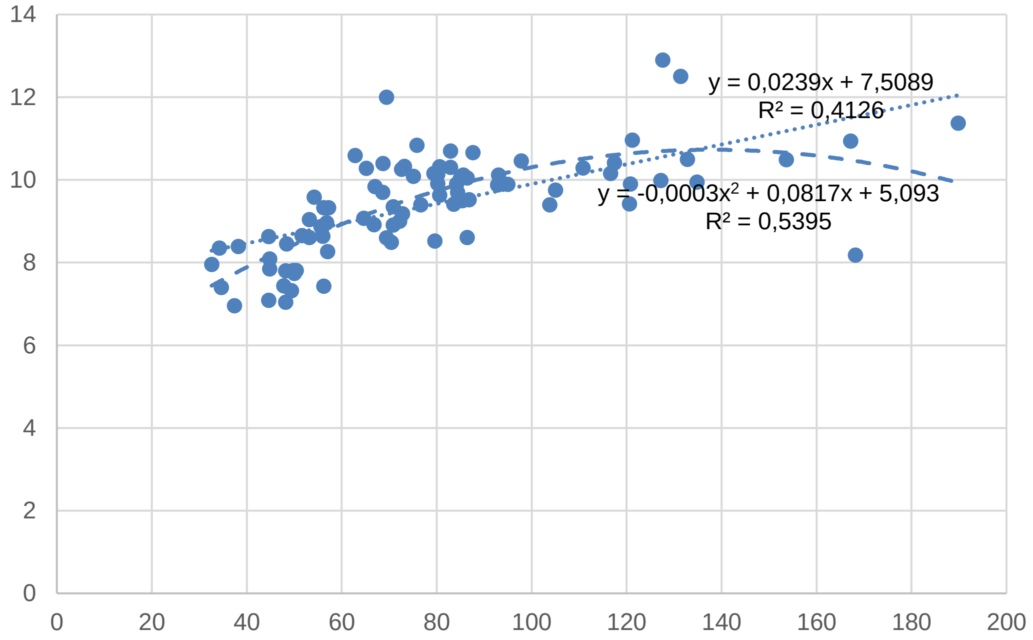

Figure 4.2.1 Linear and quadratic relationships between EML (cm, y-axis) and WCM (kg, x-axis) for all data

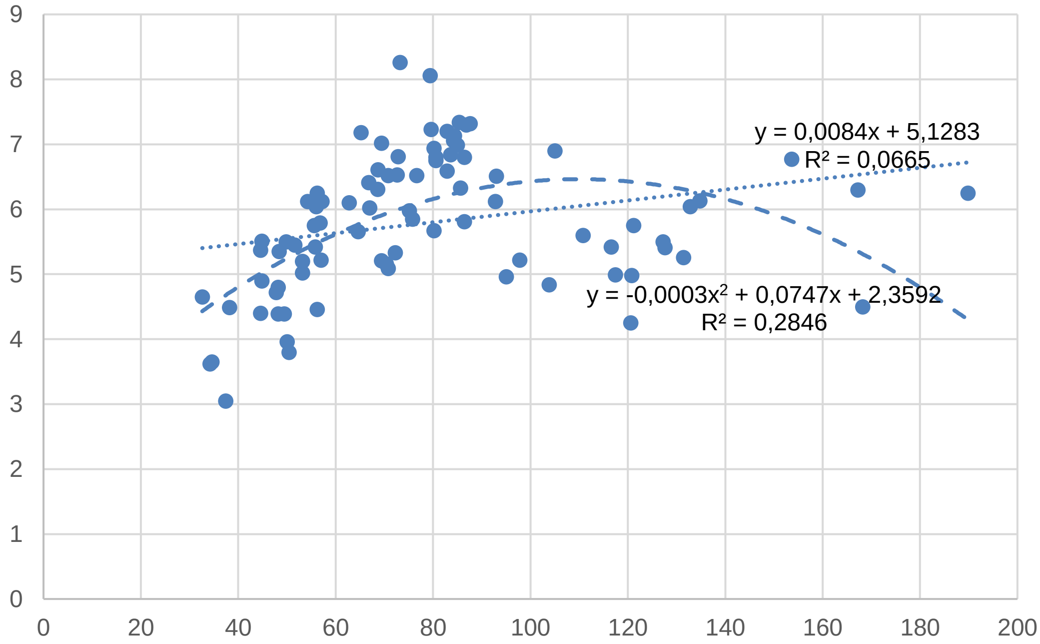

Figure 4.2.2 Linear and quadratic relationship between EMD (cm, y-axis) and WCM (kg, x-axis) for all data

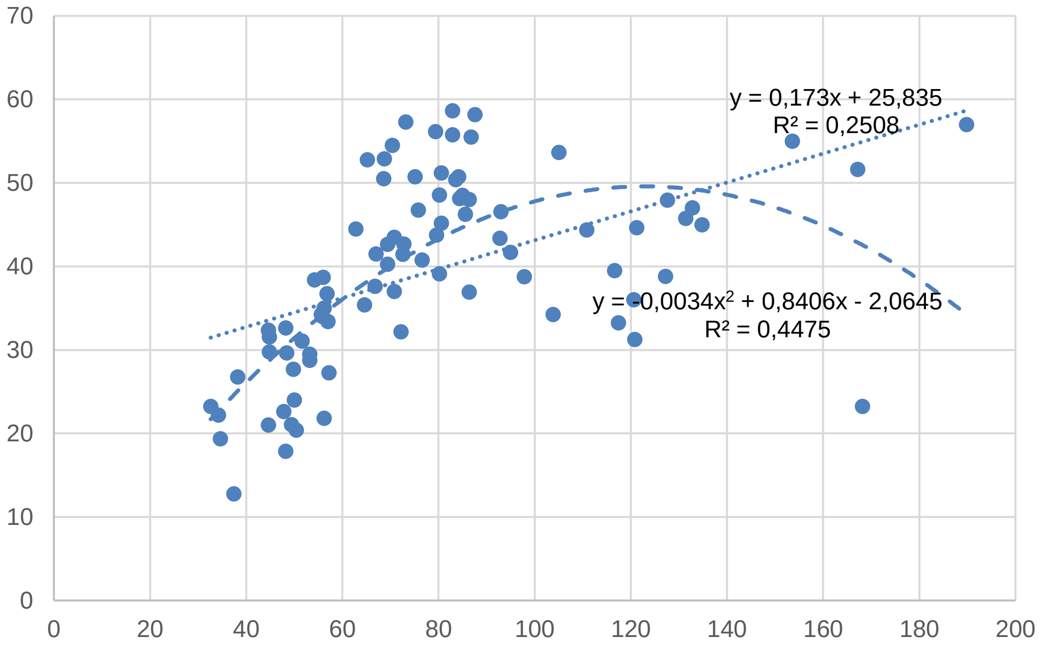

Figure 4.2.3 Linear and quadratic relationship between EMA (cm^2, y-axis) and WCM (kg, x-axis) for all data

4.2.2 All data divided into gender

There are more females (62.1%) than males (37.9%) as shown by Table 4.2.4. The WCM mean for males is 68.1 ± 17.9 kg and it is 85.7 ± 36.9 kg for females. The WCM means of males and females differ by 17.6 kg. The male carcasses WCM range covers 70.4 kg and female carcasses WCM range covers 157.3 kg.

Females have a larger mean EMA than males, 40.5 ± 10.7 cm^2 and 37.8 ± 11.8 cm^2, respectively. The mean Sfat is the same for males and females, 10.7 ± 4.0 mm and 10.7 ± 4.5 mm respectively. The mean HGPFat is similar, where males have a mean of 14.6 ± 4.5 mm and females have a mean of 14.2 ± 5.1 mm. The mean EML and EMD are similar for males and females, with males having a mean EML of 9.1 ± 1.2 cm and a mean EMD of 5.7 ± 1.1 cm and females having a mean EML of 9.6 ± 1.2 cm and a mean EMD of 5.8 ± 1.0 cm (Table 4.2.4).

Table 4.2.4 Means, standard deviations, minimum and maximum values for carcass parameters within gender

Parameter	Male (n = 33)				Female (n = 54)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
WCM (kg)	68.1	17.9	34.6	105.0	85.7	36.9	32.6	189.8
Sfat (mm)	10.7	4.0	4.3	21.0	10.7	4.5	3.9	20.1
HGPFat (mm)	14.6	4.5	7.0	24.0	14.2	5.1	6.0	26.0
EML (cm)	9.1	1.2	6.9	12.0	9.6	1.2	7.3	12.9
EMD (cm)	5.7	1.1	3.1	7.3	5.8	1.0	3.6	8.3
EMA (cm$^{2)}$	37.8	11.8	12.8	55.8	40.5	10.7	21.1	58.6

Females have a significant ($P < 0.0001$) linear relationship between WCM and HGPFat where $R^2 = 0.32$ and CV = 29.96 but a significant linear relationship was not found for males ($R^2 = 0.00093$, CV = 31.18 and P = 0.8663) (Table 4.2.5). When a quadratic variable is added to the relationship between HGPFat and WCM the R^2 value increases to 0.01 for males with the CV increasing to 31.60 and the probability decreasing to 0.8663, with females a 0.01 increase in the R^2 is seen.

Warm carcass mass and EMD for males have a R^2 value of 0.67 (CV = 11.02 and $P < 0.0001$) and for females the R^2 value is 0.01 (CV = 17.72 and P = 0.4841). A quadratic variable increases the

R^2 value to 0.73 (M; P = 0.0012) and 0.12 (F; P = 0.0107) and decreases the CV values to 10.22 (M) and 16.85 (F).

The relationship between WCM and EMA is highly significant (P < 0.0001) for males with R^2 = 0.75 and CV = 15.84 and is significant (P < 0.05) for females with R^2 = 0.17 and CV = 24.24. A quadratic variable increases the R^2 values to 0.79 (M; P = 0.0009) and 0.29 (F; P = 0.0007) and decreases the CV values to 14.80 (M) and 22.64 (F).

The only parameter that is highly significant (P < 0.0001) for males and females was EML where R^2 = 0.49 (M) and 0.42 (F) and CV = 9.65 (M) and 9.33 (F). A quadratic variable for EML and WCM increased the R^2 value to 0.61 (M) and 0.52 (F) while decreasing the CV values to 8.64 (M) and 8.51 (F). This quadratic relationship is significant for both males (P = 0.0008) and females (P < 0.0001).

The Sfat and WCM relationship for females is significant (P = 0.0012) with WCM explaining 18.4% (R^2 = 0.18 and CV = 38.34) of the variation in Sfat, however, with males the R^2 value tended to 0 with the probability tending to 1. When a quadratic variable is added to the Sfat and WCM relationship the R^2 value for males improves to 0.05 with both the CV and probability decreasing to 37.59 and 0.2041, respectively, and for females a 0.01 increase is seen in the R^2 value.

Table 4.2.5 Pearson's correlation coefficient (r) and the GLM Procedure: Carcass parameters and WCM (kg) within gender

Parameter	Male					Female				
	r	F value	R^2	CV	Pr > F	r	F value	R^2	CV	Pr > F
Sfat (mm)	-0.02	0.01	0.00027	38.004	0.9276	0.43	11.75	0.18	38.34	0.0012
HGPFat (mm)	0.03	0.03	0.00093	31.18	0.8663	0.57	24.74	0.32	29.96	0.0001
EML (cm)	0.71	30.78	0.49	9.65	0.0001	0.65	38.23	0.42	9.33	0.0001
EMD (cm)	0.82	64.31	0.67	11.02	0.0001	0.10	0.50	0.01	17.72	0.4841
EMA (cm^2)	0.87	92.26	0.75	15.84	0.0001	0.41	10.51	0.17	24.24	0.0021

4.2.3 Classes and mass clusters for WCM and Sfat

Majority of the carcasses are from the SAS class (16 carcasses), PP class (14 carcasses) and BO class (11 carcasses). The highest mean for WCM is for class SAS, with a mean of 133.9 ± 23.7 kg and the lowest mean is for class PP, with a mean of 46.1 ± 8.5 kg. The highest Sfat mean is for class PR with a mean of 17.6 ± 2.1 mm and lowest mean is for class PP with a mean of 6.8 ± 1.9 mm (Table 4.2.6).

Table 4.2.6 The number of carcasses, means, standard deviation, minimum and maximum values for WCM (kg) and Sfat (mm) within class

Class	n	WCM (kg)				Sfat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
PP	14	46.1	8.5	32.6	56.0	6.8	1.9	3.9	11.3
CP	5	61.3	4.0	56.8	65.2	7.8	0.5	7.0	8.2
BP	7	73.6	3.6	68.6	79.4	8.2	2.4	5.0	11.1
HP	3	85.3	1.3	84.2	86.8	8.0	1.3	6.7	9.3
PO	5	51.7	3.2	47.8	56.2	10.4	0.8	9.5	11.4
CO	2	61.9	6.9	57.0	66.8	8.8	1.9	7.4	10.2
BO	11	74.5	5.3	67.0	80.6	9.8	2.1	4.3	13.0
HO	8	88.3	4.8	82.9	95.0	12.5	2.9	9.0	16.3
PR	4	48.3	7.9	37.4	56.2	17.6	2.1	14.4	18.8
BR	3	73.3	5.5	69.4	79.6	11.3	1.5	10.4	13.0
HR	4	88.1	6.6	83.6	97.8	14.5	3.3	11.7	19.2
PC	3	47.7	2.9	44.6	50.4	16.4	5.1	11.0	21.0
HC	1	85.6		85.6	85.6	12.7		12.7	12.7
SAB	1	105.0		105.0	105.0	11.7		11.7	11.7
SAS	16	133.9	23.7	103.8	189.8	12.5	5.9	4.0	20.1

Class BR (P = 0.0368), HR (P = 0.0138), PP (P = 0.0171) and HO (P = 0.0496) have significant relationships between Sfat and WCM with R^2 values of 0.99, 0.97, 0.39 and 0.50 respectively. The respective CV values are 1.04, 4.54, 23.79 and 17.45 (Table 4.2.7). The other classes did not have a significant (P > 0.05) relationship between Sfat and WCM.

