

VERIFICATION OF THE SOUTH AFRICAN PORK CLASSIFICATION SYSTEM

By

Rita Myburgh

**Submitted in fulfilment of the requirements
for the degree of**

**MAGISTER SCIENTIAE AGRICULTURAE
(FOOD SCIENCE)**

In the

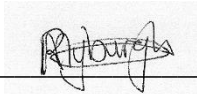
**Department of Microbial, Biochemical and Food Biotechnology
Faculty of Natural and Agricultural Sciences
University of the Free State**

**Supervisors: Prof. A. Hugo
 Prof. P.E. Strydom
Co-supervisor: Dr. M. Hope-Jones**

January 2019

DECLARATION

I declare that the dissertation hereby submitted by me for the degree M.Sc. Food Science in the Faculty of Natural and Agricultural Sciences at the University of the Free State is my own independent work and has not previously been submitted by me at another university or faculty. I furthermore cede copyright of this dissertation in favour of the University of the Free State.

A handwritten signature in black ink, appearing to read 'R. Myburgh', is written over a horizontal line. The signature is contained within a light grey rectangular box.

R. Myburgh

30 January 2019

CHAPTER	TITLE	PAGE
	Acknowledgements	iv
	List of Tables	vi
	List of Figures	viii
	Glossary of Abbreviations	x
1	INTRODUCTION	1
	1.1 Background	1
	1.2 Aims and Objectives	3
2	LITERATURE REVIEW	4
	2.1 Introduction	4
	2.2 A Short Overview of the Pork Industry and Pork Consumption	5
	2.3 Principles of Pork Carcass Classification	8
	2.4 Consumer's, Retailers and Wholesalers Expectations of Meat Quality	14
	2.5 Meat Quality Parameters Relevant to the Study	16
	2.5.1 Colour	16
	2.5.2 Water Holding Capacity	18
	2.5.3 PSE and DFD meat	21
	2.5.4 Intramuscular Fat	23
	2.5.5 Fat Quality	24
	2.5.5.1 Fatty Acid Composition	27
	2.5.5.2 Oxidative Stability of Fat	29
	2.6 Conclusions	30
3	MATERIALS AND METHODS	31
	3.1 Sampling	31
	3.2 Carcass Processing	33
	3.3 Meat Quality Analyses	33
	3.3.1 Colour Determination	33
	3.3.2 Drip Loss Determination	34
	3.4 Lipid Analyses	35
	3.4.1 Lipid Extraction	35
	3.4.2 Iodine Value and Refraction Index Determination	35

3.4.3 Fatty Acid Analysis	36
3.5 Reagents	37
3.6 Hennessy Grading Probe Calculations	37
3.7 Statistical Analysis	37
4 RESULTS AND DISCUSSION	39
4.1 Relationship between meat yield by HGP, meat yield by dissection, carcass classification measurements and meat quality parameters	39
4.2 Multiple Regression Analysis	43
4.3 Yield Groups	46
4.4 Principal Component Analysis	66
4.5 Weight Groups	67
5 GENERAL DISCUSSION AND CONSLUSIONS	78
6 REFERENCES	82
7 SUMMARY	98

ACKNOWLEDGEMENTS

I would hereby like to thank the following people, they made this thesis possible:

The Almighty God, for blessing me with the most amazing people in my life and all the opportunities that I have received.

Prof. Arno Hugo, Department of Food Science, University of the Free State, for his dedication and hard work. My study would not have been possible without him. I am very grateful for all the opportunities and many hours of guidance that he has provided me.

Dr. Michelle Hope-Jones, Agricultural Research Council, Irene, Pretoria, for providing me accommodation and guidance throughout my project and for making the deboning process a lot more bearable.

Dr. Phillip Strydom, Agricultural Research Council, Irene, Pretoria, for all his help during the carcass selection and for his guidance regarding my thesis.

ARC deboning team, Agricultural Research Council, Irene, Pretoria, for many hours of hard work without any complaints. I would never have been able to do all my sampling without your help.

Jason Opperman, for his endless support, encouragement, patience and most importantly, love. Thank you for being my shoulder to lean on and being my pillar of strength. Thank you for making me laugh on my worst days.

My mother, *Amilia Myburgh*, for all your prayers, love, support and wonderful sense of humour. I hope to someday be half the woman you are.

My father, *Koos Myburgh*, for all the sacrifices he made to allow me to study and for always believing in me no matter what.

My sister, *Carla Myburgh*, for being such a wonderful friend throughout all the difficult times and for always cheering me up with all your letters and late night talks.

Mrs. Hanli Opperman and Mr. Willem Opperman, for their unconditional love and support. Thank you for accepting me as one of the family and for all the wonderful memories I get to share with you.

Ms. Eileen Roodt, Department of Food Science, University of the Free State, for all her wisdom and assistance in the lab, for all the morning coffees and for all the wonderful lunch chats and for the many hours of assistance with my presentations and graphs without complaining once. Dynamite really does come in small packages.

Dr. Maryna de Wit, Department of Food Science, University of the Free State, for her motherly love and for always brightening up our days.

Ms. Stephani du Plessis, Ms. Anmeri Rautenbach and Ms. Schae-lee Olckers, Department of Food Science, University of the Free State, for all the coffee, wonderful times in the lab and for all your love, support and many words of encouragement.

Mrs. Ilze Auld, Department of Food Science, University of the Free State, for always helping without question and for being such a beautiful soul and for helping me print and bind my thesis.

The Meat Industry Trust (MIT) and the South African Pork Producers' Organization (SAPPO), for their financial support throughout my project. (Especially Mr. J. Kotzé from SAPPO for his encouragement and support.)

All the staff and students in the Department of Food Science, I am very grateful to be a part of such a wonderful department.

Anyone, I have not mentioned here, who has contributed to my study in any way.

LIST OF TABLES

Table Number	Table Title	Page Number
Table 2.1	Pork consumption in 2017, kg/capita	6
Table 2.2	Meat consumption in South Africa	8
Table 2.3	Classification characteristics of pork	12
Table 2.4	Classification characteristics of pork	13
Table 2.5	Bruising classification of South African red meat	14
Table 2.6	Marks for classes of pork	14
Table 3.1	Classification characteristics of pork	31
Table 3.2	Number of visits to abattoirs and carcasses selected	32
Table 3.3	Yield and weight classes of carcasses selected from the various abattoirs	33
Table 4.1	Pearson correlation coefficients between carcass classification measurements	39
Table 4.2	Pearson correlation coefficients between carcass classification measurements and selected meat quality parameters	41
Table 4.3	Pearson correlation coefficients between carcass classification measurements and proximate composition and chemical and physical properties of backfat.	41
Table 4.4	Pearson correlation coefficients between carcass classification measurements and fatty acid profile in backfat	44
Table 4.5	Pearson correlation coefficients between carcass classification measurements and fatty acid ratios in backfat	45
Table 4.6	Evaluation of the correctness of classification of pig carcasses in the different classification groups with the HGP	43
Table 4.7	Carcass composition and yields of different carcass cuts and parts according to yield class	48
Table 4.8	Fat distribution across the different primal cuts of the carcass according to yield class	51
Table 4.9	Fat distribution across the different primal cuts of the carcass according to yield class (fat content of cut expressed as % of fat content of whole carcass).	51

Table 4.10	Carcass characteristics, chemical and physical composition of backfat and meat of pigs from different classification groups	54
Table 4.11	Fatty acid composition of backfat of pigs from different classification groups	60
Table 4.12	Fatty acid ratios of backfat of pigs from different classification groups	62
Table 4.13	A comparison between dissection of the left vs the right side of the carcass in terms of yield groups	62
Table 4.14	Carcass composition and yields of different carcass cuts and parts according to weight class	68
Table 4.15	Fat distribution across the different primal cuts of the carcass according to weight class	71
Table 4.16	Fat distribution across the different primal cuts of the carcass according to weight class (fat content of cut expressed as % of fat content of whole carcass)	71
Table 4.17	Carcass characteristics, chemical and physical composition of backfat of pigs from different carcass weight groups	72
Table 4.18	Fatty acid composition of backfat of pigs from different carcass weight groups	73
Table 4.19	Fatty acid ratios of backfat of pigs from different carcass weight groups	74
Table 4.20	A comparison between dissection of the left vs the right side of the carcass in terms of weight groups	75

LIST OF FIGURES

Figure Number	Figure Title	Page Number
Figure 2.1	The Hennessey Grading Probe	12
Figure 2.2	The Intrascope	12
Figure 2.3	Fresh meat colour triangle	17
Figure 2.4	Changes in water distribution within the muscles	20
Figure 3.1	Schematic representation of a pig carcass, showing the sampling position.	34
Figure 4.1	Scatterplots of % actual meat predicted by dissection versus % Meat predicted with old and new HGP equations	46
Figure 4.2	The % of skin, meat, fat and bone that make up primal cuts of carcasses from different classification groups	50
Figure 4.3	Drip loss of meat of pigs from different classification groups. Bars with different superscripts differ significantly	53
Figure 4.4	Percentage of intramuscular fat of meat of pigs from different classification groups. Bars with different superscripts differ significantly	55
Figure 4.5	Percentage of extractable fat of meat of pigs from different classification groups. Bars with different superscripts differ significantly	56
Figure 4.6	Iodine value of backfat of pigs from different classification groups. Bars with different superscripts differ significantly	57
Figure 4.7	Refractive index of backfat of pigs from different classification groups. Bars with different superscripts differ significantly	58
Figure 4.8	Double bond index of backfat of pigs from different classification groups. Bars with different superscripts differ significantly	64
Figure 4.9	Peroxidizability index of backfat of pigs from different classification groups. Bars with different superscripts differ significantly	64
Figure 4.10	Principle Component Analysis of meat and fat quality properties of pork as affected by different classification groups	66

GLOSSARY OF ABBREVIATIONS

%	Percentage
a*	Colour coordinate – redness value
AA	Amino Acids
AI	Atherogenicity Index
ARC	Agricultural Research Council
AV	Anisidine Value
b*	Colour coordinate – yellowness value
BF	Backfat
BFT	Back fat Thickness
CC	Classification Centre
CGM	Capteur Gras-Maigre
CT	Computerized Tomography
DES	Destron
DBI	Double Bond Index
DFD	Dark, Firm and Dry
EU	European Union
EFC	Extractable Fat Content
FA	Fatty Acid/s
FAME	Fatty Acid Methyl Ester/s

Individual FAME:

<i>Abbreviation</i>	<i>Common Name</i>	<i>Complete Formula</i>	<i>Systematic Name</i>
C14:0	Myristic	C14:0	Tetradecanoic
C15:0	Pentadecylic	C15:0	Pentadecanoic
C16:0	Palmitic	C16:0	Hexadecanoic
C16:1	Palmitoleic	C16:1 _{c9}	<i>cis</i> -9-Hexadecenoic
C18:0	Stearic	C18:0	Octadecanoic
C18:1 _{c7}	Vaccenic	C18:1 _{c7}	<i>cis</i> -7-Octadecenoic
C18:1 _{c9}	Oleic	C18:1 _{c9}	<i>cis</i> -9-Octadecenoic

C18:2	Linoleic	C18:2 <i>c</i> 9,12(<i>n</i> -6)	<i>cis</i> -9,12-Octadecadienoic
C18:3 <i>n</i> -3	α -Linolenic	C18:3 <i>c</i> 9,12,15(<i>n</i> -3)	<i>cis</i> -9,12,15-Octadecatrienoic
C20:0	Arachidic	C20:0	Eicosanoic
C20:2	Eicosadienoic	C20:2 <i>c</i> 11,14(<i>n</i> -6)	<i>cis</i> -11,14-Eicosadienoic
C20:3 <i>n</i> -3	Eicosatrienoic	C20:3 <i>c</i> 11,14,17(<i>n</i> -3)	<i>cis</i> -11,14,17-Eicosatrienoic
C20:4	Arachidonic	C20:4 <i>c</i> 5,8,11,14(<i>n</i> -6)	<i>cis</i> -5,8,11,14-Eicosatetraenoic
C22:1	Erucic	C22:1 <i>c</i> 13	<i>cis</i> -13-Docosenoic

FFDM Fat Free Dry Matter

FoM Fat-o-Meter

FT Fat Thickness

GC Gas Chromatographic

GC-MS Gas Chromatography Mass Spectrometry

HGP Hennessey Grading Probe

IMF Intramuscular Fat

IV Iodine Value

L* Colour coordinate – lightness value

LM% Lean Meat Percentage

LMC Lean Meat Content

LMY Lean Meat Yield

mt Metric tons

MUFA Monounsaturated Fatty Acid/s

NIR Near Infrared Reflectance

NMR Nuclear Magnetic Resonance

O₂ Oxygen

PCA Principle Component Analysis

pl Isoelectric Point

PI	Peroxidizability Index
PSE	Pale, Soft and Exudative
PUFA	Polyunsaturated Fatty Acid/s
PV	Peroxide Value
RFN	Reddish pink Firm and Non-exudative
RI	Refractive Index
RSD	Residual Standard Deviation
SFA	Saturated Fatty Acid/s
UFA	Unsaturated Fatty Acid/s
US	United States
WBS	Warner-Bratzler shear force
WHC	Water-Holding Capacity
ZP	Zwei-Punkt-Messverfahren

CHAPTER 1

INTRODUCTION

1.1 Background

Meat has traditionally held a special place in the diet because of its appealing flavour and texture, and its high nutritional value (Morrissey, Sheehy, Galvin, & Kerry, 1998). According to archaeological records, pigs were domesticated and utilized as a food source for humans more or less 9000 years ago in the Near East (Berg, 2006). Pork is the most widely consumed meat in the world (Dugan, Vahmani, Turner, Mapiye, Juárez, Prieto, Beaulieu, Zijlstra, Patience & Aalhus, 2015)

Increased health risks have led to attention being drawn towards the nutritional properties of meat, especially regarding the quality and quantity of animal fat (Ferreira, 2014). An increasing number of consumers around the world are becoming more willing to change their standards of living and to reduce the risk associated with unhealthy food choices, including meat (Soji & Muchenje, 2017). Consumers have been advised to reduce their intake of saturated fatty acids (SFAs) and increase of polyunsaturated fatty acids (PUFAs) (Peiretti, Gai, Brugiapaglia, Mussa, & Meineri, 2015).

Pigs from very lean strains are frequently observed to have fat quality defects (Santoro, 1983). The leaner pork meat may be desired by the health conscious consumers, but to meat processors this meat creates a serious problem (Houben & Krol, 1983; Stiebing, Kühne, & Rodel, 1993; Warnants, Van Oeckel, & Boucqué, 1998; Teye, Sheard, Whittington, Nute, Stewart, & Wood, 2006). The decrease in fat has resulted in the fatty acid (FA) profile of the pigs to change to a more unsaturated one (Sather, Jones, Robertson, & Zawadski, 1995). These unsaturated FA results in a poor consistency, economical losses and processing, storage and taste disadvantages (Affentranger, Gerwig, Seewer, Schwörer, & Künzi, 1996).

The decrease in SFA causes the fat of these pigs to become soft (Raj, Skiba, Sobol, Pastuszewska, 2017). Soft fat often leads to fat layer separation in loins and may be the cause of muscle separation in the ham and shoulder. Carcasses do not set after chilling and the backfat, muscle and meat is considered to be dry and tasteless after

cooking (Kempster, Dilworth, Evans, & Fisher, 1986). Soft fat also leads to problems with product appearance when packaged (Sosnicki, 2010). One of the most important factors in ensuring or changing the FA profile of pig is through their diet. The pig's diet can be altered more readily than non-dietary influences on fat quality (Sosnicki, Mathews, Fields, & Jungst, 2010). Diet can therefore be used to solve fat quality problems in pigs.

Carcass classification systems are constantly being developed in order to ensure heterogeneous meat product trading, to achieve efficient animal production and for meat price determination. This is achieved by means of a simple and universally understood language which is used to give an indication of the yield of the carcass (Strydom, 2011; Webb, 2015). The carcass classification system impacts every person in the meat production chain, starting with the producers of the meat and ending at the meat traders. The system also allows the meat industry to reach their ultimate goal, and this is to meet the expectations of the consumers. (Strydom, 2011).

There is a worldwide tendency to produce leaner pigs. Today there is a better feed conversion relationship, therefore the composition of pigs have changed. The change in composition of pigs over the years necessitates a revision of the classification systems and formulas used in these classification systems (Schinckel, Brian & Forster, 2005; Jansons, Strazdina, Anenkova, Pule, Skadule & Melece, 2016).

In South Africa pigs are classified into six groups namely: PORCUS, according to their calculated lean meat content and backfat thickness (BFT) (Hugo & Roodt, 2015). The P classification group represents the pigs with the highest amount of lean meat ($\geq 70\%$) and has the smallest amount of backfat (BF) ($\leq 12\text{mm}$) and will be worth the most money, the O classification group represents pigs with 68-69% lean meat and 13-17mm of BF, the R classification group represents pigs with 66-67% lean meat and 18-22mm BF, the C classification group represents pigs with 64-65% lean meat and 23-27mm BF, the U classification group represents pigs with 62-63% lean meat and 28-32mm BF the S classification group will be the fattest pigs ($> 32\text{mm}$ BFT) which have the lowest amount of lean meat ($\leq 61\%$) (SAMIC, 2006; Siebrits, Hambroek, & Pieterse, 2012).

This pork classification system is based on predictive formulas which were designed by Bruwer in 1992). There are two probes used in South Africa namely the Hennessey

Grading Probe (HGP) and the Intrascoper. These probes are used to take carcass measurements, namely the muscle thickness and fat thickness which are measured between the 2nd and 3rd last rib, 45mm from the back carcass midline while the carcass is still hanging. These measurements are put into the calculations that Bruwer (1992) created and the amount of lean meat is predicted. The equations are as follows: Hennessey % lean = $72.5114 - (0.4618 \times \text{fat thickness}) + (0.057 \times \text{eye muscle thickness})$ and Intrascoper % lean = $74.4367 - (0.4023 \times \text{fat thickness})$. The problem is that since 1992 the characteristics of pork carcasses have changed, namely the weight accompanied by different tissue composition due to advances in genetics and nutrition, the formulas used by the classification systems have not been updated since (Siebrits, et al., 2012).

If the formulas used in the HGP and Intrascoper are no longer correct and the formulas cause an over prediction of lean meat, the abattoirs will lose money due to pork farmers being paid more money for their pigs than they should actually get. This is because the animals are not classified correctly, and the abattoir will pay for a pig classified as a P, but in actual fact it is a O. Another problem is that meat processors receive meat that has more fat in the meat than expected, which could influence the formulations of the products. This leads to consumers eating meat which contains much more fat than desired. This problem works both ways, if the probes under predict the lean meat content, then the farmer does not get paid the correct amount for his carcasses.