Table 4.2.7 Pearson's correlation coefficient (r) and the GLM Procedure: Sfat (mm) and WCM (kg) within class

Class	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
PP	0.62*	7.64	0.39	23.79	0.0171	3.8	0.41	24.45	0.6959
CP	-0.45	0.74	0.20	6.54	0.4517	0.52	0.34	7.26	0.5734
BP	0.48	1.5	0.23	28.44	0.2748	1.43	0.42	27.68	0.3104
HP	-0.68	0.84	0.46	16.94	0.5276		1		
PO	-0.55	1.29	0.30	7.57	0.3392	0.43	0.30	9.27	0.9913
CO	-1.00		1.00				1.00		
BO	0.39	1.62	0.15	20.93	0.2352	0.91	0.19	21.76	0.6017
HO	0.71*	6.02	0.50	17.45	0.0496	3.55	0.59	17.39	0.3376
PR	-0.14	0.04	0.02	14.58	0.8556	0.33	0.40	16.13	0.5681
BR	0.99*	299	0.99	1.04	0.0368		1.00		
HR	0.99*	70.75	0.97	4.54	0.0138	21.19	0.98	5.88	0.6966
PC	0.72	1.06	0.51	30.33	0.4909		1		
HC			0.00				0		
SAB			0.00				0		
SAS	0.30	1.43	0.09	46.35	0.2518	1.11	0.15	46.68	0.3402

*Significance level P < 0.05

The WCM mass clusters were decided upon therefore making the ranges a fixed entity for each mass cluster (Table 4.2.8). The Sfat SD values are low and range from 1.8 to 7.3 (Table 4.2.8). Mass cluster 2 and 11 have mean Sfat mean values that differ by 4 mm. Mass cluster 2 (40 to 49 kg) has the highest maximum Sfat value (21.0 mm) of all the mass clusters. Only one carcass within mass cluster 2 had a backfat thickness of 21.0 mm and was a male. If that carcass were to be removed mass cluster 2 would have a Sfat range of 4.7 to 18.3 mm.

Table 4.2.8 Number of carcasses, means, standard deviations, minimum and maximum values for WCM (kg) and Sfat (mm) within mass cluster

Mass clusters	n	WCM (kg)				Sfat (mm)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
1	5	35.4	2.3	32.6	38.2	7.8	6.1	3.9	18.7
2	12	47.6	2.3	44.6	50.4	11.3	5.3	4.7	21.0
3	12	55.3	1.8	51.6	57.2	9.9	3.2	6.5	18.8
4	12	67.9	2.6	62.8	70.8	8.2	2.3	4.3	10.9
5	13	76.8	3.4	72.2	80.6	10.1	1.8	6.1	13.0
6	12	85.1	1.5	82.9	87.6	11.1	2.7	6.7	14.7
7	4	94.7	2.3	92.8	97.8	15.4	3.4	11.1	19.2
8	3	106.5	3.7	103.8	110.8	8.0	3.4	4.9	11.7
9	5	119.3	2.2	116.6	121.2	12.6	7.3	4.0	18.8
10	4	129.8	2.8	127.2	132.8	11.9	6.9	5.5	20.1
11	5	162.7	20.3	134.8	189.8	15.3	2.9	11.9	19.6

Mass cluster 7 and 10 have high R^2 values of 0.82 (CV =11.52) and 0.86 (CV = 26.33), respectively (Table 4.2.9). The linear and quadratic relationships between Sfat and WCM are not significant (P > 0.05) for any mass cluster.

Table 4.2.9 Pearson's correlation coefficient (r) and GLM Procedure: Sfat (mm) and WCM (kg) within mass cluster

Cluster	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
1	0.38	0.52	0.15	83.14	0.5231	0.23	0.19	99.38	0.7738
2	0.54	4.02	0.29	41.93	0.0729	1.89	0.30	43.91	0.7598
3	-0.06	0.04	0.004	34.24	0.8474	0.03	0.01	36.06	0.8959
4	0.18	0.35	0.03	29.21	0.5699	0.23	0.05	30.55	0.7234
5	0.34	1.44	0.12	17.22	0.2550	1.93	0.28	16.32	0.1686
6	0.42	2.13	0.18	23.08	0.1753	0.96	0.18	24.31	0.9086
7	0.90	8.91	0.82	11.52	0.0963	2.63	0.84	15.21	0.7589
8	0.03	0.00	0.0007	60.38	0.9835		1.00		
9	-0.01	0.00	0.0002	67.26	0.9834	0.02	0.02	81.51	0.8555
10	-0.93	12.44	0.86	26.33	0.0718	23.23	0.98	14.52	0.2528
11	-0.24	0.19	0.06	21.65	0.6938	0.06	0.06	26.51	0.9924

4.2.4 Classes and mass clusters for WCM and HGPFat

The mean HGPFat and SD values for each class are given in Table 4.2.10. The HO class has a R^2 value of 0.57 and a CV value of 5.16 between HGPFat and WCM and is significant ($P = 0.0312$). The SAS class also has a significant ($P = 0.0144$) relationship between HGPFat and WCM although the R^2 value was lower and the CV value was higher, $R^2 = 0.36$ and CV = 32.94. A quadratic variable saw small increases in the R^2 values except for classes BP, PO and BR where the values increased by 0.22, 0.39 and 0.15, respectively (Table 4.2.10). For classes HP and PR, the R^2 value for the linear relationship between HGPFat and WCM is 0, this is due to all the carcasses in each of these classes having the same HGPFat measurement of 11 mm (HP) and 18 mm (PR) (Table 4.2.10). This occurs in Tables 4.2.32, 4.2.34 and 4.2.36.

Table 4.2.10 Pearson's correlation coefficient (r), means, standard deviations, minimum and maximum values for HGPFat (mm) and GLM Procedure values between HGPFat (mm) and WCM (kg) within class

Class	Mean	SD	Min	Max	r	Linear				Quadratic			
						F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
PP	8.9	1.4	7.0	11.0	0.39	2.1	0.15	15.45	0.1688	1.01	0.16	16.10	0.9009
CP	10.4	1.1	9.0	12.0	0.72	3.3	0.52	8.73	0.1663	1.15	0.53	10.58	0.8731
BP	11.6	0.8	10.0	12.0	-0.13	0.1	0.02	7.39	0.7849	0.64	0.24	7.25	0.3343
HP	11.0	0	11.0	11.0			0				0		
PO	13.4	0.9	13.0	15.0	-0.68	2.6	0.46	5.64	0.2049	5.47	0.85	3.71	0.1500
CO	13.0	0	13.0	13.0			0				0		
BO	14.4	0.7	13.0	15.0	0.28	0.8	0.08	4.75	0.4000	0.35	0.08	5.03	0.9521
HO	14.6	1.1	13.0	16.0	0.75	7.8	0.57	5.16	0.0312	3.27	0.57	5.65	0.9983
PR	18.0	0	18.0	18.0			0				0		
BR	20.0	1.0	19.0	21.0	-0.92	5.7	0.85	2.73	0.2525		1.00		
HR	18.5	2.7	15.0	21.0	0.59	1.1	0.36	14.05	0.4030	0.38	0.43	18.65	0.7805
PC	24.0	0	24.0	24.0			0				0		
HC	24.0		24.0	24.0			0				0		
SAB	15.0		15.0	15.0			0				0		
SAS	16.9	6.7	6.0	26.0	0.59	7.8	0.36	32.94	0.0144	3.67	0.36	34.10	0.9659

The mean HGPFat and SD values within each mass cluster are given in Table 4.2.11. None of the linear relationships between HGPFat and WCM are significant ($P > 0.05$), although, there were high R^2 values such as 0.67 (cluster 7, CV = 11.28), 0.76 (cluster 10, CV = 21.56) and 0.77 (cluster 8, CV =

19.33) (Table 4.2.12). Table 4.2.12 also shows that a quadratic variable made no significant difference to any of the mass clusters.

Table 4.2.11 Means, standard deviations, minimum and maximum values for HGPFat (mm) within mass cluster

Cluster	Mean	SD	Min	Max
1	10.0	4.6	7.0	18.0
2	15.1	6.4	7.0	24.0
3	11.4	2.8	8.0	18.0
4	13.9	3.4	10.0	21.0
5	13.7	2.3	10.0	19.0
6	15.0	3.9	11.0	24.0
7	17.0	2.7	15.0	21.0
8	14.3	4.0	10.0	18.0
9	13.8	8.1	6.0	23.0
10	14.8	5.3	9.0	21.0
11	22.8	3.1	19.0	26.0

Table 4.2.12 Pearson’s correlation coefficient (r) and GLM Procedure values between HGPFat (mm) and WCM (kg) within mass cluster

Cluster	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
1	0.36	0.45	0.13	49.94	0.5510	0.21	0.18	59.55	0.7648
2	0.30	0.98	0.09	42.67	0.3454	0.91	0.17	42.98	0.3856
3	-0.02	0.0	0.00	25.23	0.9520	0.17	0.04	26.11	0.5800
4	0.57	4.72	0.32	20.93	0.0549	2.13	0.32	22.05	0.9391
5	0.42	2.3	0.17	16.12	0.1576	1.60	0.24	16.18	0.3695
6	-0.01	0	0.00	27.49	0.9852	0.05	0.01	28.82	0.7631
7	0.82	3.99	0.67	11.28	0.1840	219.78	0.99	1.31	0.0530
8	0.87	3.26	0.77	19.33	0.3231		1		
9	-0.25	0.19	0.06	65.48	0.6897	0.15	0.13	77.30	0.7330
10	-0.87	6.38	0.76	21.56	0.1274	34.69	0.99	7.44	0.1559
11	0.73	3.51	0.54	10.71	0.1579	1.38	0.58	12.53	0.7637

4.2.5 Classes and mass clusters for WCM and eye muscle measurements (EML, EMD and EMA)

The mean, SD, minimum and maximum values for EML are shown in Table 4.2.13. Pearson’s correlation coefficients (r) are high except for the SAS class (r = 0.07) and only two classes had a significant r value, which are the PP (r = 0.68; P = 0.0074) and PO (r = 0.97; P = 0.0056) classes (Table 4.2.13). Therefore, these two classes (PP and PO) also have significant linear relationships between EML and WCM. No significant quadratic relationship between EML and WCM was observed within class.

The mean EML increases as mass increases until mass cluster 7 and then it plateaus until mass cluster 11 (Table 4.2.14 and Figure 4.2.4). This relationship is further shown by the a high R^2 value of 0.76 in Figure 4.2.4.

There is a low amount of variation within EML that is explained by WCM within a mass cluster except for mass cluster 8 where 94% ($R^2 = 0.94$) of the variation is explained by WCM and has a CV value of 1.54; however, this relationship is not significant (P > 0.05) (Table 4.2.15). The relationship between EML and WCM within mass cluster is not significant for any mass cluster, linearly and quadratically.

Table 4.2.13 Means, standard deviations, minimum and maximum values for EML (cm) and Pearson’s correlation coefficient (r) and GLM Procedure values between EML (cm) and WCM (kg) within class

Class	Mean	SD	Min	Max	r	Linear				Quadratic			
						F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
PP	8.4	0.6	7.4	9.6	0.68	10.33	0.46	5.20	0.0074	5.73	0.51	5.18	0.4416
CP	9.6	0.7	8.9	10.6	0.53	1.18	0.28	7.51	0.3565	0.93	0.48	7.82	0.4672
BP	9.8	0.8	8.5	10.8	0.58	2.56	0.34	7.10	0.1704	1.08	0.35	7.86	0.7696
HP	9.8	0.3	9.5	10.0	-0.84	2.45	0.71	2.09	0.3618		1.00		
PO	8.4	0.7	7.4	9.3	0.97	51.18	0.94	2.43	0.0056	20.12	0.95	2.75	0.5339
CO	8.6	0.5	8.2	8.9	1.00		1.00				1.00		
BO	10.0	0.8	9.0	12.0	-0.20	0.38	0.04	8.18	0.5553	0.48	0.11	8.36	0.4530
HO	10.1	0.4	9.5	10.7	-0.38	1.02	0.15	4.00	0.3506	0.46	0.16	4.36	0.8020
PR	7.4	0.3	6.9	7.7	0.73	2.24	0.53	3.68	0.2733	1.30	0.72	3.99	0.5272
BR	8.7	0.2	8.5	8.9	-0.56	0.45	0.31	2.79	0.6231		1.00		
HR	9.5	0.8	8.6	10.5	0.69	1.85	0.48	7.07	0.3071	3.74	0.88	4.76	0.3194
PC	7.3	0.4	7.0	7.8	0.75	1.3	0.57	5.49	0.4584		1.00		
HC	10.1		10.1	10.1			0				0		
SAB	9.8		9.8	9.8			0				0		
SAS	10.5	1.1	8.2	12.9	0.07	0.07	0.01	11.33	0.7999	0.14	0.02	11.65	0.6312

Table 4.2.14 Means, standard deviations, minimum and maximum values for EML (cm) within mass cluster

Cluster	Mean	SD	Min	Max
1	7.8	0.6	6.9	8.4
2	7.8	0.5	7.0	8.6
3	8.8	0.6	7.4	9.6
4	9.7	1.0	8.5	12.0
5	9.8	0.7	8.5	10.8
6	9.9	0.6	8.6	10.7
7	10.1	0.3	9.9	10.5
8	9.8	0.5	9.4	10.3
9	10.2	0.6	9.4	10.9
10	11.5	1.4	9.9	12.9
11	10.2	1.2	8.2	11.4

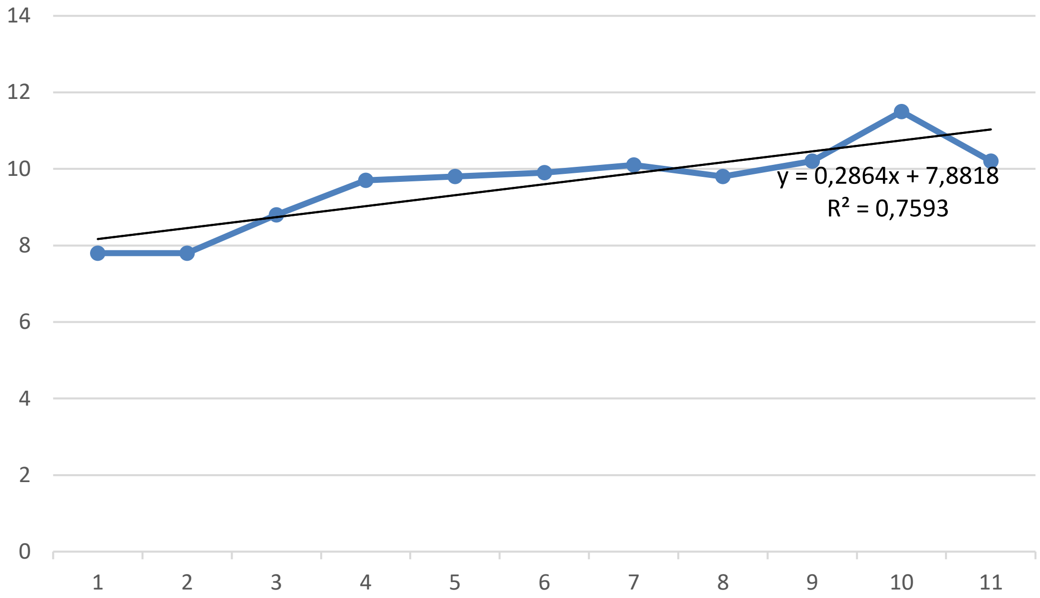

Figure 4.2.4 Mean eye muscle lengths (EML; cm) per mass cluster (1 to 11)

Table 4.2.15 Pearson's correlation coefficient (r) and GLM Procedure values between EML (cm) and WCM (kg) within mass cluster

Cluster	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
1	-0.14	0.06	0.02	9.08	0.8212	0.18	0.15	10.36	0.6331
2	-0.19	0.36	0.04	6.48	0.5595	0.30	0.06	6.74	0.6136
3	-0.08	0.07	0.007	6.71	0.8032	0.10	0.02	7.01	0.7154
4	-0.25	0.66	0.06	10.66	0.4344	0.32	0.07	11.21	0.8646
5	0.04	0.02	0.002	6.87	0.8990	0.27	0.05	7.02	0.4870
6	-0.20	0.44	0.04	6.04	0.5228	1.98	0.31	5.42	0.0970
7	0.76	2.68	0.57	2.16	0.2431	2.55	0.84	1.89	0.4286
8	0.97	16.7	0.94	1.54	0.1528		1.00		
9	-0.06	0.01	0.004	6.50	0.9205	0.31	0.23	6.98	0.5183
10	-0.05	0.0	0.002	15.38	0.9534	0.80	0.61	13.52	0.4274
11	0.28	0.26	0.08	13.48	0.6469	0.27	0.21	15.27	0.6350

Table 4.2.16 displays the mean, SD, minimum and maximum values for EMD. Pearson's correlation coefficient is highest for class PR (r = 0.94) although this is not significant (P = 0.0624). Class PP shows a high r value of 0.83 and is significant (P = 0.0002). Table 4.2.16 also displays the linear and quadratic R^2 and CV values for the relationship between EMD and WCM where class HO is significant for both and class PP is significant linearly.