1.2 Aims and Objectives

1. To evaluate the accuracy of the current formula in predicting lean pork yield.
2. To determine the effect of carcass weight and yield on meat cut composition, and meat quality.
3. To assess the effect of carcass weight and yield on fat quality and fatty acid composition.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The agricultural product market has changed from a generally producer dominated market approach, to a demanding, informed, consumer-dominated market (Visser, 2004). Today consumers are more aware of diet, health, and nutrition than ever before (Majid, Shariff, Majid, Aszahar, & Omar, 2015), they, therefore, demand high-quality meat with health-promoting properties (Taljaard, Jooste, & Afsaha, 2006; Scollan, Dhanoa, Choi, Maeng, Enser, & Wood, 2001), a small amount of visible fat on the cuts, ease of preparation and serving, increased tenderness and flavour, and a large variety of products that are consistently available and affordable (Bruwer, 1992). The meat industry will be able to remain in business, or even expand if they meet the demands of the consumers regarding their expectations of meat quality (Bernués, Olaizola, & Corcoran, 2003).

The South African pork industry is quite small when compared to the beef and chicken industries (Davids, Jooste, & Meyer, 2014), but globally pork is by far the most consumed of all meat products (OECD, 2018). Over the past few years, consumers have shown an increasing preference for products that contain high levels of unsaturated fatty acids (UFAs) because of the health benefits they provide (Wood, Enser, Fisher, Nute, Sheard, Richardson, Hughes & Whittington, 2008). Pigs are a monogastric species, amenable to changes in the FA composition of adipose tissue and muscle using diets containing different oils (Wood et al., 2008). If pig's diets are supplemented with oils that contain high amounts of UFAs it may lead to healthier products for consumers (Park, Kim, Lee, Jang, Kim, Lee, Jung, Kim, Seong & Choi, 2012).

Carcass classification and grading systems are developed in an attempt to describe the yield and features of carcasses which are useful for trading and pricing purposes (Soji & Muchenje, 2017). The pork industry has been making use of the carcass merit pricing and evaluation system for twenty years. The two main value determinants in today's meat industry, are yield and quality (Mckeith, 2010). Carcass weight, amount of BF and muscling account for 79% of the changes in carcass value (Hayenga,

Gridale, Kauffman, Cross, & Christian, 1985). The yield and quality of pork that can be derived from the pig's carcass is mainly determined by the amount of muscle tissue and its distribution (de Lange, Morel, & Birkett, 2003).

South Africa used a grading system for pig carcasses in abattoirs developed in 1985 until it was replaced by a carcass classification system in 1992 (Bruwer, 1992). The current equations used to predict the pig carcass lean content in South Africa were calculated by Bruwer (1992). The genetics of pigs has since changed, which has caused the composition of the pigs to change dramatically. The pork classification systems, therefore, need to be re-evaluated (Siebrits, et al., 2012).

2.2 A short overview of the Pig Industry and Pork Consumption

Pork production systems have progressed from forest-based to pasture-based and finally into specially-designed buildings. The world pork industry is constantly changing and it is complicated, not only in the production methods but in economics and cultural value (McGlone, 2013). Higher incomes and increased urbanization has led to a continuous increase in demand for meat (BFAP, 2013). Pork production has increased by 18.5% over the past decade worldwide (BFAP, 2013). The increase in pork production can be attributed to better genetics and improved production practices. The greatest growth is recorded in Vietnam (65.4%), Russia (49.6%), Brazil (27.1%) and China (24.7%). South Africa contributes less than 0.2 % to global pork production. The most important pork producing countries remain China, the European Union (EU), United States of America (USA) and Brazil. These countries contribute to 80% of global pork production (BFAP, 2013).

The Asian pork production system is rapidly changing from free-ranging and mixed (backyard) systems to the industrialized model, in order to become more like the European/American model. An industrial model makes use of very high quality genetic material and artificial insemination to ensure sows fall pregnant immediately after weaning of piglets. North American industrialized production facilities are fairly new, with a turnover from free range to a more industrialised system currently taking place (McGlone, 2013). It has been predicted that the world population will grow to more or less 9.6 billion by 2050. The increase in population will require 70 – 100% more food than current production. The consumption of meat is expected to rise along with the

population growth. In order to produce enough meat, the meat industry will have to increase livestock production significantly (FAO, 2009).

Approximately 37% of all meat consumed globally is pork. As developing countries become more affluent, the population consumes more meat. World pork consumption will likely double in the next 30-50 years. In the next decades, the pig and pork facilities will not only double in size, but they will also be completely replaced by newer, more sustainable systems, as part of the normal turnover of assets (McGlone, 2013).

According to Table 2.1 (OECD, 2018), the EU was the largest pork consuming region in 2017, followed by China, Vietnam, Korea, Russia and Australia who all consumed more than 20 kg pork per capita. Some countries like Bangladesh, Iran and Sudan, do not consume pork at all and this is due to religious reasons (Giorda, Bossi & Messina, 2014).

Table 2.1: Pork Consumption in 2017, kg/capita (USDA, 2017; OECD, 2018)

Country	Pork Consumed (kg/capita)	Country	Pork Consumed (kg/capita)
Australia	20.7	Korea	28.7
Bangladesh	0.0	Pakistan	0.0
China	30.8	Russia	20.7
European Union	32.5	South Africa	5.0
India	0.8	Sudan	0.0
Indonesia	2.2	United States	23.6
Iran	0.0	Viet Nam	29.0

According to BFAP (2013), the demand for prime cuts, processing cuts and fifth quarter products differ between regions due to differences in religion, tradition, culture and wealth. The differences in demand for specific parts of the carcass offers opportunities to increase the total carcass value, this further increases the importance of international trade in pork products. The 0.18 % that the South African pig industry contributes to the total pork produced worldwide, makes South Africa an insignificant player in the world markets and is making it vulnerable to changes in global pork markets (BFAP, 2013). The majority of pig production takes place in the North-west province, KwaZulu-Natal, and the Western Cape (BFAP, 2014). South Africa is a net

importer of pork products and uses imports to balance the market. South Africa is expected to remain a net importer of pork products over the next 10 years (BFAP, 2014).

Pork production in South Africa usually takes place in a closed system, meaning that the breeding, weaning and finishing operations are all undertaken by the same producer. This differs from the EU, where piglet production and the finishing operations are not undertaken by the same producer. In the EU system, producers often specialize in a single aspect of production, which allows for greater specialization (BFAP, 2014). South Africa, however, has the benefit that piglets enter the finishing barn at cost price and not market price, this allows for a decrease in the cost of production for the finishing unit. Around 70% of South African pork producers mix their own feed rations, this ensures optimum feed conversion at the different stages of growth on the farm (BFAP, 2014).

In 2015, South Africa exported 13 500 metric tons (mt) of pork, which is the equivalent of about 5.5% of South Africa's total pork production, mostly to neighbouring countries such as Namibia, Mozambique, Lesotho, and Swaziland. In that same year, South Africa imported 38 500 mt pork, with Germany, Canada, and Spain being the main suppliers (NHF, 2016). According to the USDA (2017), it is estimated that South African pork imports will increase by 2.5% annually, reaching more or less 32 000 mt in 2017 and 33 000 mt in 2018. South African exports are expected to stay constant at more or less 14 000 mt in 2017 and 2018, this is due to the increasing demand for pork caused by the increase in the price of beef and lamb.

The total pork consumed in South Africa in 2015 was more or less 270 000 mt (NHF, 2016). South African urbanized consumers have displayed an increase in per capita income, which has led to improved living standards and increased spending power, and this had led to an increase in per capita pork consumption. From Table 2.2 we can see that from 2010 to 2017 there has been an increase in the consumption of pork in South Africa (USDA, 2017). Greater population numbers have further increased total pork consumption. South African population numbers are expected to increase through the coming decade, this will lead to a further increase in total pork consumption (BFAP, 2013; Grimbeek, Davids, & Human, 2014).

Table 2.2: Meat Consumption in South Africa (USDA, 2017)

Year	Beef (kg/capita)	Poultry meat (kg/capita)	Pork (kg/capita)	Mutton/lamb (kg/capita)
2010	17.8	38.4	4.4	3.5
2011	17.6	39.9	4.6	3.1
2012	16.7	39.4	4.6	3.0
2013	17.4	39.4	4.7	3.3
2014	18.5	38.6	4.5	3.6
2015	19.5	39.6	4.7	3.5
2016	20.9	40.0	4.8	3.6
2017	21.3	41.2	5.0	3.7

2.3 Principles of Pork Carcass Classification

The simplified definition of meat, is animal tissue which is used as food. More commonly meat refers to the skeletal muscle and the associated fat, and these two attributes of meat are very important as they determine the quality and the commercial value of pork carcasses and cuts. For more than fifty years, the pig industry has acknowledged the need to place an objective value on pork carcasses (Pomar, Marcoux, Gispert, & Font i Furnols, 2009). Carcass grading or classification was established in the largest meat producing countries during the early 1900s (Strydom, 2011). The difference between a grading system and a classification system is that a grading system ranks the carcasses in order of perceived excellence and a classification system describes and quantifies the carcass characteristics if it is possible (Bruwer, 1992).

According to Bruwer (1992) and Strydom (2011), a classification system provides a universal language for describing important determinants of yield and composition and provides a platform for buyers to express their demands and preferences. A proper classification system should be very informative and useful for all persons involved in the production and consumption of the meat. A classification system can be used by farmers as a guideline to show them what type of animal they should rear in order to

meet the demands of the consumers and is there to discourage the supply of livestock that is of low quality or low in demand (Strydom, 2011).

An effective classification system is required by the producer and the seller of the meat. Producers who supply carcasses that are of high quality and are up to standard, according to the buyer, will be rewarded (Strydom, 2011). The carcass classification system should give an indication of the meat quality and it is used to predict the amount of meat from the carcass that can be sold. The classification system should be accurate, simple to apply, inexpensive and it should be verifiable (Strydom, 2011).

In the past, carcass composition and the Lean Meat Percentage (LM %) for pork was originally estimated by dissection. Dissection however had many limitations and therefore alternative methods were created with the objective in mind to find a method which is quicker, more accurate and cheaper (Pomar, et al., 2009). Various methods have been used to determine and measure pork carcass composition and a lot is being done to ensure that the pork carcass evaluation procedures are standardized and that these procedures are well defined. The carcass endpoints should be accurately and economically predicted from easily obtained carcass measurements (Schinckel, Wagner, Forrest, & Einstein, 2001). The grading of live pigs was established in the early 1920s. An effective value-based system was only familiarized to many countries in the 1960s, which led to the ability to measure fat depths with automatic probes in slaughter plants (Pomar, et al., 2009).

Over the last few decades, there has been increasing concern regarding the measurement of carcass lean, especially when it comes to carcass classification and animal breeding in the livestock industry (Mckeith, 2010). According to Busk, Olsen & Brøndum (1999), various technologies have been used at the abattoirs for on-line measurement of LM % in carcasses. The definition of LM % differs greatly between countries, but in general LM % is predicted using the strong relationship between the lean meat yield (LMY) and the subcutaneous fat and muscle depths measured at specific locations of the carcass (Engel, Buist, Walstra, Olsen, & Daumas, 2003). The most popular and accurate method is the measurement of fat and muscle depths by an optical probe and subsequently calculating the LM % on the basis of the measurements. Measurements are taken manually with a probe at the end of the slaughter process (Busk, et al., 1999).

Over a long period of time, many types of equipment for pig carcass evaluation and grading have been developed and tested. These devices are categorized based on their degree of automation, namely manual, semiautomatic or fully automatic equipment (Pomar, et al., 2009). Manually operated devices depend entirely on the operator. These devices can measure tissue depths at the split line or laterally. The Zwei-Punkt-Messverfahren (ZP) method can be done with rulers or callipers at the split line. The Intrascop (or Optic Probe, OP) measures the depth between the fat and muscle, lateral to the split line (Pomar, et al., 2009).

The manually operated probes need to be inserted properly at the correct angle otherwise the data that is recorded will be incorrect (Mckeith, 2010). The tissue that is not penetrated by the probe becomes compressed when the readings are taken and the penetrated tissue becomes stretched. This may create bias because some structures may appear deeper as the probe originally penetrates the carcass, opposed to when the probe is removed from the carcass. This is why the measurements should be taken when the probe is pulled out of the carcass (Mckeith, 2010). These devices are low of cost and mainly used in low volume slaughterhouses (Pomar, et al., 2009).

In order to decrease the operator effect, semiautomatic devices were developed. These devices automatically determine fat and loin depth using light reflectance (optical) or ultrasound probes. The operators of these probes require training in order to reduce error due to wrong measurement location (Pomar, et al., 2009). Examples of semiautomatic devices are the Fat-o-Meter (FoM), the HGP, Capteur Gras-Maigre (CGM) and Destron (DES). The FoM and HGP use near-infrared reflectance (NIR). These optical probes measure the reflection of light in the spectral range of 700 – 2500 nm. The probes have two diodes, one is a light emitting diode and the other is a detector. The diodes pass through the muscle and into the fat and once the diodes have done so, they are then removed from the muscle. The diodes record the increase in light reflection and the depth of the probe as the change in reflection occurs, this data is then used to determine the meat yield of the carcass (Mckeith, 2010).

Using probes to take measurements is an invasive process, and can cause damage or potentially introduce contamination (Busk, et al., 1999). In order to prevent damage and contamination of the carcass, non-invasive methods for taking measurements have been tested during the last few years. Examples of these methods are

computerized tomography (CT), nuclear magnetic resonance (NMR), electrical conductivity and ultrasound. Measurement of fat and lean depth with ultrasound has been used successfully for many years (Busk, et al., 1999). All the non-invasive semiautomatic devices use ultrasound to take measurements. The fact that these probes are non-invasive means that they can measure fat thickness (FT) in other cuts such as ham. This is important in countries such as Spain and Italy, where hams can only be cured properly if they have narrow fat depths (Pomar, et al., 2009).

The operator effect is completely avoided when using fully automatic devices. These devices are mainly used at large slaughterhouses, and they take multiple measurements which they use to estimate the parameters of interest (Pomar, et al., 2009). The Classification Centre (CC) is a fully automated device, which measures fat and meat depth using a robotic technique. Other examples of fully automatic devices include the Vision Carcass System (VSC) (Pomar, et al., 2009).

Throughout the world, hog carcasses are commercially graded and classified based on BF measurements alone or together with the carcass weight and/or muscle depth (Fortin, 1986). A rapid, accurate method is needed to provide information regarding the fat and lean content during the processing of pork carcasses (Mitchell, Scholz & Pursel, 2003). The Canadian, Japanese, South Korean, USA and Australian systems consist of further assessments such as the marbling score, meat colour, meat texture, fat colour, FT and skeletal development. These assessments provide more information about the meat quality and expected eating quality. (Strydom, 2011)

In South Africa, the major abattoirs use the HGP, but most of the small abattoirs still use the Intrascoper. These probes take certain carcass measurements and use a formula to assign a certain class to the carcasses. In South Africa the HGP predicts Lean Meat Content (LMC) by measuring FT and muscle thickness between the 2nd and 3rd last rib, 45mm from the back carcass midline while the carcass is still hanging. The Intrascoper only measures the FT. The HGP and Intrascoper use the PORCUS classification system to assess pig carcasses (Siebrits, et al., 2012; Hugo & Roodt, 2015). Table 2.3 shows the criteria used to classify the pigs into one of the PORCUS groups (SAMIC, 2006). The criteria in Table 2.4 to Table 2.6 are also used to mark the carcasses with information regarding the conformation, damage, sex, bruising and

classes. The carcasses are marked with a certain symbol or number in order to inform the buyer about the certain carcass characteristics (SAMIC, 2006).



Figure 2.1: The Hennessey Grading Probe



Figure 2.2: The Intrascoper

Table 2.3: Classification Characteristics of Pork (SAMIC, 2006)

Class	Calculated % meat of carcass based on measured fat and muscle thickness at a certain point	Fat thickness measured by means of an Intrascoper (mm)
P	≥ 70	≤ 12
O	68-69	13-17
R	66-67	18-22
C	64-65	23-27
U	62-63	28-32
S	≤ 61	> 32

According to Bruwer (1992), the % lean meat in the carcass is estimated by:

- ❖ Measuring the FT and eye muscle thickness with a thickness meter, example the Hennessey Grading Probe
 - The following formula is used:
 - $\text{Hennessy \% Lean} = 72.5114 - (0.4618 \times \text{fat thickness}) + (0.057 \times \text{eye muscle thickness})$

- ❖ Measuring the FT with an Intrascope
 - The following formula is used:
 - $\text{Intrascope \% Lean} = 74.4367 - (0.4023 \times \text{fat thickness})$

Lean meat percentage, fatness, conformation, damage and sex are the main characteristics used in order to assess the carcasses, age is not considered in pork classification (DOA, 2004). In the case of suckling, sausage, and rough pig, neither the meat percentage (%) nor FT applies. (SAMIC, 2006). Carcasses that

Table 2.4: Classification Characteristics of: Pork (SAMIC, 2006)

Conformation	Class
Very flat	1
Flat	2
Medium	3
Round	4
Very round	5

Damage	Class
Slight	1
Moderate	2
Severe	3

Sex
The carcass of a boar as well as of a barrow showing signs of late castration are identified

Table 2.5: Bruising classification of South African red meat (Soji & Muchenje, 2017)

Class	Classification	Description
1	Slightly bruised	Only the subcutaneous tissue is damaged
2	Moderately bruised	Subcutaneous and muscular tissue is damaged
3	Severely bruised	Subcutaneous and muscular tissue is damaged as well as the bones

Table 2.6: Marks for classes of pork (SAMIC, 2006)

Class	Mark	Where on the carcass
Suckling pig	S	One mark on forehead
P,O,R,C,U, and S	P,O,R,C,U, and S	One mark on each side
Sausage pig	W	One mark on each buttock
Rough	RU	One mark on each side

weigh less than 20kg are regarded as suckling pigs and more than 100kg as sausage pigs (DOA, 2004).

Bruising is an indication of poor animal welfare and affects meat quality and yield negatively. Bruising is defined as the discolouration and actual bleeding at the site of injury, and can reduce the carcass value dramatically. Bruises on a carcass are usually removed just after evisceration (removal of internal organs, especially those in the abdominal cavity) during primary meat inspection. Bruised meat is often trimmed off due to the fact that the bruised areas are usually bloody and stimulate bacterial growth if not removed, and can lead to a more rapid rate of decomposition and spoilage (Soji & Muchenje, 2017).