Table 4.2.17 and Figure 4.2.5 do not show the trend of the carcass parameter increasing with mass as was seen before with Table 4.2.14. Instead no trend or a weak relationship ($R^2 = 0.13$) is seen with the mean EMD values with increasing mass (Figure 4.2.5). The amount of variation within EMD explained by WCM is low except for mass cluster 7 where 58 % ($R^2 = 0.58$) of the variation is explained by WCM and has a CV value of 10.21, however this relationship is not significant (P > 0.05) (Table 4.2.18). No significant relationship between EMD and WCM was seen within mass cluster, linearly and quadratically.

Table 4.2.16 Means, standard deviations, minimum and maximum values for EMD (cm) and Pearson’s correlation coefficient (r) and GLM Procedure values between EMD (cm) and WCM (kg) within class

Class	Mean	SD	Min	Max	r	Linear				Quadratic			
						F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
PP	5.0	0.8	3.6	6.1	0.83	27.33	0.69	8.78	0.0002	12.83	0.70	9.09	0.4414
CP	6.2	0.6	5.7	7.2	0.42	0.64	0.18	10.16	0.4813	0.45	0.31	11.39	0.6024
BP	6.6	1.2	5.2	8.3	0.45	1.25	0.20	17.08	0.3140	0.57	0.22	18.86	0.7824
HP	7.1	0.2	6.9	7.3	0.87	3.02	0.75	1.61	0.3324		1.00		
PO	5.4	0.6	4.7	6.3	0.84	7.03	0.70	6.47	0.0769	2.44	0.71	7.80	0.8666
CO	5.8	0.8	5.2	6.4	1.00		1.00				1.00		
BO	6.3	0.6	5.2	6.9	0.41	1.78	0.17	9.35	0.2147	0.85	0.18	9.85	0.7766
HO	6.6	0.8	4.9	7.3	-0.75	7.75	0.56	8.56	0.0318	13.73	0.85	5.57	0.0317
PR	3.9	0.6	3.1	4.5	0.94	14.54	0.88	6.97	0.0624	5.33	0.91	8.30	0.5564
BR	6.4	1.2	5.1	7.2	0.47	0.28	0.22	22.88	0.6907		1.00		
HR	6.3	0.9	5.2	7.1	-0.86	5.63	0.74	8.93	0.1409	4.35	0.89	7.92	0.4240
PC	4.2	0.3	3.8	4.4	-0.79	1.75	0.64	6.98	0.4122		1.00		
HC	6.3		6.3	6.3			0				0		
SAB	6.9		6.9	6.9			0				0		
SAS	5.5	0.7	4.3	6.8	0.44	3.36	0.19	11.69	0.0883	1.89	0.23	11.89	0.3975

Table 4.2.17 Means, standard deviations, minimum and maximum values for EMD (cm) within mass cluster

Cluster	Mean	SD	Min	Max
1	3.9	0.7	3.1	4.7
2	4.8	0.6	3.8	5.5
3	5.6	0.5	4.5	6.3
4	6.1	0.7	5.1	7.2
5	6.7	0.9	5.3	8.3
6	6.9	0.5	5.8	7.3
7	5.7	0.7	4.9	6.5
8	5.8	1.0	4.8	6.9
9	5.1	0.6	4.3	5.8
10	5.6	0.3	5.3	6.0
11	5.9	0.9	4.5	6.8

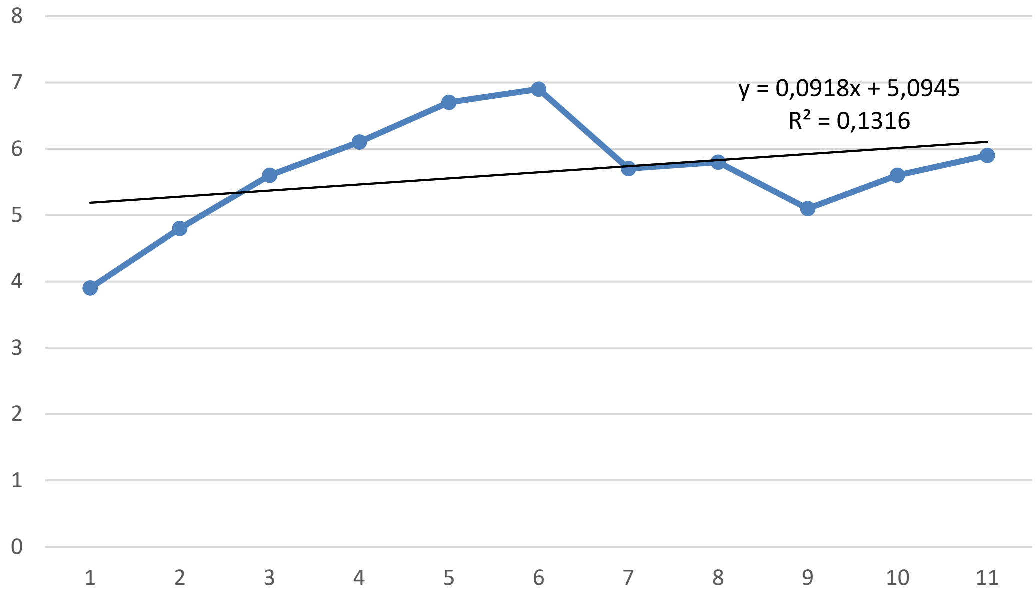

Figure 4.2.5 Mean eye muscle depths (EMD; cm) per mass cluster (1 to 11)

Table 4.2.18 Pearson's correlation coefficient (r) and GLM Procedure values between EMD (cm) and WCM (kg) within mass cluster

Cluster	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
1	-0.26	0.22	0.07	19.08	0.6734	2.38	0.70	13.17	0.1722
2	-0.45	2.54	0.20	11.59	0.1423	1.63	0.27	11.73	0.4109
3	0.23	0.58	0.05	9.87	0.4643	0.26	0.05	10.41	0.9856
4	-0.26	0.7	0.07	11.72	0.4216	0.98	0.18	11.59	0.3015
5	0.17	0.33	0.03	13.27	0.5766	0.15	0.03	13.91	0.9974
6	-0.02	0.0	0.0005	6.99	0.9457	0.15	0.03	7.26	0.5977
7	-0.76	2.75	0.58	10.21	0.2393	4.34	0.89	7.15	0.3273
8	0.01	0.0	0.0001	25.49	0.9931		1.00		
9	-0.15	0.06	0.02	12.68	0.8159	1.67	0.63	9.61	0.2140
10	0.51	0.7	0.26	6.45	0.4898	32.12	0.98	1.31	0.0922
11	-0.15	0.07	0.02	16.53	0.8062	0.08	0.08	19.69	0.7597

The mean, SD, minimum and maximum values for EMA within class are shown in Table 4.2.19. Pearson's correlation coefficient was highest for class PO where r = 0.92 and the probability is 0.0269. Linearly, the only classes with significant results are classes PP ($P < 0.0001$), PO ($P = 0.0269$) and HO ($P = 0.0173$) and have R^2 values of 0.79, 0.85 and 0.64, respectively. The quadratic variable resulted in no significant differences within class (Table 4.2.19).

A trend is seen with the mean EMA values across mass clusters (Table 4.2.20 and Figure 4.2.6) although the R^2 value ($R^2 = 0.47$) is lower than that between EML and mass ($R^2 = 0.76$; Figure 4.2.4). The variation within EMA explained by WCM per mass cluster is low except for mass cluster 7 where 81% ($R^2 = 0.81$) of the variation is explained by WCM and has a CV value of 4.13 but this relationship is not significant ($P > 0.05$) (Table 4.2.21).

Table 4.2.19 Means, standard deviations, minimum and maximum values for EMA (cm^2) and Pearson's correlation coefficient (r) and GLM Procedure values between EMA (cm^2) and WCM (kg) within class

Class	Mean	SD	Min	Max	r	Linear				Quadratic			
						F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
PP	30.2	5.7	19.4	38.7	0.89	46.34	0.79	8.94	0.0001	22.83	0.81	9.08	0.2222
CP	39.3	9.7	27.3	52.8	0.69	2.74	0.48	20.56	0.1965	0.95	0.49	24.95	0.8776
BP	51.2	5.3	42.7	57.3	0.14	0.10	0.02	11.12	0.7697	0.32	0.14	11.64	0.4991
HP	51.6	3.6	48.5	55.5	0.81	1.92	0.66	5.74	0.3981		1.00		
PO	29.0	4.5	22.6	35.0	0.92	16.52	0.85	7.09	0.0269	6.08	0.86	8.32	0.6621
CO	35.5	3.0	33.4	37.6	1.00		1.00				1.00		
BO	43.3	5.9	32.2	52.9	0.20	0.37	0.04	14.08	0.5578	1.31	0.25	13.23	0.1807
HO	50.0	6.6	41.7	58.6	-0.80	10.62	0.64	8.58	0.0173	4.43	0.64	9.39	0.9739
PR	19.9	4.9	12.8	24.0	0.87	6.30	0.76	14.90	0.1288	8.70	0.95	10.00	0.2851
BR	41.1	3.6	37.0	43.8	0.52	0.38	0.28	10.59	0.6485		1.00		
HR	43.6	6.7	36.9	50.4	-0.63	1.29	0.39	14.68	0.3741	22.3	0.98	3.94	0.1205
PC	19.8	1.7	17.9	21.0	-0.32	0.12	0.10	11.20	0.7917		1.00		
HC	46.3		46.3	46.3			0				0		
SAB	53.6		53.6	53.6			0				0		
SAS	42.2	9.1	23.3	57.0	0.40	2.70	0.16	20.42	0.1229	1.27	0.16	21.17	0.7706

Table 4.2.20 Means, standard deviations, minimum and maximum values for EMA (cm^2) within mass cluster

Cluster	Mean	SD	Min	Max
1	20.9	5.3	12.8	26.8
2	25.9	5.6	17.9	32.6
3	32.4	4.9	21.8	38.7
4	44.4	6.7	35.4	54.5
5	45.8	7.0	32.2	57.3
6	50.4	6.0	36.9	58.6
7	42.6	3.3	38.8	46.6
8	44.1	9.7	34.3	53.6
9	36.9	5.3	31.3	44.6
10	44.9	4.1	38.8	47.9
11	46.4	13.7	23.3	57.0

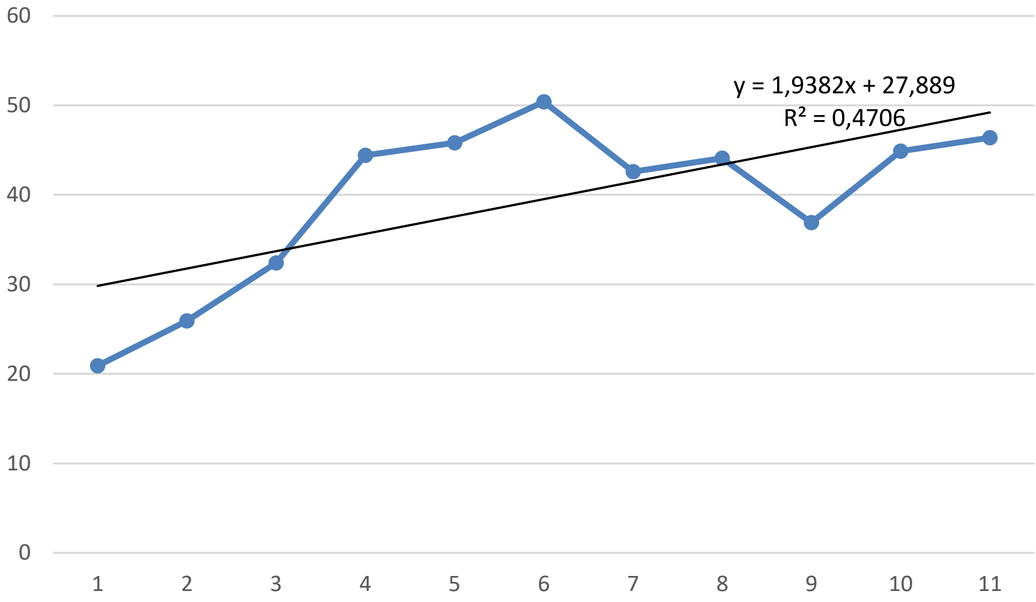

Figure 4.2.6 Mean eye muscle area (EMA; cm^2) per mass cluster (1 to 11)

Table 4.2.21 Pearson's correlation coefficient (r) and GLM Procedure values between EMA (cm^2) and WCM (kg) within mass cluster

Cluster	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
1	-0.14	0.06	0.02	28.76	0.8229	0.37	0.27	30.43	0.4946
2	-0.41	2.06	0.17	19.52	0.1819	0.95	0.17	20.53	0.8543
3	0.09	0.09	0.009	15.97	0.7718	0.33	0.07	16.32	0.4654
4	0.10	0.11	0.01	15.71	0.7458	0.07	0.01	16.53	0.8531
5	0.24	0.69	0.06	15.49	0.4227	0.77	0.13	15.60	0.3739
6	-0.23	0.56	0.05	12.22	0.4708	5.44	0.55	8.91	0.0119
7	-0.90	8.34	0.81	4.13	0.1019	2.10	0.81	5.82	0.9389
8	0.19	0.04	0.03	30.55	0.8808		1.00		
9	0.11	0.04	0.01	16.49	0.8618	1.61	0.62	12.59	0.2181
10	0.49	0.62	0.24	9.86	0.5123	0.21	0.29	13.45	0.8289
11	0.13	0.05	0.02	33.84	0.8353	0.14	0.13	39.08	0.6745

4.2.6 Sfat and eye muscle measurements (EML, EMD and EMA)

The amount of variation in all the eye muscle measurements (EML, EMD and EMA) that is explained by Sfat are low (R^2 = 0.01, 0.02 and 0.02 for EML, EMD and EMA, respectively) and not significant ($P > 0.05$) (Table 4.2.22). The CV values are 12.74, 17.99 and 28.01 for EML, EMD and EMA, respectively. The quadratic relationship between Sfat and EMD ($P < 0.0001$) and EMA ($P = 0.0003$) are significant with 31% ($R^2 = 0.31$) and 19% ($R^2 = 0.19$) of the variation within Sfat being explained by EMD and EMA, respectively. The CV values are 15.18 for EMD and 25.69 for EMA.