2.4 Consumer's, Retailer's and Wholesaler's Expectations of Meat Quality

Quality can be seen as a measure of the consumer's satisfaction or as the relationship between the real and the desirable properties of a product (Hugo & Roodt, 2007). Quality can also be seen as the measure of the agreement between the properties of the product and the quality standard or contract conditions (Ingr, 1989). Many factors influence the quality of meat, this includes the requirements for food safety and animal welfare, sensory appeal, perceived healthiness, especially regarding the quality and quantity of fat and other fatty acid components (Thu, 2006).

Consumers use intrinsic and extrinsic cues in order to help them form an opinion regarding the quality of the product (Veale, Quester & Karunaratna, 2006). Consumers use quality cues, such as visible or intrinsic features like fat content/leanness, marbling, appearance/colour, texture/tenderness, freshness or extrinsic factors such as packaging, labelling, price and nutritional value to be able to judge the quality of the product (Bredahl & Andersson, 1998).

Once the meat is bought, cooked, and served, the aroma, tenderness, juiciness, and flavour must meet the expectations of the consumer (Thu, 2006). The consumer will not be satisfied with the meat if the meat has a poor water holding capacity (WHC) and shrinks when it is cooked, if the meat has a thick layer of fat or if the fat is soft, if the meat has a pale or dark colour (e.g. Pale Soft Exudative (PSE) or Dark, Firm and Dry (DFD) meat), off-flavour or off-odours, if the meat is tough or does not have sufficient marbling/ intramuscular fat (IMF), if the meat is not packaged properly or if the label of the meat does not contain sufficient information regarding the nutritional properties of the meat. The aroma, tenderness and juiciness can be improved using spices and different cooking methods, but the flavour depends on the textural characteristics, the composition of the meat and many other factors (Thu, 2006).

Carcass quality can be defined by certain carcass characteristics. These include the class or weight group the carcass is classified under, the LM%, the FT, damage on the carcass and the conformation (flat or round carcass). The carcass quality of the animal gives an indication of the quality of meat that is obtained from that animal (SAMIC, 2006). Carcass quality is of concern to the wholesaler because they need to supply the types of carcasses that are in the greatest demand by the meat trade. It is mandatory that the retailer meets the demands of the consumer in terms of size, attractiveness, and composition of cuts or products. The retailer should also be able to estimate the saleable yield from each carcass (Bruwer, 1992).

Consumers demand pork with minimal visual fat even though it results in a less favourable eating experience (Genesis, 2016). Fat quality has a major impact on pork quality (Roodt, 2003). According to Wenk (2000), in order to have high-quality pork, the muscle and adipose tissues should consist of the following characteristics:

- ❖ High content of essential nutrients
- ❖ Good distribution of muscle fibre and connective tissue

- ❖ High oxidative stability
- ❖ Good consistency of the adipose tissues

2.5 Meat quality parameters relevant to the study

Meat is mammalian skeletal muscle which has undergone a post-mortem chain of metabolic changes. Muscle cells are among the most highly organized cells in the animal body and perform a varied array of mechanical functions. Muscle is made up of muscle fibres, each surrounded by connective tissue (endomysium), which are organised into muscle bundles, which are separated from each other by a connective tissue called perimysium. The largest constituent of muscle is water, which makes up 75% of the weight of the muscle. The second largest component of muscle is protein, which makes up 18.5% of the weight of the muscle. Muscle proteins maintain the structure and organization of the muscle and muscle cells and they are important in the contractile process (Candek-Potokar, Zlender, Lefaucheur, & Bonneau, 1998).

2.5.1 Colour

Consumers use the colour and appearance of meat to select or reject products, therefore suppliers must create and maintain the desired colour attributes, this is also known as the perceived quality approach (Bernués, et al., 2003; AMSA, 2012). Colour can be determined instrumentally or subjectively. Instrumental methods include extraction and quantification of pigment content and the measuring of surface reflectance (Mckeith, 2010).

Measuring surface reflectance gives an indication of the amount of each light's wavelength that is reflected by the surface of the object and is similar to the colour perceived by the human eye (Mckeith, 2010). Reflectance measurements are quick to obtain, non-destructive, and repeatable. Colour values are given as L^* , a^* and b^* . The L^* values determine the change in lightness with 0 equal to black and 100 equal to white. The a^* values represent measurements from red (+) to green (-), and b^* values represent measurements from yellow (+) to blue (-) (Mckeith, 2010).

There are three major pigments found in meat, namely myoglobin, hemoglobin and cytochrome c. Myoglobin has a globular protein portion (globin) which consists of 140 to 160 amino acids (AA) as well as a non-protein heme ring. The oxidation state of the

iron within the heme ring influences the colour of the meat. When the ferrous form of the iron (Fe^{2+}) is oxidized to the ferric form (Fe^{3+}), metmyoglobin is produced (Mckeith, 2010).

Myoglobin and hemoglobin are the pigments that give meat its red colour (Lindahl, 2005). Myoglobin makes up 80-95% of the pigment concentration and contains 95% of the total muscle iron. Hemoglobin and cytochrome c make up 5-20% of the pigment concentration (Mckeith, 2010). Muscle appearance is determined by the chemical state of muscle pigments. In the absence of oxygen (O_2), the meat pigment is in the deoxymyoglobin state, which has a dark, purple-red colour. When the meat pigments are exposed to O_2 , it is rapidly oxygenated to form oxymyoglobin, the meat then has the desirable bright red colour (Kropf, 2003).

As can be seen in Figure 2.3, the fresh meat colour triangle, deoxymyoglobin and oxymyoglobin are both in the reduced state and they can be oxidized to metmyoglobin, which has a dull brown colour that is associated with a deterioration of colour (Kropf, 2003). Metmyoglobin is a more stable pigment and it is slowly converted to deoxymyoglobin by enzyme-mediated reactions, these are known as metmyoglobin-reducing activities. Muscles differ greatly in metmyoglobin-reduction activity, and it dissipates during the storage of the meat (Kropf, 2003).

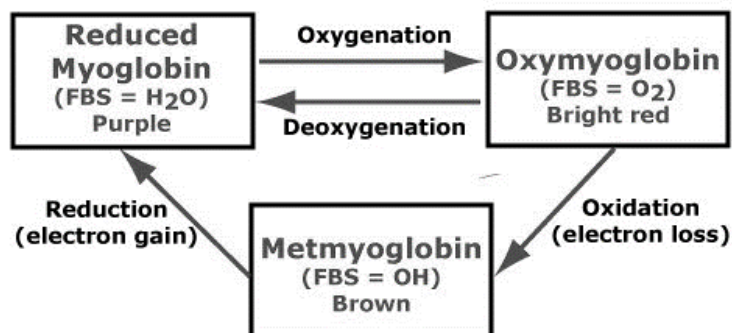


Figure 2.3: Fresh Meat Colour Triangle (Lindahl, 2005)

Meat is displayed in a display case in the retail market, and as time progresses the meat gradually becomes discoloured (brown). The change in colour can be due to exposure to light and heat, which causes the muscle to change colour (Marchello & Dryden, 1968). Spoilage of meat can often result in the darkening of meat, this is often accompanied by a very unpleasant odour. The desired colour of beef is cherry-red, in lamb it is light-pink and in pork, it is greyish-pink (Marchello & Dryden, 1968).

The amount of water in or on the meat also affects the colour of fresh meat. The proteins in the meat which have a low pH, below 5.4, do not bind water tightly which results in a lot of “free water”. This unbound water in the tissues reflects or scatters the light in many directions, which causes the meat to have a pale appearance. As the pH of the meat increases, the water becomes more tightly bound, resulting in the colour of the meat becoming darker (Brewer, 2012).

Fresh pork fat which has been exposed to oxygen has a pink colour due to the presence of oxypigments. The pink colour changes to white with a tint of yellow when the meat is vacuum packed (Barton-Gade, 1983). Hard adipose tissues seem to be whiter than it is because the colour haem components of the fat tissues are sequestered by the cloudiness of the hard lipid (Enser, 1983).

2.5.2 Water Holding Capacity

Cheng & Sun (2008) defines WHC as the ability of meat to retain water, both intrinsic and added water, and Huff-Lonergan (2010) describes WHC as the ability of post-mortem muscle (meat) to retain water even though external pressures (e.g. gravity or heating) are applied to it. WHC of meat products is a very important meat quality characteristic. It has an influence on the product yield, which in turn has economic and eating quality implications (juiciness and tenderness). When a whole carcass is hung up and left to age, moisture is lost due to evaporation (Meat Suite, 2012). The loss of water in a meat product results in a reduction in the weight of the product, which leads to a financial loss (Cheng & Sun, 2008).

More or less 75% of water in the muscle is held within the protein matrix of the individual muscle cell. Water can exist in meat either in the bound, immobilized or in the free state (Mckeith, 2010). Bound water can be found around non-aqueous components such as proteins. Immobilized water, also known as entrapped water, is held within the cell by steric effects or by weak attractions to bound water. Free water is held together by weak surface forces and can flow throughout the muscle with ease and can be easily lost during meat processing or storage (Mckeith, 2010).

More than 50% of pork that is produced has an unacceptable purge loss. Weight loss in meat due to purge can be 1-3% in fresh retail cuts and as high as 10% in PSE classified meats (Mckeith, 2010). A higher loss of moisture gives an expectation of

less optimal quality, due to shrinkage. A severe loss of water will reduce the acceptability of the product, and it will decrease the sale value (Cheng & Sun, 2008). The loss of moisture also entails the loss of a significant amount of protein (Huff-Lonergan & Lonergan, 2005). The mechanism by which drip is lost from meat is influenced by both the pH of the tissue and the amount of space in the muscle cell and particularly the myofibril that exists for water to reside (Huff-Lonergan, 2010).