Table 4.2.22 GLM Procedure: Carcass parameters and Sfat (mm) for all data

Parameters	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
EML (cm)	-0.11	0.95	0.01	12.74	0.3322	1.4	0.03	12.68	0.2586
EMD (cm)	-0.14	1.78	0.02	17.99	0.1861	18.89	0.31	15.18	0.0001
EMA (cm^2)	-0.14	1.65	0.02	28.01	0.2019	9.52	0.19	25.69	0.0003

The relationship between Sfat and the eye muscle measurements (EML, EMD and EMA) is low within gender (Table 4.2.23). The R^2 values for males are 0.22 (CV = 12.00 and P = 0.0054) for EML, 0.08 (CV = 18.52 and P = 0.1087) for EMD and 0.13 (CV = 29.51 and P = 0.0415) for EMA with the significant relationship being between Sfat and EML and Sfat and EMA. The R^2 values for females are 0.01 (CV = 12.22) for EML, 0.004 (CV = 17.77) for EMD and 0.00007 (CV = 26.58) for EMA with none of the values being significant (P > 0.05).

A quadratic variable for EMA and Sfat improved the R^2 values to 0.37 (M) and 0.12 (F), decreased the CV values to 25.47 (M) and 25.14 (F) and decreased the probability to 0.0083 (M) and 0.0118 (F). When a quadratic variable is included in the relationship between EML and Sfat the R^2 values increased to 0.28 (M) and 0.02 (F), CV decreased to 11.75 for males and increased to 12.31 for females and the probability increased to 0.3901 (M) and decreased to 0.5136 (F). When a quadratic variable is included in the relationship between EMD and Sfat the R^2 values increased to 0.36 (M) and 0.30 (F), the CV decreased to 15.66 (M) and 15.08 (F) and the probability decreased to 0.0034 (M) and 0.0001 (F).

Table 4.2.23 GLM Procedure: Carcass parameters and Sfat (mm) for all data within gender

Parameters	Male					Female				
	r	F value	R^2	CV	Pr > F	r	F value	R^2	CV	Pr > F
EML (cm)	-0.47	8.94	0.22	12.00	0.0054	0.10	0.57	0.01	12.22	0.4526
EMD (cm)	-0.28	2.73	0.08	18.52	0.1087	-0.06	0.20	0.004	17.77	0.6542
EMA (cm^2)	-0.36	4.52	0.13	29.51	0.0415	-0.01	0	0.00007	26.58	0.9504

The relationship between EMA and Sfat within class is not significant linearly or quadratically for any class except for class SAS, where the quadratic variable increased the R^2 value to 0.63, decreased the CV to 14.13 and lowered the probability to 0.0008 (Table 4.2.24). Table 4.2.24 also displays the Pearson's correlation coefficient for EMA and Sfat within class, however these r values are not significant.

The mass clusters 1, 2, 3 and 11 show significant relationships (P < 0.05) between Sfat and EMA (Table 4.2.25). Cluster 1 has a R^2 value of 0.83 (CV = 11.82, P = 0.0302), cluster 2 has a R^2 value of 0.80 (CV = 9.49, P < 0.0001), cluster 3 has a R^2 value of 0.55 (CV = 10.71, P = 0.0055) and cluster 11 has a R^2 value of 0.78 (CV = 16.09, P = 0.0479).

Table 4.2.24 Pearson's correlation coefficient (r) and GLM Procedure: EMA (cm^2) and Sfat (mm) within class

Class	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
PP	0.45	3.04	0.20	17.62	0.1069	2.34	0.30	17.25	0.1658
CP	0.23	0.16	0.05	27.70	0.7149	0.08	0.07	33.50	0.8471
BP	-0.20	0.22	0.04	10.99	0.6619	0.61	0.23	10.98	0.3892
HP	-0.98	23.52	0.96	1.98	0.1295		1.00		
PO	-0.77	4.25	0.59	11.63	0.1312	1.48	0.60	14.06	0.8674
CO	-1.00		1.00				1.00		
BO	0.26	0.66	0.07	13.87	0.4379	0.36	0.08	14.59	0.8414
HO	-0.51	2.08	0.26	12.31	0.1996	0.91	0.27	13.40	0.7449
PR	-0.57	0.98	0.33	24.87	0.4274	0.27	0.35	34.66	0.8971
BR	0.57	0.49	0.33	10.20	0.6118		1.00		
HR	-0.65	1.43	0.42	14.37	0.3542	0.90	0.64	15.91	0.5499
PC	-0.89	3.83	0.79	5.38	0.3008		1.00		
HC			0				0		
SAB			0				0		
SAS	-0.18	0.44	0.03	21.96	0.5163	10.94	0.63	14.13	0.0008

Table 4.2.25 Pearson's correlation coefficient (r) and the GLM Procedure: EMA (cm^2) and Sfat (mm) within mass cluster

Cluster	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
1	-0.91	15.12	0.83	11.82	0.0302	23.46	0.96	7.19	0.1000
2	-0.90	41.07	0.80	9.49	0.0001	20.77	0.82	9.54	0.0750
3	-0.74	12.44	0.55	10.71	0.0055	5.73	0.56	11.22	0.8279
4	-0.13	0.18	0.02	15.66	0.6785	0.14	0.03	16.41	0.7883
5	-0.15	0.25	0.02	15.79	0.6260	0.26	0.05	16.34	0.5704
6	-0.45	2.49	0.19	11.23	0.1455	1.29	0.22	11.67	0.5293
7	-0.64	1.4	0.41	7.19	0.3581	1.85	0.79	6.13	0.4430
8	0.99	37.8	0.97	4.99	0.1026		1.00		
9	-0.26	0.21	0.07	16.04	0.6775	0.07	0.07	19.64	0.9656
10	-0.65	1.49	0.43	8.55	0.3462	70.22	0.99	1.34	0.0805
11	-0.88	10.49	0.78	16.09	0.0479	92.17	0.99	4.33	0.0330

The relationship between EML and Sfat within class is not significant linearly or quadratically for any class except for class BO where both the linear (P = 0.0149) and quadratic (P = 0.0243) relationships are significant (Table 4.2.26). Class BO also shows a strong negative relationship between EML and Sfat (r = -0.71, P = 0.0149).

Table 4.2.27 shows that 51% ($R^2 = 0.51$, CV = 4.61) of the variation within EML can be explained by Sfat within cluster 2 and is significant (P = 0.0090). Clusters 3 (P = 0.0009) and 11 (P = 0.0264) also shows significant relationships between Sfat and EML, with $R^2 = 0.68$ and 0.85, respectively, and CV = 3.79 and 5.48, respectively.

Table 4.2.26 Pearson's correlation coefficient (r) and GLM Procedure: EML (cm) and Sfat (mm) within class

Class	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
PP	0.34	1.59	0.12	6.66	0.2309	0.85	0.13	6.89	0.7884
CP	0.18	0.10	0.03	8.73	0.7770	0.29	0.22	9.57	0.5503
BP	0.32	0.57	0.10	8.27	0.4839	0.57	0.22	8.62	0.4495
HP	0.97	14.08	0.93	0.99	0.1658		1.00		
PO	-0.54	1.23	0.29	8.69	0.3480	0.42	0.29	10.62	0.9516
CO	-1.00		1.00				1.00		
BO	-0.71	9.02	0.50	5.90	0.0149	8.60	0.68	4.99	0.0243
HO	-0.16	0.16	0.03	4.28	0.6997	0.29	0.10	4.49	0.5279
PR	-0.78	3.20	0.62	3.32	0.2154	0.80	0.62	4.69	0.9633
BR	-0.61	0.58	0.37	2.67	0.5863		1.00		
HR	0.69	1.85	0.48	7.07	0.3068	1.05	0.68	7.88	0.6069
PC	0.08	0.01	0.01	8.31	0.9493		1.00		
HC			0				0		
SAB			0				0		
SAS	-0.33	1.72	0.11	10.71	0.2104	3.06	0.32	9.72	0.1020

Table 4.2.27 Pearson's correlation coefficient (r) and GLM Procedure: EML (cm) and Sfat (mm) within mass cluster

Cluster	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
1	-0.82	6.02	0.67	5.29	0.0914	3.84	0.79	5.11	0.3285
2	-0.72	10.46	0.51	4.61	0.0090	5.75	0.56	4.61	0.1576
3	-0.83	21.36	0.68	3.79	0.0009	9.90	0.69	3.96	0.7625
4	-0.36	1.45	0.13	10.28	0.2555	1.31	0.23	10.21	0.2610
5	-0.41	2.17	0.17	6.28	0.1683	1.38	0.22	6.38	0.5628
6	-0.11	0.12	0.01	6.13	0.7343	0.06	0.01	6.46	0.9806
7	0.77	2.86	0.59	2.12	0.2326	1.36	0.73	2.42	0.6597
8	0.26	0.07	0.07	6.23	0.8307		1.00		
9	-0.78	4.7	0.61	4.07	0.1187	1.57	0.61	4.98	0.9466
10	-0.32	0.22	0.09	14.16	0.6850	0.33	0.40	16.93	0.6367
11	-0.92	16.75	0.85	5.48	0.0264	16.86	0.94	4.07	0.2873

The relationship between EMD and Sfat within class is significant linearly for class PO (P = 0.0317) and quadratically for class SAS (P = 0.0095) (Table 4.2.28). Class PO has a strong negative relationship between EMD and Sfat as shown by the r value (r = -0.91).

Table 4.2.28 Pearson's correlation coefficient (r) and GLM Procedure: EMD (cm) and Sfat (mm) within class

Class	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
PP	0.39	2.10	0.15	14.65	0.1727	1.46	0.21	14.75	0.2838
CP	0.60	1.65	0.36	8.99	0.2886	0.71	0.41	10.50	0.7133
BP	0.59	2.73	0.35	15.36	0.1592	1.10	0.35	17.16	0.9749
HP	-0.95	9.98	0.91	0.98	0.1952		1.00		
PO	-0.91	14.54	0.83	4.89	0.0317	5.34	0.84	5.75	0.6773
CO	-1.00		1.00				1.00		
BO	0.55	3.95	0.30	8.53	0.0782	1.85	0.32	8.97	0.4930
HO	-0.46	1.65	0.22	11.48	0.2468	2.25	0.47	10.30	0.2037
PR	-0.02	0	0.001	20.04	0.9759	0.04	0.07	27.32	0.8295
BR	0.52	0.37	0.27	22.15	0.6540		1.00		
HR	-0.82	4.26	0.68	9.86	0.1750	1.07	0.68	13.90	0.8985
PC	-0.15	0.02	0.02	11.44	0.9031		1.00		
HC			0				0		
SAB			0				0		
SAS	-0.09	0.13	0.01	12.96	0.7265	5.05	0.44	10.14	0.0095

Table 4.2.29 shows that within mass clusters 2 (P = 0.0029), 3 (P = 0.0039) and 8 (P = 0.0097), Sfat and EMD have significant relationships where R^2 is 0.60, 0.58 and 0.99, respectively. The CV values are 8.17 (cluster 2), 6.57 (cluster 3) and 0.39 (cluster 8). The other mass clusters did not show significant (P > 0.05) relationships between Sfat and EMD.

Table 4.2.29 Pearson's correlation coefficient (r) and GLM Procedure: EMD (cm) and Sfat (mm) within mass cluster

Cluster	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
1	-0.74	3.68	0.55	13.24	0.1508	1.59	0.61	15.02	0.5601
2	-0.78	15.27	0.60	8.17	0.0029	10.00	0.69	7.63	0.0502
3	-0.76	13.93	0.58	6.57	0.0039	6.30	0.58	6.91	0.6789
4	0.36	1.53	0.13	11.29	0.2442	1.18	0.21	11.38	0.3186
5	0.25	0.74	0.06	13.03	0.4085	0.34	0.06	13.66	0.8241
6	-0.36	1.49	0.13	6.53	0.2506	0.76	0.14	6.83	0.6273
7	-0.65	1.43	0.42	12.02	0.3547	0.38	0.43	16.73	0.9341
8	0.99	4336.85	0.99	0.39	0.0097		1.00		
9	-0.42	0.64	0.18	11.64	0.4833	0.21	0.18	14.26	0.9676
10	-0.20	0.08	0.04	7.34	0.8002	0.03	0.06	10.27	0.9237
11	-0.82	6.24	0.68	9.53	0.0879	20.03	0.95	4.47	0.0950

4.2.7 HGPFat and eye muscle measurements (EML, EMD and EMA)

The linear relationships between HGPFat and EML (P = 0.8768), EMD (P = 0.6363) and EMA (P = 0.9057) are not significant (Table 4.2.30). The quadratic relationship between HGPFat and EML (P = 0.1809) is not significant, however the relationships between HGPFat and EMD (P = 0.0009) and EMA (P = 0.0030) are significant. The R^2 values for EMD and EMA are 0.13 (CV = 17.02) and 0.10 (CV = 26.93), respectively.