Cooking and cooling procedures for the final meat product can also affect the moisture content of the product, especially the cooking and cooling methods, the heating and cooling rate, the cooking temperature, and the endpoint temperature. The water content of meat products is one of the essential quality parameters for meat processors because it is an indication of what the final yield of the end product will be (Cheng & Sun, 2008). A common problem during meat processing is water loss, other terms sometimes used is drip loss, expressible water, cook loss, and cooling loss depending on which stage during processing it was measured (Cheng & Sun, 2008). Meat with low WHC tends to produce inferior processed products (Huff-Lonergan, 2010).

During the conversion of muscle to meat, there is an accumulation of lactic acid, which causes the pH to decrease. When the pH decreases until the point where it reaches the isoelectric point (pI) of meat, which is between 5.1 and 5.2, the net charge of the myofibrillar proteins approaches zero (Mckeith, 2010). This means that there are the same amount of positive and negative charges associated with the side chains of the AAs of the protein. This causes the positive and negative groups to attract one another rather than water molecules, which allows the water to be forced out of the muscle by external forces like e.g. gravity (Mckeith, 2010).

According to Huff-Lonergan (2010) the characteristics of the muscle in the live animal will have a strong influence on the amount of moisture lost from the resulting meat product. Cheng & Sun (2008), stated that drip loss in meat is caused by the rapid decline in pH of the muscle post-mortem, especially at high temperatures, which causes extensive denaturation of the meat proteins, this causes changes in the molecular level such as shrinkage of the myofilament lattice post-mortem due to pH fall and actomyosin cross-bridges, myofibrillar shrinkage and contraction, and myosin denaturation as can be seen in Figure 2.4.

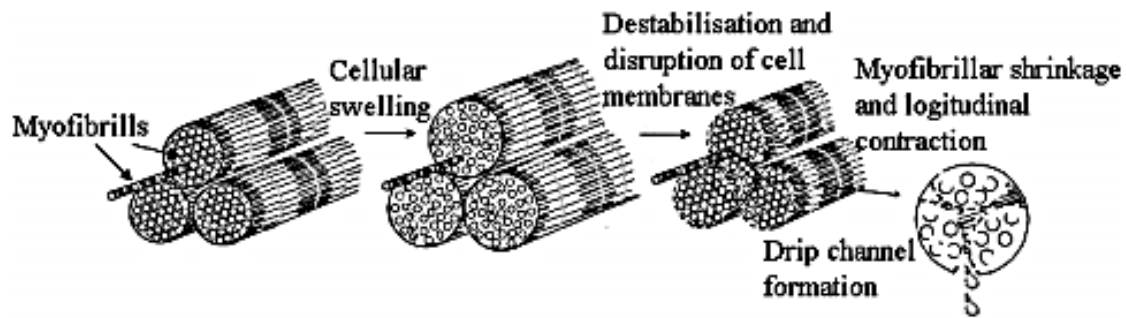


Figure 2.4: Changes in water distribution within the muscles (Cheng & Sun, 2008).

The water binding capacity of meat increases when the pH decreases to below the pI , because there are more positively charged groups on the protein. When the pH increases to above the pI , the water binding increases because of the increase in negatively charged groups on the protein. It can, therefore, be deduced that when the post-mortem pH is above or below the pI of meat, there are greater percentages of bound or immobilized water within the muscle cell (Mckeith, 2010).

There are several methods that have been developed to determine WHC, these include:

- ❖ Gravimetical bag method (Honikel, 1998)
- ❖ Nuclear magnetic resonance (NMR) relaxation measurement (Keeler, 2010)
- ❖ Filter paper press (Grau & Hamm, 1953)
- ❖ Methods based on centrifugation (Cheng & Sun, 2008)

The filter paper press method was the first method developed to determine WHC. The procedure removes unbound water by pressing a small sample between two filter papers using a 40kg weight (Mckeith, 2010). This method had many disadvantages, such as losses due to evaporation, erratic results and the sample has to be homogenized. This led to the development of the gravimetical method in the 1980s. In this procedure, a piece of meat is placed in a hanging net and suspended in a plastic bag for 48 hours. The WHC is determined by the weight changes in the suspended samples (Mckeith, 2010).

2.5.3 PSE and DFD meat

Reddish pink, firm, and non-exudative (RFN) meat is regarded as the ideal meat which has a normal colour, texture, and WHC (Lui, Ngadi, Prasher, & Gariépy, 2010). Extreme paleness or darkness is often found in pig meat and beef, due to a combination of environmental and genetic factors (Wood, Holder, & Main, 1998). PSE and DFD meat are two of the major quality defects that the meat industry faces. These defects greatly reduce consumer acceptability, shelf-life, and yield of meat which leads to a financial loss (Adzitey & Nurul, 2011). These meats have poor processing characteristics, reduced yield and have a higher spoilage potential compared to normal meat. There can also be the danger that consumers will begin to associate poor quality meat to food safety issues. PSE and DFD meats are defined in connection with the pH of the meat at a certain time after the animal has been slaughtered (Adzitey & Nurul, 2011).

After an animal is slaughtered, a number of post-mortem changes take place. The circulatory system loses its function and the oxygen which remained in the muscles becomes depleted and the glycogen metabolism switches from an aerobic pathway to an anaerobic pathway (Huff-Lonergan & Page, 2001). Lactate is a by-product of this anaerobic pathway which gradually builds up in the muscle, which causes a drop in the pH of the tissue. Within 24 hours the pH of the tissue drops from 7.4 to 5.5. The rapid pH drop in the tissue causes extensive protein denaturation, including myoglobin denaturation and this results in PSE meat (Huff-Lonergan & Page, 2001). Differences in the rate and level of post-mortem glycolysis are responsible for a large part of the variation in the WHC and colour of meat (OMAFRA, 2016).

In PSE meats, the rate of acidification after slaughter is stimulated faster than normal and lower pH values are reached in the muscle when the temperature of the carcass is still high (Adzitey & Nurul, 2011). The PSE condition is characterized by muscle that is pale in colour, has a soft texture and is very watery. PSE meat is not only undesirable due to its unappealing appearance, but also because of shrinkage due to drip loss, lowered processing yields, increases cooking losses, and reduced juiciness (Lee & Choi, 1999). PSE meats have a lot of exudates, which indicates poor WHC (Adzitey & Nurul, 2011).

The PSE condition is influenced by genetics, production systems, environment, and handling of the carcass both pre- and post-slaughter (Lee & Choi, 1999). Exposing animals to acute stress just before slaughtering can lead to PSE. Acute or short-term stress can be caused by the use of electric goads, fighting among animals just before sticking, beating of animals prior to slaughtering and overcrowding in the holding pens (Adzitey & Nurul, 2011).

Chronic or long-term stress antemortem can give rise to DFD meat. The long-term stress can be due to the transportation of the animals for long distances, long hours of food deprivation, unfavourable holding conditions (overcrowding of animals in the holding pen over a long period of time) and severe weather. The high levels of stress can cause muscle glycogen levels to become depleted and cause the DFD condition in pork muscle (Extension, 2011; Adzitey & Nurul, 2011).

DFD meat results from a lack of lactic acid production in the muscles post-slaughter. The muscles have low levels of glycogen after slaughter, which limits the amount of acid that can be produced, and limits pH fall. DFD muscle usually has a final pH of above 6.0, compared to normal and PSE meat which has a pH of 5.5 (Adzitey & Nurul, 2011). The reduced acidity results in an increase in WHC of the lean meat, water is tightly bound to the muscle proteins and little or no exudates are formed, which contributes to the firm texture. The muscle cells are swollen because of the retained water and because they are so tightly packed together, more light is absorbed giving the meat its dark colour (Extension, 2011; Adzitey & Nurul, 2011).

DFD meat has short sarcomere lengths but is still swollen laterally and this results in small extracellular space, therefore DFD meat is usually tender. PSE meat has a large variation in sarcomere length (Tornberg, 1996). It is suggested that long sarcomeres of PSE meat are caused by reduced shortening, due to denaturation of the sarcoplasmic proteins during rigor. The short sarcomeres could be caused by a higher percentage of rigor development. There is a large variation in tenderness of PSE meat. PSE is more common to occur in pork and DFD meat is more frequent in beef (Tornberg, 1996).

2.5.4 Intramuscular Fat

The lipid content of muscle ranges from 1.5% to 13%. Most of these lipids are present in the adipose tissues but some of these lipids are found intracellularly in muscle fibres, this is known as marbling. Marbling is intramuscular fat that is deposited within the muscle, in a loose network of perimysial connective tissues, between the muscle bundles. Consumers rate pork with high amounts of marbling as more tender, juicy and flavourful (Arkfeld, Mohrhauser, King, Wheeler, Dilger, Shackelford & Boler, 2017).

Muscle growth slows down and bone growth stops completely as an animal ages, but fat growth continues in a well-fed animal. The total amount of marbling in muscle results from an increase in the number of marbling cells as well as the size of these cells. The cells are dispersed among several groups of fat cells, and when many of these groups merge, it looks like a seam. Therefore marbling is sometimes referred to as seam fat. The number of cells in a particular group determines the appearance of marbling, which increases with animal age (Thu, 2006). Marbling is a visual estimation of IMF (Ngapo, Riendeau, Laberge, & Fortin, 2012)

Marbling has a very important role in meat quality and has much stronger and more predictable effects on juiciness and flavour of meat than tenderness does. Marbling score has a great effect on meat tenderness and cooking quality (Thu, 2006). Marbling is usually assessed subjectively by visual assessment. Marbling scores encompass size, number, and distribution of fat particles (Qiao, Ngadi, Wang, Gariépy, & Prasher, 2007).