Table 4.2.30 Pearson's correlation coefficient (r) and GLM Procedure: HGPFat (mm) and eye muscle measurements for all data

Parameters	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
EML (cm)	-0.02	0.02	0.0003	12.81	0.8768	0.99	0.02	12.74	0.1809
EMD (cm)	-0.05	0.23	0.003	18.15	0.6363	6.49	0.13	17.02	0.0009
EMA (cm^2)	-0.01	0.01	0.0002	28.28	0.9057	4.87	0.10	26.93	0.0030

The relationship between HGPFat and EMD (P = 0.1185) and EMA (P = 0.1003) within males is not significant (Table 4.2.31). The relationship between HGPFat and EML (P = 0.0393) within males is significant with a R^2 of 0.13 and a CV of 12.71. The relationship between HGPFat and EML (P = 0.1846), EMD (P = 0.5807) and EMA (P = 0.2619) within females is not significant.

When a quadratic variable is included for the relationship between HGPFat and EMD the R^2 value increases to 0.33 (M) and 0.1 (F), the CV decreases to 16.05 (M) and 17.07 (F) and the probability decreases to 0.0054 (M) and 0.0228 (F). Adding a quadratic variable for the relationship between HGPFat and EML improves the R^2 value to 0.36 for males and made no improvement for females, the CV value decreased to 11.10 for males and increased to 12.20 for females and the probability decreased to 0.0097 for males and increased to 0.7627 for females. The R^2 values improves to 0.36 (M) and 0.09 (F), the CV values decrease to 25.76 (M) and 25.67 (F) and the probability decreased to 0.0037 (M) and 0.0497 (F) when a quadratic variable is added to the relationship between HGPFat and EMA.

Table 4.2.31 Pearson's correlation coefficient (r) and GLM Procedure: HGPFat (mm) and eye muscle measurements for all data within gender

Parameters	Male					Female				
	r	F value	R^2	CV	Pr > F	r	F value	R^2	CV	Pr > F
EML (cm)	-0.36	4.63	0.13	12.71	0.0393	0.18	1.81	0.03	12.08	0.1846
EMD (cm)	-0.28	2.58	0.08	18.56	0.1185	0.08	0.31	0.006	17.75	0.5807
EMA (cm^2)	-0.29	2.87	0.08	30.22	0.1003	0.16	1.29	0.02	26.25	0.2619

The relationship between EMD and HGPFat within class is only quadratically significant (P = 0.0073) for class CP where $R^2 = 0.99$ and CV = 1.07, none of the other classes are significant (Table 4.2.32). Pearson's correlation coefficient shows that the relationship between EMD and HGPFat for class CP is strong and positive (r = 0.73).

Table 4.2.32 Pearson's correlation coefficient (r) and GLM Procedure: EMD (cm) and HGPFat (mm) within class

Class	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
PP	0.26	0.85	0.07	15.35	0.3746	0.48	0.08	15.92	0.6581
CP	0.73	3.48	0.54	7.62	0.1589	163.17	0.99	1.07	0.0073
BP	0.21	0.22	0.04	18.69	0.6566	0.13	0.06	20.68	0.7789
HP			0				0		
PO	-0.71	3.02	0.50	8.35	0.1805	3.02	0.50	8.35	0.1805
CO			0				0		
BO	-0.34	1.14	0.11	9.64	0.3135	0.52	0.11	10.21	0.9056
HO	-0.39	1.07	0.15	11.94	0.3416	0.45	0.15	13.07	0.9835
PR			0				0		
BR	-0.09	0.01	0.01	25.77	0.9433		1.00		
HR	-0.64	1.42	0.41	13.34	0.3560	0.36	0.42	18.86	0.9498
PC			0				0		
HC			0				0		
SAB			0				0		
SAS	0.26	0.98	0.07	12.58	0.3381	0.88	0.12	12.68	0.3228

Table 4.2.33 shows a relationship between HGPFat and EMD within clusters 2 ($R^2 = 0.66$ and CV = 7.63), 3 ($R^2 = 0.41$ and CV = 7.82) and 5 ($R^2 = 0.34$ and CV = 5.59), all of which are significant (P = 0.0014, 0.0256 and 0.0483 for clusters 2, 3 and 5, respectively).

Table 4.2.33 Pearson's correlation coefficient (r) and GLM Procedure: HGPFat (mm) and EMD (cm) within mass cluster

Cluster	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
1	-0.75	3.97	0.57	12.96	0.1404	1.33	0.57	15.85	0.8385
2	-0.81	19.01	0.66	7.63	0.0014	8.84	0.66	7.95	0.3337
3	-0.64	6.86	0.41	7.82	0.0256	3.73	0.45	7.91	0.6084
4	0.02	0	0.0004	12.12	0.9486	0	0.001	12.78	0.9783
5	-0.07	0.05	0.004	13.43	0.8302	0.13	0.03	13.94	0.6356
6	-0.58	5.06	0.34	5.71	0.0483	2.28	0.34	6.01	0.7944
7	-0.28	0.17	0.08	15.10	0.7194	10.09	0.95	4.84	0.1466
8	0.49	0.32	0.24	22.16	0.6710		1.00		
9	0.02	0	0.0003	12.82	0.9778	2.71	0.73	8.15	0.1467
10	-0.06	0.01	0.003	7.48	0.9432	0.16	0.24	9.21	0.6772
11	-0.68	2.65	0.47	12.19	0.2023	0.88	0.47	14.93	0.9528

In Table 4.2.34, classes BP, HO and BR have R^2 values tending to zero and probability values tending to one. The quadratic variable improves the R^2 and probability values by increasing the R^2 values and decreasing the probability values for class BP and HO. Class BR has 3 carcasses and therefore establishing a quadratic relationship between EML and HGPFat within BR is not possible (Table 4.2.34). Class CP has the highest r value of 0.75 between EML and HGPFat and class BP has the lowest r value of 0.03 (Table 4.2.34).

Table 4.2.34 Pearson's correlation coefficient (r) and GLM Procedure: EML (cm) and HGPFat (mm) within class

Class	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
PP	0.12	0.19	0.02	7.04	0.6705	0.45	0.08	7.12	0.4037
CP	0.75	3.82	0.56	5.88	0.1458	1.37	0.58	7.05	0.8443
BP	0.03	0.01	0.001	8.73	0.9443	0.33	0.14	9.05	0.4664
HP			0				0		
PO	-0.69	2.78	0.48	7.43	0.1937	2.78	0.48	7.43	0.1937
CO			0				0		
BO	-0.05	2.48	0.22	7.39	0.1496	1.40	0.26	7.62	0.5365
HO	-0.06	0.02	0.004	4.32	0.8839	0.16	0.06	4.60	0.6092
PR			0				0		
BR	0.19	0.04	0.04	3.29	0.8756		1.00		
HR	0.33	0.25	0.11	9.26	0.6688	125.09	0.99	0.88	0.0433
PC			0				0		
HC			0				0		
SAB			0				0		
SAS	-0.22	0.73	0.05	11.07	0.4070	0.59	0.08	11.28	0.5852

Table 4.2.35 shows a relationship between HGPFat and EML within clusters 2 (R^2 = 0.62 and CV = 4.08), 3 (R^2 = 0.69 and CV = 3.72) and 5 (R^2 = 0.34 and CV = 5.59), all of which are significant (P = 0.0024, 0.0008 and 0.0371 for clusters 2, 3 and 5, respectively). The Pearson's correlation coefficient shows that the relationship between EML and HGPFat is negative (Table 4.2.35).

Table 4.2.35 Pearson's correlation coefficient (r) and GLM Procedure: EML (cm) and HGPFat (mm) within mass cluster

Cluster	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
1	-0.66	2.33	0.44	6.88	0.2245	2.05	0.67	6.44	0.4054
2	-0.79	16.23	0.62	4.08	0.0024	9.89	0.69	3.89	0.0789
3	-0.83	22.72	0.69	3.72	0.0008	11.25	0.71	3.79	0.8658
4	-0.30	0.96	0.09	10.51	0.3509	1.39	0.24	10.14	0.2523
5	-0.58	5.62	0.34	5.59	0.0371	4.84	0.49	5.14	0.1799
6	-0.18	0.33	0.03	6.07	0.5791	0.23	0.05	6.34	0.6557
7	0.93	13.31	0.87	1.19	0.0676	3.35	0.87	1.68	0.9062
8	0.96	13.47	0.93	1.69	0.1693		1.00		
9	-0.39	0.55	0.15	5.99	0.5137	4.39	0.81	3.44	0.1094
10	-0.40	0.39	0.16	14.08	0.5960	0.15	0.23	19.10	0.8479
11	-0.26	0.21	0.07	13.58	0.6767	0.09	0.09	16.46	0.8675

In Table 4.2.36 classes BR and SAS have R^2 values tending to zero and probability values tending to one for the linear relationship between EMA and HGPFat. The quadratic variable increases the R^2 value to 0.07 and decreases the probability value to 0.3367 for class SAS but there are too few carcasses in class BR (3 carcasses) to determine the quadratic relationship between EMA and HGPFat (Table 4.2.36). The linear relationship between EMA and HGPFat is the strongest ($P < 0.0001$) within class CP where the R^2 value is 0.99 and CV value is 1.50 and is shown with the r value of 0.99 (Table 4.2.36).

Table 4.2.36 Pearson's correlation coefficient (r) and GLM Procedure: EMA (cm^2) and HGPFat (mm) within class

Class	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
PP	0.36	1.84	0.13	18.36	0.1997	1.03	0.16	18.91	0.5296
CP	0.99	1076.15	0.99	1.50	0.0001	397.56	0.99	1.74	0.2233
BP	0.38	0.86	0.15	10.37	0.3956	2.36	0.54	8.50	0.1414
HP			0				0		
PO	-0.79	4.88	0.62	11.16	0.1143	4.88	0.62	11.16	0.1143
CO			0				0		
BO	-0.69	8.13	0.47	10.41	0.0191	3.76	0.48	10.94	0.6581
HO	-0.38	0.99	0.14	13.23	0.3584	1.15	0.32	12.94	0.3235
PR			0				0		
BR	-0.15	0.02	0.02	12.29	0.9010		1.00		
HR	-0.27	0.16	0.07	18.11	0.7274	0.09	0.15	24.60	0.8133
PC			0				0		
HC			0				0		
SAB			0				0		
SAS	0.06	0.05	0.004	22.26	0.8202	0.50	0.07	22.30	0.3367

In Table 4.2.37, the variance within EMA can be explained by HGPFat within mass cluster 2 by 87% ($R^2 = 0.87$), the CV value is 7.73 and it is highly significant ($P < 0.0001$). Within cluster 3, 37% ($R^2 = 0.37$) of the variance can be explained by EMA and is significant ($P = 0.0357$). The relationship between EMA and HGPFat within clusters 1 ($P = 0.0670$), 4 ($P = 0.3414$), 5 ($P = 0.1040$), 6 ($P = 0.2262$), 7 ($P = 0.3089$), 8 ($P = 0.5587$), 9 ($P = 0.5195$), 10 ($P = 0.3650$) and 11 ($P = 0.4627$) are not significant.

Table 4.2.37 Pearson's correlation coefficient (r) and GLM Procedure: EMA (cm^2) and HGPFat (mm) within mass cluster

Cluster	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
1	-0.85	7.93	0.73	15.23	0.0670	3.04	0.75	17.69	0.8245
2	-0.93	66.93	0.87	7.73	0.0001	33.39	0.88	7.79	0.0705
3	-0.61	5.89	0.37	12.73	0.0357	4.00	0.47	12.31	0.3603
4	-0.30	1.00	0.09	15.06	0.3414	0.62	0.12	15.61	0.6531
5	-0.47	3.14	0.22	14.09	0.1040	1.70	0.25	14.47	0.4186
6	-0.38	1.66	0.14	11.63	0.2262	0.75	0.14	12.25	0.9119
7	-0.69	1.83	0.48	6.78	0.3089	2.66	0.84	5.28	0.3803
8	0.64	0.69	0.41	23.92	0.5587		1.00		
9	-0.39	0.53	0.15	15.29	0.5195	0.46	0.31	16.82	0.5328
10	-0.63	1.35	0.40	8.73	0.3650	6.36	0.93	4.31	0.2501
11	-0.44	0.71	0.19	30.71	0.4627	0.24	0.19	37.61	0.9675

4.2.8 Mass clusters 2 to 6 combined

For mass clusters 2 to 6 combined the carcass parameters have the following means; WCM = 66.7 ± 13.9 kg, Sfat = 10.1 ± 3.4 mm, HGPFat = 13.8 ± 4.1 mm, EML = 9.2 ± 1.1 cm, EMD = 6.0 ± 1.0 cm and EMA = 39.9 ± 10.9 cm^2 (Table 4.2.38).

Table 4.2.38 Means, standard deviation, minimum and maximum values for carcass parameters for mass clusters 2 to 6 combined

Parameter	Mean	SD	Min	Max
WCM (kg)	66.7	13.9	44.6	87.6
Sfat (mm)	10.1	3.4	4.3	21.0
HGPFat (mm)	13.8	4.1	7.0	24.0
EML (cm)	9.2	1.1	7.0	12.0
EMD (cm)	6.0	1.0	3.8	8.3
EMA (cm^2)	39.9	10.9	17.9	58.6

Sfat = subcutaneous backfat measured with callipers; HGPFat = backfat measured with Hennessy Grading Probe; EML= eye-muscle length; EMD = eye-muscle depth and EMA = eye-muscle area

In Table 4.2.39, WCM has highly significant ($P < 0.0001$) relationships with EML, EMD and EMA where R^2 = 0.48 (CV = 8.29), 0.56 (CV = 11.12) and 0.66 (CV =15.99), respectively. The quadratic variable improves the relationship between WCM and EML, EMD and EMA to the following R^2 values, 0.56 (CV = 7.73), 0.57 (CV = 11.13) and 0.68 (CV = 15.78), respectively. The quadratic relationship between WCM and the following: EML is significant (P= 0.0004), EMD is not significant (P = 0.1043) and EMA is significant (P = 0.0153).

Table 4.2.39 Pearson's correlation coefficient (r) and GLM Procedure: WCM (kg) and carcass parameters for mass clusters 2 to 6 combined

Parameters	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
Sfat (mm)	0.03	0.05	0.0009	33.53	0.8167	1.87	0.06	32.79	0.0631
HGPFat (mm)	0.12	0.93	0.2	29.60	0.3395	1.25	0.04	29.46	0.2481
EML (cm)	0.70	55.39	0.48	8.29	0.0001	36.86	0.56	7.73	0.0004
EMD (cm)	0.75	75.38	0.56	11.12	0.0001	38.08	0.57	11.13	0.1043
EMA (cm^2)	0.81	116.14	0.66	15.99	0.0001	60.97	0.68	15.78	0.0153

Table 4.2.40 shows that for mass clusters 2 to 6 combined, EMA is larger for females (mean = 41.2 ± 11.1 cm^2) than for males (mean = 38.3 ± 10.7 cm^2) by 2.9 cm^2. The other carcass parameters, WCM, Sfat, HGPFat, EML and EMD means are similar for males and females and are shown in Table 4.2.40.

Table 4.2.40 Means, standard deviations, minimum and maximum values for carcass parameters for mass clusters 2 to 6 combined within gender

Parameter	Male (n = 28)				Female (n = 33)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
WCM (kg)	67.3	14.5	44.6	86.4	66.2	13.7	44.6	87.6
Sfat (mm)	10.4	3.9	4.3	21.0	9.9	2.9	5.0	18.3
HGPFat (mm)	14.6	4.6	7.0	24.0	13.2	3.6	8.0	24.0
EML (cm)	9.2	1.2	7.0	12.0	9.2	0.9	7.3	10.7
EMD (cm)	5.8	0.9	3.8	7.3	6.2	1.0	3.9	8.3
EMA (cm$^{2)}$	38.3	10.7	17.9	55.8	41.2	11.1	21.1	58.6

In Table 4.2.41 and Table 4.2.42, the variation in EML described by WCM is lower for males (R^2 = 0.44 and CV = 9.89) than for females (R^2 = 0.55 and CV = 6.97) and are significant ($P < 0.0001$). The variance in EMD described by WCM is higher for males (R^2 = 0.63 and CV = 10.14; Table 4.2.41) than for females (R^2 = 0.57 and CV = 11.09; Table 4.2.41) and are significant ($P < 0.0001$). The variance in EMA described by WCM is higher for males (R^2 = 0.71 and CV = 15.22) than for females (R^2 = 0.66 and CV = 15.78) and are significant ($P < 0.0001$).

Table 4.2.41 Pearson's correlation coefficient (r) and GLM Procedure: Carcass parameters and WCM (kg) for mass clusters 2 to 6 combined for males

Parameter	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
Sfat (mm)	-0.07	0.14	0.005	37.86	0.7099	1.40	0.10	36.71	0.1110
HGPFat (mm)	-0.09	0.20	0.008	31.86	0.6571	1.29	0.09	31.06	0.1296
EML (cm)	0.66	20.35	0.44	9.89	0.0001	17.67	0.59	8.66	0.0025
EMD (cm)	0.79	43.45	0.63	10.14	0.0001	20.90	0.63	10.33	0.5541
EMA (cm^2)	0.85	64.99	0.71	15.22	0.0001	34.2	0.73	15.02	0.0654

Table 4.2.42 Pearson's correlation coefficient (r) and GLM Procedure: Carcass parameters and WCM (kg) for mass clusters 2 to 6 combined for females

Parameter	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
Sfat (mm)	0.15	0.69	0.02	29.48	0.4124	0.73	0.05	29.58	0.4237
HGPFat (mm)	0.36	4.51	0.13	25.74	0.0418	2.19	0.13	26.16	0.7646
EML (cm)	0.74	37.69	0.55	6.97	0.0001	20.35	0.58	6.87	0.0670
EMD (cm)	0.76	41.22	0.57	11.09	0.0001	21.07	0.58	11.10	0.1393
EMA (cm^2)	0.81	61.14	0.66	15.78	0.0001	30.8	0.67	15.83	0.1300

Table 4.2.43 shows that EML explains 13% (R^2 = 0.13, CV = 10.79 and P = 0.0049) and EMA explains 9% (R^2 = 0.09, CV = 26.18 and P = 0.0144) of the variation within Sfat and are significant. The relationship between Sfat and EMD (P = 0.099) is not significant. The quadratic variable increases the R^2 value for each parameter to 0.18, 0.21 and 0.19 and decreases the CV values to 10.54, 15.04 and 25.03 for EML, EMD and EMA, respectively, but the relationship between Sfat and EML (P = 0.2063) and between Sfat and EMA (P = 0.0572) are not significant but the relationship between Sfat and EMD (P = 0.0039) is significant.

Table 4.2.43 Pearson's correlation coefficient (r) and GLM Procedure: Sfat (mm) and carcass parameters for mass clusters 2 to 6 combined

Parameters	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
EML (cm)	-0.36	8.56	0.13	10.79	0.0049	6.41	0.18	10.54	0.2063
EMD (cm)	-0.21	2.81	0.05	16.39	0.0990	7.72	0.21	15.04	0.0039
EMA (cm^2)	-0.31	6.35	0.09	26.18	0.0144	6.75	0.19	25.03	0.0572

Table 4.2.44 and 4.2.45 show that the R^2 values are higher for males than for females with males having R^2 values of 0.31 (CV = 10.93 and P = 0.0019), 0.11 (CV = 15.65 and P = 0.0896) and 0.18 (CV = 25.75 and P = 0.0236) for EML, EMD and EMA respectively, and females having R^2 values of 0.004 (CV = 10.35 and P = 0.7159), 0.001 (CV = 16.88 and P = 0.6609) and 0.03 (CV = 26.78 and P = 0.3205) for EML, EMD and EMA respectively. The significant relationships are between EML and Sfat and EMA and Sfat for males. None of the relationships are significant for females.

Table 4.2.44 Pearson's correlation coefficient (r) and GLM Procedure: Carcass parameters and Sfat (mm) for mass clusters 2 to 6 combined for males

Parameter	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
EML (cm)	-0.56	11.91	0.31	10.93	0.0019	5.98	0.32	11.07	0.8769
EMD (cm)	-0.33	3.11	0.11	15.65	0.0896	5.34	0.30	14.14	0.0420
EMA (cm^2)	-0.43	5.79	0.18	25.75	0.0236	6.18	0.33	23.76	0.0934

Table 4.2.45 Pearson's correlation coefficient (r) and GLM Procedure: Carcass parameters and Sfat (mm) for mass clusters 2 to 6 combined for females

Parameter	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
EML (cm)	-0.07	0.13	0.004	10.35	0.7159	2.29	0.13	9.82	0.0553
EMD (cm)	-0.08	0.20	0.001	16.88	0.6609	2.31	0.13	16.02	0.0575
EMA (cm^2)	-0.18	1.02	0.03	26.78	0.3205	0.96	0.06	26.82	0.4643

The quadratic variable improves the R^2 and the CV values for all the HGPFat and carcass parameter relationships (Table 4.2.46). The R^2 values increase to 0.18 (P = 0.0198), 0.16 (P = 0.0166) and 0.18 (P = 0.0076) for EML, EMD and EMA, respectively. The CV values decrease to 10.54, 15.54 and 25.19 for EML, EMD and EMA, respectively. All the quadratic relationships are significant.

Table 4.2.46 Pearson's correlation coefficient (r) and the GLM Procedure: HGPFat (mm) and carcass parameters for mass clusters 2 to 6 combined

Parameters	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
EML (cm)	-0.27	4.48	0.07	11.13	0.0386	6.39	0.18	10.54	0.0198
EMD (cm)	-0.21	2.72	0.04	16.40	0.1046	5.39	0.16	15.54	0.0166
EMA (cm^2)	-0.21	2.68	0.04	26.95	0.107	6.29	0.18	25.19	0.0076

The relationship between EML and HGPFat in males has the highest R^2 value than the other two carcass parameters, the R^2 value being 0.24 (CV = 11.53 and P = 0.0087) and the relationship is significant (Table 4.2.47).

Table 4.2.47 Pearson's correlation coefficient (r) and the GLM Procedure: Carcass parameters and HGPFat (mm) for mass clusters 2 to 6 combined for males

Parameter	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
EML (cm)	-0.49	8.06	0.24	11.53	0.0087	7.89	0.39	10.54	0.0640
EMD (cm)	-0.44	6.39	0.19	14.84	0.0179	8.53	0.41	13.02	0.0215
EMA (cm^2)	-0.43	5.94	0.19	25.69	0.0220	8.34	0.40	22.49	0.0195

The carcass parameters EMD and EMA for males have the same R^2 value of 0.19 but different CV values of 14.84 (P = 0.0179) and 25.69 (P = 0.0220), respectively, and are both significant (Table 4.2.48). Table 4.2.48 shows that the relationship between the carcass parameters and HGPFat is not significant for females (P > 0.05).

Table 4.2.48 Pearson's correlation coefficient (r) and the GLM Procedure: Carcass parameters and HGPFat (mm) for mass clusters 2 to 6 combined for females

Parameter	r	Linear				Quadratic			
		F value	R^2	CV	Pr > F	F value	R^2	CV	Pr > F
EML (cm)	0.03	0.02	0.0007	10.37	0.8838	0.42	0.03	10.40	0.3641
EMD (cm)	0.07	0.14	0.005	16.89	0.7075	0.39	0.03	16.99	0.4038
EMA (cm^2)	0.06	0.11	0.003	27.16	0.7443	0.66	0.04	27.07	0.2620

Figure 4.2.7 illustrates that across the 14 carcasses within the PP class variation is low regarding EML (cm) and EMD (cm) as the values are similar for each carcass while variation within WCM (kg) and EMA (cm^2) is higher as the values show greater differentiation.

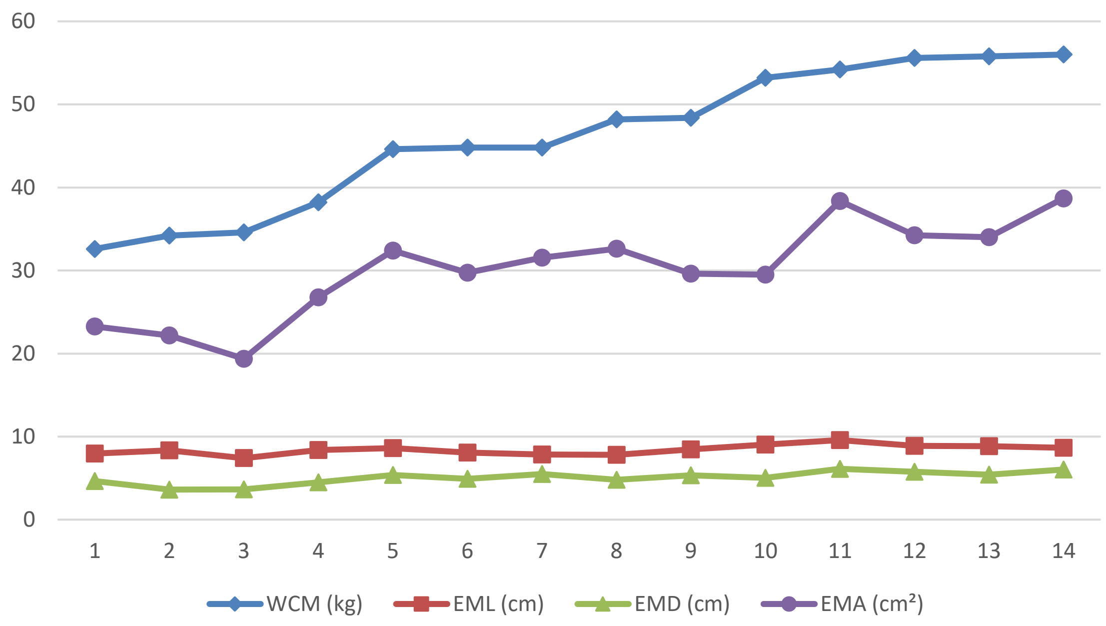

Figure 4.2.7 Individual warm carcass mass (WCM), eye muscle length (EML), eye muscle depth (EMD) and eye muscle area (EMA) measurements for the fourteen carcasses classed PP

CHAPTER 5
DISCUSSION AND RECOMMENDATIONS

5.1 Part 1

5.1.1 Data pooled, divided by gender and within Sausagers

Sather *et al.* (1989) identified the existence of bias introduced by breed in the Canadian carcass grading system when predicting lean meat but concluded that the specific animals had weights and conformations in the extremes resulting in the bias. The high CV values seen for all the data pooled (Table 4.1.2) and for the data pooled into boars and sows (Table 4.1.4) could be attributed to the same reason; that the data had information from animals that had WCM (kg) and Fat (mm) at both extremes or it could be from sows losing body condition during lactation and were unable to regain the lost body condition during the recovery phase resulting in failure to conceive and sent to slaughter with low Fat and high WCM. Interestingly though, when the WCM (kg) ranges were narrowed down, as seen within the Sausagers class (Table 4.1.7) the R^2 values for both males and females decreased, and the CV values increased. This was also seen when the data was divided into the mass categories (Table 4.1.9), where the R^2 values decreased, however the CV values decreased. This could be attributed to the wide Fat range still being present. The wide Fat range seen within Sausagers could be attributed to these animals being breeding animals and not meat production animals and would have received different diets, are at different physiological ages and would have different physiological processes occurring within the body (for example being pregnant) which would all affect the rate of fat deposition. The low Fat for females in cluster 1 seen in Figure 4.1.1 may have also contributed to the high CV values in Table 4.1.7. These low Fat values could significantly increase the weaning to oestrus interval and may be the reason these sows were culled.

The Sausagers are constituted of 6.34% males and 93.66% females. The reason for the large difference between the number of males and females may be because 70 to 75% of producers make use of artificial insemination (AI) (Visser *et al.*, 2014) and may only keep a few boars as teaser animals. Louw *et al.* (2010) showed that for a producer to be economically viable, a sow herd of ≥ 300 is required. Also, when the data was divided into males and females across all the data (Table 4.1.4) the relationship between Fat and WCM was stronger ($P < 0.0001$) in females which was also seen within the Sausagers class. However, when the carcasses that are classified into P, O, R, C, U or S (Table 4.1.15) was examined the relationship between Fat and WCM was stronger ($P < 0.0001$) for males. This could be attributed to males being leaner and depositing less fat than females causing variation within the males to be lower; CV values 19.34 (M) and 23.70 (F).

A high Pearson's correlation coefficient (r) was found for Fat and WCM across all the data, $r = 0.68$. Rossouw (1982) found high correlation coefficients between backfat measurements and LW and suggested that it could be attributed to the wide range of LW, therefore it may be possible that the r value was high due to a wide range of both Fat and WCM because when the data set was narrowed to a WCM range of 30.0 to 89.9 kg (which will be only pigs that were classified into P, O, R, C, U or S) a r value of 0.51 (Table 4.1.28) was seen.

Sather *et al.* (1989) suggested that when using pigs over a wide range of WCM (kg), the accuracy of lean meat prediction could be improved by 2 to 3% although Sather *et al.* (1991b) is not in agreement with this suggestion. And in this study, it was seen that the amount of variation between carcasses decreases when the WCM range is narrowed.