For the last few decades, there has been a large focus on the selection of animals with a high LMY, this has resulted in a reduction in marbling and therefore the meat has become healthier in the eyes of the consumers, but meat should contain at least 2.5% IMF otherwise the meat tends to be dry (Fernandez, Monin, Talmant, Mourot, & Lebet, 1999; Genesis, 2016). Acceptability of marbling depends from country to country. Meat produced in South Africa has very little marbling due to the consumer's preference for lean meat (Ngapo, Martin & Dransfield, 2002).

2.5.5 Fat Quality

There are four different depots with different anatomical locations that porcine fat can be deposited into, namely: visceral, subcutaneous, intermuscular (fat found between the muscles) or intramuscular (fat found within the muscle). The degree of saturation of these deposits follows a positive gradient from the inside outwards (Monziols, Bonneau, Davenel & Kouba, 2007). Intermuscular adipose tissue saturation increases from the internal to external deposition sites. The difference in the composition of the fat layers could be ascribed to an adaptation to temperature, nutrition, diet or carcass fat level. Deposition and composition of fat vary among and within different breeds and is highly heritable (Kasprzyk, 2007; Monziols, Bonneau, Davenel & Kouba, 2007).

Fat quality can be best defined by the firmness of the fat (Sosnicki, et al., 2010). The firmness and the quality of the adipose tissue depend on the ratio of fat, but to an even greater extent, both depend on the degree of fat saturation, more specifically the unsaturation of the fat (Metz, 1983). The saturation of fatty acids determines the melting point of fat. A highly saturated fat (firm fat) has a higher melting point than unsaturated fat. Typically as the degree of fatness increases, the fat becomes more saturated or firmer (Sosnicki, et al., 2010).

According to Hugo and Roodt (2007), a good quality fat can be defined as firm and white, whereas a poor quality fat is defined as soft, oily, wet, grey and floppy. The most important criteria used to determine fat quality are colour, consistency, oxidative stability, taste and percentage extractable fat. When it comes to the production of lard, the percentage of extractable fat is of economic importance. The fat tissue should contain at least 80-90% fat, in other words, there should be no "empty" fat tissues and the depot fat should be more than 15% of the total fat content (Prabucki, 1991).

Fat quality has become increasingly important in the meat industry. This is due to its effect on nutritional, sensory, and technological properties of animal products, especially regarding pork. Fat quality of meat is chemically defined in terms of FAs (Ros-Freixedes & Estany, 2013). Fat tissue is known to be an important aspect of carcass quality, in terms of meat processing and consumer acceptability (Whittington, Prescott, Wood, & Enser, 1986).

Fat acts as one of the precursors of meat flavour, by combining with AAs from proteins and other components when heated (Thu, 2006). The FA composition of pork fat influences the processing characteristics of pork and pork processors to prefer firm fat in pork products (Johnston & Li, 2011). Fats that have a high unsaturated fatty acid content have softer consistencies, lower melting points and greater susceptibility to oxidative spoilage (Wood, Jones, Francombe, & Whelehan, 1986).

According to Roodt (2003), there are a few factors influencing fat quality in pigs, namely:

- ❖ Breed or race
- ❖ PSE or DFD Conditions
- ❖ Backfat Thickness
- ❖ Age and Slaughter Weight
- ❖ Sex and Gender
- ❖ Growth Promoters
- ❖ Diet
- ❖ Environmental Temperature

Fat quality can be measured by a number of methods, namely:

Gas Chromatographic (GC) Analyses, used to separate and quantify fatty acid methyl esters in order to determine the fatty acid composition (García-Olmo, De Pedro, Garrido, Paredes, Sanabria, Santolalla, Salas, García-Hierro, Gonzalez, Gonzalez & Guirao, 2002). Factors that affect FA composition of pig muscle and adipose tissue include fatness, weight, age, energy intake, dietary FA composition, gender and genetic background (Kasprzyk, Tyra & Babicz, 2015).

The subcutaneous FA composition of industrial pigs is, 36% SFA, 44% monounsaturated fatty acids (MUFA) and 12% PUFA (Pietro Lo Fiego, Mocchioni, Minelli & Santoro, 2010). Gender has such an important effect on the FA composition due to its effect on carcass fatness. Females are leaner and have a more unsaturated FA composition than castrated males, but intact males are leaner and deposit less fat throughout their body and within their muscles. Older pigs have harder, firmer and more saturated fat, whereas younger pigs deposit more unsaturated fat and therefore have a softer fat (Ferreira, 2014).

According to (Prabucki, 1991), if the double bond index of fatty acids is less than 80, the BF will be of good quality. Research done by Enser (1983) and Honkavaara (1989) shows that stearic acid (C18:0) seems to be the most important fatty acid when it comes to the regulation of BF consistency, but when the animal is fed linoleic acid (C18:2) it results in soft fat. This shows the important relationship between dietary C18:2 and the deposition of C18:0. The C18:0/C18:2 ratio influences the backfat, a ratio above 1.2 results in firm fat and a ratio below 1.2 results in soft fat.

Iodine value (IV), is an analytical value for the addition of a halogen to a double bond. This gives an overall indication of fatty acid unsaturation (Davenel, Riaublanc, Marchal & Gandemer, 1999). Iodine value can indicate the percentage of UFA or soft fat and rancidity (Barton-Gade, 1983; Alais & Linden, 1991; Irie & Sakimoto, 1992). According to Lea, Swoboda, & Gatherum (1970), hard adipose tissues have an iodine value of less than 65 and soft adipose tissues have an iodine value of more than 70. BF used for manufacturing firm-cut sausage should have an iodine value below 60. Iodine value is negatively correlated with C18:2 and linolenic acid (C18:3) content (Whittington, Prescott, Wood, & Enser, 1986). An iodine value of below 70 is most generally considered as an indicator of good quality BF (Barton-Gade, 1983).

Refraction index (RI), which is an indication of how easily light passes through the fat. The refraction index value is affected by temperature and degree of saturation. According to Houben & Krol (1983), the refraction index of BF should be below 1.4598 for good fat quality.

The melting point and Slip point, which determines the firmness of the fat at a particular temperature. The melting point is the physical property of a fatty acid that affects quality the most (Wood, 1984). Enser (1983) stated that it is possible to use the slip point as an indicator of BF consistency and Lea, et al. (1970) used the slip point to evaluate fat quality. The melting point increases as the carbon chain become longer and decrease when more unsaturated bonds are introduced. This happens more often in the *cis* than in the *trans* form (Wood, 1984). It was observed by Enser (1983) that the variation in the melting point and the consistency of fat is strongly correlated with the C18:0 content. When C18:2

concentrations are above 15%, the fat firmness and melting point are mainly determined by using concentrations of palmitic acid (C16:0) and C18:2, rather than C18:0 (Cameron, Warris, Porter, & Enser, 1990).

The colour of the fat indicates oxidation. As oxidation advances, the oxidized fat changes from normal light yellow to an intense brownish orange (Hugo & Roodt, 2007). Yellow fat is objectionable because it is associated with inferior breeding or advanced age of the animal at the time of slaughter (Marchello & Dryden, 1968). Fat tissue in which the lipids have not completely solidified appears to have a grey or yellow colour and this is because of the capillaries containing blood, connective tissue, and carotenoid pigments which are visible (Wood, 1984). Carotenoids are the cause of the yellow colour and are mainly associated with C18:2 and C18:3 (Maw, Fowler, Hamilton, & Petchey, 2003). High content of PUFAs result in a yellow discolouration of fat, known as “yellow fat disease” (Warnants, et al., 1996)

There are several physical measures of fat hardness, these include the Instron compression test, the Durometer, the hardness meter, a texturometer, used to measure FT (Irie & Sakimoto, 1992), Penetrometers, used to measure the objective fat softness, these measurements are not as accurate as IV determination of fat softness (Bruwer, 1992), and the belly flop or belly flex test, which has been widely used to measure the degree of flex demonstrated by a pork belly that is suspended over an elevated stick. A belly that demonstrates minimal flex indicates a firmer fat (Johnston & Li, 2011).

2.5.5.1 Fatty Acid Composition

Fat and fatty acids (FA), in muscle or adipose tissue, contribute a great deal to several aspects of meat quality, such as juiciness and are essential to the nutritional value of meat (Wood, et al., 2008). FA differ from each other in length of their hydrocarbon chains and in the absence or presence of double bonds. FA that do not contain double bonds are known as SFA (Thu, 2006). The composition of fatty acids and their physical characteristics are used to determine fat quality (Kühne, 1983).

Pigs are monogastric animals and are therefore especially susceptible to changes in the FA composition of their muscle and adipose tissue (Ferreira, 2014). Dietary fats are readily converted to carcass fat, the carcass fat takes on the general

characteristics of the dietary fat. Pork fat becomes increasingly soft when pigs are fed unsaturated fats/oils (feeds high in unsaturated FA) (Seman, Barron, & Matzinger, 2013). Dietary carbohydrates are converted to body fat through de novo FA synthesis. This process results in predominantly SFA and MUFA, which yield a firmer carcass fat (Sosnicki, et al., 2010).