5.1.2 Mass categories

When the mass categories are divided into males (Table 4.1.12) and females (Table 4.1.13), the R^2 values for the relationship between Fat and WCM increase and the CV values decrease for males for all four mass categories whereas the opposite occurred for the females. This may have resulted from the males (Table 4.1.10) having narrower Fat ranges for each mass category than the females (Table 4.1.11); where the males had differences between minimum and maximum Fat values that ranged from 26.4 to 38.4 mm and females had differences that ranged from 44.2 to 84.0 mm across the four mass categories. However, this was due to female outliers with high Fat measurements being present in the Porkers (three carcasses), Cutters (two carcasses) and Heavy Baconers (two carcasses) mass categories.

Tables 4.1.10 and 4.1.11 show how males and females have similar mean Fat but the difference between the genders increases as mass increases which is expected as pigs have a higher potential for lean gain up to 57 – 64 kg LW (Viljoen *et al.*, 2014) after which it decreases and the potential for fat gain increases and more so for females than males.

Baconers constitute 31.7% of the carcasses classified, Porkers 28.7%, Cutters 22.7% and Heavy Baconers 16.9%. This is not surprising as most abattoirs prefer to take Baconers, with some taking only Baconers, as more uniformity between the carcasses makes the mechanisation process simpler (Davids *et al.*, 2014). Also producing more Baconers would be beneficial to the producer as these pigs would have gone through the phase of a higher rate of lean deposition thereby being more energy efficient than heavier pigs and compared to the lighter pigs would have utilised the phase fully. Baconers also receive a better price than Porkers and Heavy Baconers.

Overlaps between the mass categories was seen in Table 4.1.8 which could be financially unfair as it could lead to producers being under or over paid for carcasses. Within the Porker and Cutter overlap range (56.3 to 61.6 kg) there were 462 Porkers and 6671 Cutters, within the Cutters and Baconers overlap range (64.8 to 75.4 kg) there were 3049 Cutters and 11220 Baconers and within the Baconers and Heavy Baconers overlap range (73.2 to 82.4 kg) there were 10828 Baconers and 138 Heavy Baconers. The average purchase price (per kg) for week 34 of 2017 for classed carcasses was R26.68 for PP, R28.13 for CP, R26.85 for BP and R26.48 for HP (RMAA, 2017).

The overlaps could cause financial discrepancies within the meat value chain. For example, out of 100 pigs brought to the abattoir all with a WCM of 58 kg (within the Porkers and Cutters overlap range), 60 are classed as PP which would equal R92 846.40 and 40 are classed as CP which would equal R65 261.60, therefore for the 100 pigs the total would be R158 108.00 (using the prices for week 34 of 2017 on RMAA, 2017). If the same scenario were reversed, then the 40 PP classed carcasses would equal R61 897.60 and the 60 classed CP carcasses would equal R97 892.40, with a total amount of R159 790.00. The difference between the two scenarios would be R1682.00

5.2.3 Within classes

The CV is low (< 10.00) for 19 of the classes (Table 4.1.17) which is a good indication that variance between carcasses within class is low except for classes PP, PS, CS, BS and HS. The high CV for classes PS, CS, BS and HS could be attributed to the differences in the minimum and maximum Fat ranges between them whereas the other classes have smaller minimum and maximum Fat ranges within their P, O, R, C or U groups. The high CV for class PP could have resulted from the wider WCM range that class PP has compared to the other classes. Overall this shows that the PORCUS carcass classification system has low variation between carcasses within the 24 classes. Webb (2015) concluded that from recent studies in cattle and sheep, it would seem that the carcass classification system is being treated as a carcass grading system and that the classes have carcasses with different physical and compositional characteristics which would result in high amounts of variation to exist between carcasses within the same class, which is not seen in this study on the pig carcass classification system in South Africa.

The relationship between Fat and WCM within class was weak with $R^2 \leq 0.16$ across all the classes and the relationship was not significant ($P > 0.05$) for 13 of the classes. Soji *et al.* (2015a) found no association between the fat classes P, O or R classes and WCM which conflicts with this study as this study had highly significant differences ($P < 0.0001$) between Fat and WCM within the P class and significant differences ($P < 0.05$) within the O class.

Dividing the classes into males (Table 4.1.20) and females (Table 4.1.21) saw small increases and decreases in the CV values therefore illustrating that gender may improve the accuracy of the prediction equations but not to any extent that could be economically beneficial or outweigh the impracticality of including gender in the LM% prediction equations. Which is further illustrated by only 6 classes for males and 8 classes for females having a relationship between WCM and Fat that is highly significant ($P < 0.0001$). Therefore, this study shows that gender did not have a significant effect ($P > 0.05$) on the relationship between Fat and WCM within class.

This study found that carcasses classified according to PORCUS, 55.59% are male and 44.41% are female which is different to what Soji *et al.* (2015a) found; of pigs slaughtered 31% were males and 69% were females.

There has been speculation that majority of the carcasses classified fall under specific Fat classes. This study supports this as 84.7% of the 65 788 carcass records received were from either the P or O class. To further support this finding this study shows that 51.7% of the carcasses that were classified according to PORCUS fell under the P class and 41.1% of the carcasses were of the O class which agrees with Soji *et al.* (2015a) who found 49% of carcasses to fall under the P class and 44% of carcasses to fall under the O class. It is understandable that majority of the carcasses fall under the P and O classes as, firstly, the production of leaner and later maturing pigs is more efficient because better FCR are achieved and secondly, it is assumed that the consumer prefers leaner meat with less trimmable fat which has resulted in these classes receiving a higher monetary value. With the outcome that producers are rewarded twice for producing carcasses that fall within the P and O classes; by receiving a higher price for these carcasses and by saving on feed costs.

5.1.4 Mass clusters

The Pearson's correlation coefficient (r) between WCM and Fat for mass clusters across all the data was strongest for clusters 1 ($r = 0.3131$, $P = 0.0074$) and 2 ($r = 0.2025$, $P = 0.0029$) (Table 4.1.22) which is to be expected as pigs in these low mass ranges have little fat deposition and therefore low variance.

The mass clusters may have high CV values (Table 4.1.23) because the Fat ranges (Table 4.1.22) were not narrowed therefore still allowing carcasses to fall at the extremes. Although mass clusters 1 and 2 had the lowest difference between minimum and maximum Fat values, which may have also resulted in the higher r values but had amongst the highest CV values. This could be attributed to these low mass clusters being associated with young pigs that have not attained puberty and should therefore not be depositing more fat than lean at this stage. However, there are carcasses in these low mass clusters with high Fat values. This is illustrated with mass cluster 1 where there are 11 carcasses that have a Fat measurement between 8.00 to 15.00 mm and in mass cluster 2 where there are 56 pigs that have a Fat measurement between 10.00 to 28.00 mm. Therefore, these pigs may have been sent to the abattoir due to poor production performance. It may be possible for the producer to have an effect as 65.3% of the carcasses in cluster 1 came from a single producer (Producer X) and 59.5% of the carcasses from cluster 2 also came from Producer X.

5.1.5 Mass clusters 4 to 9 combined

Combining mass clusters 4 to 9 (Table 4.1.28) resulted in the R^2 and CV values decreasing compared to when all the data was pooled (Table 4.1.2). The decrease in the CV value may be attributed to mass clusters 4 to 9 covering most of the carcasses that are classed according to PORCUS therefore representing a more uniform population with lower variation between the carcasses. The relationship between WCM and Fat, shown by the Pearson's correlation coefficient (r) was stronger for all the data pooled together ($r = 0.68$, $P < 0.0001$) than when mass clusters 4 to 9 were combined ($r = 0.51$, $P < 0.0001$; Table 4.1.28).

Dividing mass clusters 4 to 9 combined into males and females (Table 4.1.30) increased the R^2 value but did improve the CV values when comparing them to the values for all the data pooled divided into males and females (Table 2.1.4) and decreased the R^2 values and the CV values when comparing it to the carcasses classified to PORCUS (Table 4.1.15). Which further illustrates that gender need not be included within the carcass classification system.

5.1.6 Producer effect

By selecting 15 producers who had 200 or more carcasses in the data set the R^2 value improved from 47% across the whole data set (Table 4.1.2) to 57% (Table 4.1.32). The reason could be that these carcasses may represent better uniformity as there were a smaller number of producers and the producers are top producers. This could result in similarities between these producers with regards to genetics, feeding strategies and housing facilities. Being commercial farmers, they would have set routines and calculated programmes regarding vaccinations, breeding, farrowing, weaning and feeding (specific to each age group) that would ensure maximum production is achieved and will therefore produce pigs of a consistent standard. This can also be shown by Table 4.1.31 where the mean WCM increased to 79.1 kg for the 15 fifteen producers from a mean WCM of 74.1 kg for all data pooled without seeing an increase in Fat; Fat for all data pooled is 13.3 mm and is 13.4 mm for the fifteen producers. Also, when the carcasses from the fifteen producers were divided into males and females (Table 4.1.37) the mean WCM increased while the mean Fat was similar to the means from the all the data split into males and females.

Within class for the 15 producers there are small decreases between the minimum and maximum Fat measurements (Table 4.1.33) compared to all the data within class (Table 4.1.16), this may have led to the small increases seen with the R^2 values for the relationship between Fat and WCM within class for the 15 producers (Table 4.1.34) compared to all data pooled (Table 4.1.17). With the exceptions of classes HP and CR which decreased and tended towards zero.

Pearson’s correlation coefficient (r) between WCM and Fat per producer ranged from 0.34 to 0.85 (mean r = 0.67) but by removing Producer D the range narrowed down to 0.57 to 0.85 (mean r = 0.70). Whereas, for the entire data set the Pearson’s correlation coefficient was 0.68.

Therefore, this study shows that the producer has a significant effect ($P < 0.0001$) on the relationship between Fat and WCM.

5.1.7 Conformation score

The conformation score was 3 for majority (82.31%) of the carcasses while the other conformation scores, 1, 2, 4 and 5, had 0.08, 4.42, 11.89 and 1.30% respectively. Therefore, a low correlation would result between conformation and WCM and between conformation and Fat. It seems the only advantages of the conformation score is when determining if a carcass should be classed as a Rough, as one of the criteria in the Government Notice No. R. 55 of 2015 for a carcass to be classified as a Rough is if it has a conformation score of 1 or if a consumer buys carcasses in bulk and will therefore make use of the conformation score (SAMIC, 2006).

5.2 Part 2

5.2.1 WCM, HGPFat and Sfat

The HGPFat and Sfat mean measurements (Table 4.2.1) differed by 3.6 mm, this could be as a result of two different measuring apparatus being used, because the HGPFat was taken on warm carcasses while the Sfat was measured on cold carcasses or it could be a combination of the two factors. The difference was also noted by the Pearson's correlation coefficient (Table 4.2.2) which was 0.31 ($P = 0.0033$) between WCM and Sfat and 0.42 ($P < 0.0001$) between WCM and HGPFat. The stronger relationship as seen with Pearson's correlation coefficient between WCM (kg) and HGPFat (mm) than with WCM (kg) and Sfat (mm) could be as a result of measurements taken from a warm carcass being better predictors of carcass composition than measurements taken from a cold carcass (Berg *et al.*, 1999; Hambrock, 2005). Another possible reason for the differences observed between the two measurements could be that the carcasses kept aside for data collection were not stored in the cooler for the same length of time before the measurements could be taken, allowing for more variation within the Sfat measurements. Sather *et al.* (1991a) noted a carcass cooler shrinkage of 25.5 g kg^{-1} although this was not significant, cooler shrinkage may have contributed towards the high CV seen between WCM and Sfat (Table 4.2.3) and towards the difference seen between the HGPFat and Sfat measurements.

The R^2 value for WCM and HGPFat is 0.18 and the CV is 30.95 (Table 4.2.3) which is a large discrepancy from Part 1 where the R^2 value across all the data was 0.47 and the CV was 28.36 (Table 4.1.1). This could be because of the difference in sample size and that the sample group covered more of the population in Part 1 resulting in the WCM and Fat ranges for Part 2 to be smaller.

Part 1 and Part 2 have similar mean WCM for males (66.1 kg for Part 1 and 68.1 kg for Part 2) and females (82.5 kg for Part 1 and 85.7 kg for Part 2) and similar mean HGPFat for males (12.1 mm for Part 1 and 14.6 mm for Part 2) and females (14.6 mm for Part 1 and 14.2 mm for Part 2). But, differences between WCM and HGPFat minimum and maximum values for males and females were large; with males having differences for WCM of 341.6 kg (Part 1) and 70.7 kg (Part 2) and for HGPFat of 78.4 mm (Part 1) and 17 mm (Part 2) and females having differences for WCM of 312.2 kg (Part 1) and 157.2 kg (Part 2) and for HGPFat of 93.6 mm (Part 1) and 20 mm (Part 2). But, the amount of variation within HGPFat explained by WCM is higher ($P < 0.0001$) for both males and females in Part 1 (Table 4.1.4) than it is in Part 2 (Table 4.2.5). An anomaly may have occurred to cause the low R^2 value of 0.00093 for HGPFat and WCM for males in Part 2 as the discrepancy from the Part 1 R^2 value (0.36) is large. Gilts had lower ($P < 0.0001$) fat depths (mm) than castrates when measured with the HGP (Sather *et al.*, 1991b) which agrees with this study where the average HGPFat was 0.4 mm lower for females than males.

Although there are too few carcasses ($P > 0.05$) for there to be a complete distribution across all classes and also a few carcasses within the available classes, it is still interesting to note that the CV between Sfat and WCM (Table 4.2.7) varied across class but the values were mostly high (> 10) while the CV between HGPFat and WCM (Table 4.2.10) were mostly low (< 10). Here again the reason for the difference could be linked to that measurements taken on a warm carcass are better predictors of carcass composition. The same trend is seen within mass cluster where the CV is lower amongst the HGPFat mass clusters (Table 4.2.11) than the Sfat mass clusters (Table 4.2.9).

5.2.2 WCM and eye muscle measurements (EML, EMD and EMA)

The present study and the study by Winarski *et al.* (2004) found similar results where; an average WCM of a group of pigs weighing between 60 and 80 kg was 71.38 kg and 73.01 kg, respectively, both studies had a mean EML of 9.4 cm across all data (Table 4.2.1), the mean EML of pigs weighing 60 – 80 kg was 9.8 cm and 9.3 cm, respectively, and the mean EML of pigs weighing 80.1 – 120 kg was 9.9 cm and 9.6 cm, respectively.

Linearly, the parameter that best explains the variation seen in WCM is EML with R^2 being 0.41 and the CV being 9.82 (Table 4.2.3). This is also illustrated with the Pearson's correlation coefficient being 0.64 between WCM and EML (Table 4.2.2). However, on the quadratic side, EML (Figure 4.2.1) and EMA

(Figure 4.2.3) could explain 54% and 45%, respectively, of the variation within WCM although the CV was high for EMA. Pearson's correlation coefficient was 0.50 between WCM and EMA (Table 4.2.2).

The trend seen for EMA is that as WCM increases there is an increase in EMA until mass cluster 4 after which EMA seems to meet an equilibrium and fluctuates until mass cluster 11 with a slight deviation at mass cluster 9 (Table 4.2.20 and Figure 4.2.6).

Pearson's correlation coefficient between WCM and EMD was low at 0.26 (Table 4.2.2) which can be seen across the mass clusters as EMD fluctuates slightly between an average of 3.9 to 6.9 cm across the mass clusters (Table 4.2.17) with no linear pattern seen (Figure 4.2.5).

A poor ($P = 0.0159$) linear relationship is seen with EMD and WCM (Table 4.2.3) where EMD can explain 7% of the variation within WCM and a stronger ($P < 0.0001$) quadratic relationship between the two variables is seen where EMD can explain 28% of the variation within WCM; this relationship is also seen in Figure 4.2.2.

In this study females had on average a larger EMA than males and a larger WCM (Table 4.2.4). This could have been attributed to more data on females classified as Sausagers being collected than males classified as Sausagers. However, similar results from Sather *et al.* (1991a) also displayed females (40.8 cm^2) having larger ($P < 0.001$) EMA than males (38.0 cm^2). Eye muscle area is able to explain 75% ($P < 0.0001$) of the variation seen within WCM for males and only 17% ($P < 0.05$) in females (Table 4.2.5).

Gilts have been found to have greater eye muscle width compared to castrates (Sather *et al.*, 1991b) which agrees with this study although only a 0.5 cm difference is seen between males and females average EML (Table 4.2.4). The general trend of EML is to increase with increasing WCM (Table 4.2.14, Figure 4.2.4 and Figure 4.2.1) and as females had a larger average WCM than males it could explain why females had a larger EML than males.

Eye muscle length (EML) compares more favourably with regards to R^2 and CV values than the other eye muscle measurements by having similar R^2 and CV values for WCM for males and females (Table 4.2.5), with EML explaining 49% (M) and 42% (F) of the variation seen in WCM and low CV values of 9.65 (M) and 9.33 (F). As the other two eye muscle measurements for males and females have different R^2 and CV values from each other; EMD R^2 and CV values are 0.67 and 11.02 respectively for males ($P < 0.0001$) and 0.009 and 17.72 for females ($P = 0.4841$), respectively, and EMA R^2 and CV values are 0.75 and 15.84 respectively for males ($P < 0.0001$) and 0.17 and 24.24 respectively for females ($P = 0.0021$).

From this study, the linear relationship between any of the Fat measurements and WCM fit better for females than males whereas the linear relationship between the eye muscle measurements and WCM fit better for males than females (Table 4.2.5).

It is interesting to note that for class PP as WCM increased, both EML and EMD fluctuated slightly between each individual while EMA had larger fluctuations between individuals (Figure 4.2.7). This may illustrate that variation within a class of the PORCUS carcass classification system is low for certain carcass traits, which would be the case as the carcass classification system is based on placing carcasses of certain fat thicknesses into a class.

5.2.3 Mass clusters 2 to 6 combined

The mass clusters 2 to 6 (40 to 89 kg) are a good representation of most of the carcasses that are classified according to P, O, R, C, U and S. When mass clusters 2 to 6 are combined there is a decrease in the mean measurements for WCM, Sfat, HGPFat, EML and EMD but an increase for EMA (Table 4.2.38) when compared to all the data pooled together (Table 4.2.1). Also, the R^2 values increase, with EML explaining 48% of the variation seen within WCM, EMD explaining 56% and EMA explaining 66% (Table 4.2.39) while the CV values also show that there is less variation within this group of carcasses regarding the eye muscle measurements. Even within gender the R^2 values are high with regards to the eye muscle measurements for both males (Table 4.2.41) and females (Table 4.2.42).

5.3 Recommendations

5.3.1 The classes P, O, R, C, U and S along with the class sub-category (Porkers, Cutters, Baconers and Heavy Baconers) can be maintained as variation within classes was low.

5.3.2 Clear mass ranges should be established for the mass categories ‘Porkers’, ‘Cutters’, ‘Baconers’ and ‘Heavy Baconers’ in order to decrease the variation between carcasses within the same classes. Table 5.3.1 lists suggested mass category ranges. Including heavier carcasses (>100 kg) should be considered as pig genotypes are improving and it is possible to take pigs to heavier LW with minimum changes to the FCR and changes to the carcass composition, unless the animal was used for breeding. In the current study some carcasses classified according to PORCUS had a WCM of 103 kg.

Table 5.3.1 Suggested mass ranges for the mass categories

Mass categories	Mass ranges (kg)
Suckling	< 20.1
Porkers	20.1 – 41.3
Cutters	41.4 – 62.6
Baconers	62.7 – 83.9
Heavy Baconers	84 – 105.2
Sausager	> 105.2

5.3.3 Lean meat % is a defining carcass characteristic in the PORCUS carcass classification system but is not stated on the records of the carcasses at this abattoir, this may be for the reason that if the class and fat thickness are specified the LM% can be assumed however for the P and S class the LM% can be anywhere from 70 to 100% or from 0 to 61%, respectively. Therefore, making the use of LM% redundant. If LM% remains a criterion in the PORCUS carcass classification system, it may be beneficial to include WCM as a parameter within the regression prediction equations. As it has been found to improve the prediction accuracy of the LM% prediction equations (Sather *et al.*, 1989). Warm carcass mass is already a parameter that is measured and recorded and used to determine carcass prices.

5.3.4 Otherwise a look at revising the carcass classification system in terms of removing LM% as a criterion and basing the system on Fat and WCM could be explored.

5.3.5 The effects of the use of growth promoters on carcass composition and quality should be studied further in South Africa and the number of producers who make use of growth promoters should be identified. Along with producers making use of immunocastration and the effects of the treatment on meat quality. Specifying between intact males and castrates should be recorded as the literature review outlined some of the differences in carcass composition between the two genders and could be considered to be a quality parameter. Therefore, it could be considered to divide all carcasses by sex before classification, as is done with the USA grading system where gilts and barrows are graded according to a separate list of criteria than sows. A list of criteria could be introduced for boars as fat quality tends to be poorer in intact males than barrows and females (Wood *et al.*, 2008).

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5.3.6 A consumer orientated quality parameter could be researched and included in the carcass classification system similar to the systems in the USA and Australia, in which sow carcasses with fat thicknesses associated with better eating quality could receive a higher monetary value. This could help to ensure uniformity within the Sausagers class, because the results from this study have shown a large variation of back fat thickness (5.2 to 95 mm) within the SAS class (Table 4.1.6).

The concept of a consumer orientated quality parameter could help promote more care to be given to sows and ultimately result in improved living conditions and welfare standards. Welfare issues are becoming an increasing concern for consumers especially amongst the wealthy, therefore to help the pig industry grow further, considerations of how to improve the welfare of pigs being farmed should be researched. This could then make marketing pig meat as ‘welfare conscious’ a viable option.

5.3.7 The effect of production systems used in South Africa on the composition and quality of pig carcasses should be researched further, with the end goal being how the results could be used to improve the carcass classification system. And taking a further look at the effect of commercial versus communal farming on composition and quality of a carcass and how the indigenous breeds do not need to be penalised by the PORCUS carcass classification system; possibly by introducing the suggestion by Hugo & Roodt (2015) of separate classification systems for the fresh meat and processing industries as the quality of fat in the leaner classes is not preferred by the processing industry. Also, the survey conducted by Oyewami & Jooste (2006) showed that value added products are preferred over fresh meat in South Africa, therefore having a second carcass classification for the processing industry may be beneficial.

Soji *et al.* (2015b) highlighted an important and interesting problem that communal and small-scale farmers may shun the formal red meat sector as the carcass classification systems that are currently in place favour leaner carcasses. And because these farmers make use of indigenous breeds that tend to have fatter carcasses they would therefore be penalised in a monetary sense by the formal pig carcass classification system. With this leading to the possibility of contaminated meat entering the meat value chain as other entry points into the chain may be explored. Another interesting problem that may emerge and face these farmers is that SAPPO would like all producers to become Pork 360 (South African Quality Assurance and Traceability Programme) accredited. Farmers are required to maintain a level of biosecurity which would require a certain level of infrastructure. This may be expensive for communal farmers to build up, if it has not already been done, and with their pig carcasses being penalised by the carcass classification system it could make it even more difficult to become Pork 360 accredited. Therefore, having two carcass classification systems, one for the fresh meat market and the other for the processing market, may help to encourage communal farmers to join the formal red meat sector as their pigs may be able to receive a higher monetary value within a carcass classification system for the processing industry.

However, an assessment of the socio-economic impact (SEIAS) two pig carcass classification systems (one for the fresh meat market and another for the processing industry) would have on each level of the value chain, with attention to the impact on communal and commercial pig farmers, would be important to conduct to ensure that any unforeseen consequences associated with its execution and compliance are avoided or minimised. This in turn could help produce mitigation strategies against any anticipated implementation risks (DPME, 2015).

5.3.8 It has also been suggested by Orcutt *et al.* (1990) that in order to have more accurate estimations of LM%, two prediction equations could be beneficial where one is used for carcasses weighing < 100 kg and another equation for carcasses weighing ≥ 100 kg. The study by Sather *et al.* (1989) may support this suggestion as it was found that the HGP underestimated LM% with increasing carcass mass and having two prediction equations could improve the accuracy of the HGP.

Also, another factor to regard with introducing a second carcass classification system could be that it may result in increased genetic diversity among the pig population in South Africa as leaner pigs would not be the only breeding goal that is targeted by producers anymore.

5.3.9 A survey aimed at identifying the needs of each level of the pork value chain may help to identify problem areas of the PORCUS carcass classification system and whether it would be worth looking at adding a quality parameter to the system.

Conducting another survey aimed at uncovering what consumer preferences are with regards to pork products and if leaner products are still preferred may help to identify if an element of the PORCUS carcass classification system needs to change or if other components should be added to improve it.

CHAPTER 6
CONCLUSION

The objectives of the present study were to determine the existence of variation between the PORCUS carcass classification system parameters across all data, within gender, class, mass category and mass cluster. The existence of a producer effect was also examined among 15 of the producers. The second part of the study looked at variation between measured carcass characteristics. Both parts aimed at answering the question of whether or not the PORCUS carcass classification system needs to be revised.

Results showed that gender does not need to be accounted for when using the LM% equations as the amount of variation accounted for in Fat by WCM within class and gender are small.

Warm carcass mass is able to explain the variation seen within Fat across all data, within gender, mass categories and within classed carcasses significantly. Therefore, making WCM a possible predictor for Fat and LM%. The null hypothesis of a predictor cannot be identified is therefore rejected.

This study shows that the PORCUS carcass classification system is still able to reliably place carcasses in a class as the amount of variation seen within a class was small and would therefore not make any significant difference economically. However, larger amounts of variation are seen amongst the fatter carcasses of class S (fat thickness of ≥ 32 mm).

An area for concern is the overlap of the mass categories as this may have financial consequences.

Just as the use of conformation score is under question in the South African sheep carcass classification system due to less variability between carcasses (RMIF, 2016) it may need to be reviewed in the PORCUS carcass classification system too as 82.31% of the carcasses analysed in Part 1 of this study had a conformation score of 3.

A producer effect was noted, as the amount of variation within Fat that is explained by WCM across the 15 producers increased by 10% compared to when all data was pooled together. There were also significant differences ($P < 0.0001$) found between the 15 producers.

Therefore, the null hypothesis that no significant differences exist between WCM and Fat within producer is rejected and the differences are highly significant.

Based on the results of this study the null hypothesis that no significant differences exist between WCM and Fat across all the data, within gender, mass category, class and mass cluster is rejected.

With regards to Part 2, WCM was found to better explain the variation seen within EML than with EMD or EMA. The eye muscle measurements however were not able to explain the variation seen within Sfat. The hypothesis of WCM and Fat can be reliable predictors of EMA and LM% is rejected but an alternative was found that WCM could be a reliable predictor for EML with the relationship being stronger for carcasses weighing between 40 – 89 kg.

Lean meat % was not given as a criterion on the pig carcass records received from the abattoir therefore raising the question as to whether the LM% needs to be calculated if Fat and WCM are the main criteria buyers take into consideration when purchasing pig carcasses. Therefore, on this basis the hypothesis that the legislated prediction equation is still required is rejected.

CHAPTER 7
CRITICAL ASSESSMENT

This critical assessment of Parts 1 and 2 of the study is a hindsight view of the analyses and a consideration of what could have been done to have answered questions that emerged during the analyses.

7.1 Part 1

7.1.1 Repeating the data analysis with data from other abattoirs in Gauteng and the other provinces in South Africa could have provided interesting insight about the amount of variation between carcasses across the South African pig population. It is recognised however, that the commercial production of pork carcasses is aimed at a narrow band in the classification system that accommodates 84.7% of the carcasses.

7.1.2 Conducting a survey to the 15 selected producers to determine the type of production system they had implemented would have allowed for a complete explanation of the effect of different production systems on carcass composition and quality according to the classification system.

7.1.3 Dividing the data into the LM% classes i.e., clustering the classified carcasses into the P, O, R, C, U or S classes and not just into the mass categories, may have made it easier to make more comparisons with other work conducted on pig carcasses in South Africa, such as the studies by Hugo & Roodt (2015) and Soji *et al*, (2015a).

7.1.4 Combining mass clusters 4 to 10 (30.0 to 99.9 kg) instead of only mass clusters 4 to 9 (30.0 to 89.9 kg), may have been a better representation of carcasses that were classified as the mass range of carcasses classified was 20.8 to 103.2 kg. Also, mass clusters 4 to 10 includes 90.0% of the carcasses analysed and mass clusters 4 to 9 includes 84.9% of the carcasses analysed.

7.2 Part 2

7.2.1 Measuring Fat with the callipers on warm carcasses at the same time as the HGPFat measurement was taken may have allowed for a better comparison better Sfat and HGPFat measurements. This was not possible though under the operational circumstances in the abattoir.

7.2.2 With regards to the Sfat measurements, interesting results may have surfaced if all carcasses were kept for the same length of time in the cooler before measurements were taken. This could have accounted for shrinkage within and between classes.

7.2.3 Combining classes SAB and SAS may have produced interesting results as Sausagers are divided into boars and sows and combining the two may have given an indication if a gender effect exists and the extent thereof.

CHAPTER 8
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