Fatty acid composition plays a very important role in human health and is an important factor in the nutritional quality of meat and adipose tissues and has therefore been a subject of study in meat science for a long time and has received considerable attention (Furman, Malovrh, Levart, & Kovac, 2010). Consumers, nutritionists, and food technologists are very concerned with the proper composition of FAs in meat and fat (Nürnberg, Fisher, Nürnberg, Kuechenmeister, Klosowska, Eliminowska-Wenda, Fiedler, & Ender, 2005).

Excessive intake of SFAs has been considered as the one out of many other factors for cancer and coronary heart disease (Webb & O'Neill, 2008). Not all SFA express the same behaviour as regards the increase in serum cholesterol. Stearic acid is considered a neutral fatty acid, on the other hand lauric (C12:0), myristic (C14:0) and C16:0 acids increased plasma cholesterol concentration (Ulbricht & Southgate, 1991). Furthermore, C14:0 was considered to have the most harmful cardiovascular effect on humans, the effect being almost four times the effect of C12:0 and C16:0 (Hegsted, Gotsis, Stare, & Worcester, 1959). Palmitic and stearic acids are predominant in the saturated fatty acids group in animal fat.

To promote human health, a relatively low $n-6:n-3$ ratio from an adequate intake of $n-3$ fatty acids is recommended as $n-3$ PUFAs are essential for brain development, visual sight, and the immune system (Simopoulos, 1996). Scollan, Hocquette, Nürnberg, Dannenberger, Richardson, & Malone (2006) recommended that the $n-6:n-3$ PUFA ratio be limited to 4:1. Ulbricht and Southgate (1991) suggested that the ratio of PUFAs to SFAs (P:S) should be at least 0.4 and the atherogenic index lower than 0.5. The atherogenic index indicate the global dietetic quality of lipids and their potential effects on the development of coronary disease (Jankowska, Zakes, Zmijewski, & Szczepkowski, 2010).

2.5.5.2 Oxidative Stability of Fat

Griffiths (2014) stated that oxidation of fats or oils is a complex process initiated by free radical reactions which occur at the double bonds of unsaturated FA. Therefore, an increase in the number of double bonds or degree of saturation causes an increase in the susceptibility of oxidation. Oxidation is affected by:

- ❖ Atmospheric oxygen
- ❖ Heat
- ❖ Heavy metals
- ❖ Exposure to light
- ❖ Other chemical components which initiate oxidation

These factors can promote the formation of free radicals which lead to the formation of peroxide radicals, hydroperoxides and subsequent chain reactions which lead to the formation of secondary oxidation products such as aldehydes and ketones. The secondary oxidation products are usually responsible for the undesirable rancid off-flavours (Griffiths, 2014). Storing meat at low temperatures and using packaging which excludes oxygen retards the rapid development of rancidity, but oxidation may continue even during frozen storage. Lipid oxidation affects the flavour, colour, texture and nutritional value of meat (Kemin, 2009). Long storage can result in greenish pork fat (Kropf, 2003).

Often products are considered unacceptable and are rejected by consumers due to change in flavour, with one of the most pronounced effects being rancid off-flavours caused by the oxidation of fat and oils. Lipid oxidation is one of the primary mechanisms of quality deterioration in meat products, especially during storage (Gray, Gomma, & Buckley, 1996; Kemin, 2009; Griffiths, 2014).

Lipid oxidation is measured by placing products into carefully controlled storage conditions which simulate similar conditions the product will undergo during its shelf life or even harsher conditions which will accelerate the oxidation process. The samples will be taken at set points and they will be analysed to determine the impact on the sensory quality and level of oxidation (Griffiths, 2014).

According to Griffiths (2014) some of the methods used to monitor oxidation are:

- ❖ Peroxide Value (PV) determination
- ❖ Sensory evaluation
- ❖ Anisidine Value (AV)
- ❖ Thiobarbituric Acid Reactive Substances Analysis (TBARS)
- ❖ Gas Chromatography Mass Spectrometry (GC-MS) for aldehydes
- ❖ Conjugated Dienes.

2.6 Conclusions

Consumers have become increasingly health conscious over the last few years, especially regarding the impact that diet has on health. This has caused consumers to become pickier when they buy their food and now prefer products that contain high levels of UFAs. This caused some negative consumer perceptions towards the meat industry due to meats' contribution to fat in the human diet. Pork is very popular meat consumed by many people all over the world, approximately 37% of all meat consumed globally is pork. The pork industry has responded to consumer demands by changing their production strategies in order to produce leaner, healthier meat.

Consumers make it very clear about what kind of meat they want, therefore the shops and meat product manufacturers know exactly what kind of meat they need to put on their shelves in order to make the most money. Therefore it is important for abattoirs to classify and label pork carcasses in order to inform the buyers of the carcass properties. In South Africa, the PORCUS system is used to classify pig carcasses. The PORCUS system uses carcass measurements, which are taken by specific probes, to sort pigs into the different classification groups. These probes use the measurements that they take and put them in an equation which was derived by Bruwer in 1992.

The composition of pigs has changed drastically since 1992. Pig carcasses have become heavier and leaner, but irrespective of this the same classification system is still being used. In the past, it was very rare to find a pig carcass that weighed more than 90kg, but today they are frequently found. Therefore the current pork classification system used in South Africa needs to be revised, in order to determine if the probes used still classify the pigs correctly, especially the heavier carcasses which exceed 90kg.

CHAPTER 3

MATERIALS AND METHODS

3.1 Sampling

To ensure a representative sample of the South African pig population, selection of carcasses was done at the following major abattoirs in South Africa: Enterprise Pork Packers (Olifantsfontein), Eskort (Heidelberg), Lynca (Meyerton), Frey's Cato Ridge (Pietermaritzburg) and Winelands (Western Cape). These abattoirs represent the major geographical areas in South Africa and are the abattoirs with the highest throughput in South Africa. Carcasses were selected based on their classification group (PORCUS), shown in Table 3.1, and based on their weight groups within these classification groups.

Table 3.1: Classification Characteristics of Pork (SAMIC, 2006)

<i>Class</i>	<i>Calculated % meat of carcass based on measured fat and muscle thickness at a certain point</i>	<i>Fat thickness measured by means of an intrascope (mm)</i>
<i>P</i>	≥ 70	≤ 12
<i>O</i>	68-69	13-17
<i>R</i>	66-67	18-22
<i>C</i>	64-65	23-27
<i>U</i>	62-63	28-32
<i>S</i>	≤ 61	> 32

It was decided that pig carcasses from the C, U, and S classification groups were excluded from the trial because of the low percentage of their occurrence. Over a period of three months, a total of 97 pig carcasses were sampled from the P, O, and R classification groups.

Although weight class is not part of the official South African meat classification system, the meat industry devised and use the following weight classes that were also used in this study, namely:

- ❖ S: Sausage Pigs - ≥ 100 kg
- ❖ H: Pork Heavies - $\pm 90-99$ kg
- ❖ V: Heavy Baconer – $\pm 80-90$ kg

- ❖ W: Baconer - \pm 70-79kg
- ❖ X: Heavy Porker/ Pork Cutters - \pm 55-69kg

The number of visits to abattoirs is shown in Table 3.2. The most carcasses were selected at the Eskort abattoir because there was a wide variety of pigs to choose from the different classification groups. Unequal numbers were collected at different abattoirs due to the fact that certain class/weight combinations could not be found at certain abattoirs. Winelands was only visited once due to logistical difficulties and restrictions placed on the ARC due to the way the carcasses were collected with the rented cool truck and the carcasses were transported on a slatted floor instead of in a hanging position. Although this process was perfectly sound with regards to hygiene, it was against the abattoir safety and hygiene protocol.

Table 3.2: Number of visits to abattoirs and carcasses selected

Abattoir	Location	Number of visits	Number of carcasses
Enterprise Pork Packers	Olifantsfontein	1	12
Eskort	Heidelberg	4	37
Frey's Cato-Ridge	Meyerton	2	24
Lynca	Pietermaritzburg	1	12
Winelands Pork	Western Cape	1	12

For two of the yield classes namely, P and O, carcasses were selected in each of the weight categories mentioned, as far as it was practically feasible. The P and O yield classes were selected after obtaining percentages of yield classes slaughtered from industry. The R classification group was represented in just the three heavier weight groups namely, Heavy Baconers (V) Pork Heavies (H) and Sausage Pigs (S). According to the information provided, the R class made up just 4% of total animals slaughtered and the numbers in some of the lower weight groups were negligible.

The objective was to obtain eight carcasses from each the following groups: PX, PW, PV, PH, OX, OW, OV, OH, OS, RV, RH and RS. It was not possible to obtain certain carcasses because they were not available at all the abattoirs. This is not a problem, because there is no abattoir effect on carcass classification because they all use the same probe. Therefore it is not of major concern that the groups were not balanced

across the abattoirs, because the objective was more about obtaining pigs from across the country to be representative. Table 3.3 shows the distribution of pigs selected in the different weight classes. Most of the pigs collected were from the P, O, classification groups and the sausage weight group, because at all of the abattoirs there was an abundance of these pigs.

Table 3.3: Yield and weight classes of carcasses selected from the various abattoirs

Abattoir (kg)	Class and Weight										
	PX 55-69	PW 70-79	PV 80-89	PH 90-99	OX 55-69	OW 70-79	OV 80-89	OH 90-99	RV 80-89	RH 90-99	Sausage >100
Enterprise Pork Packers	0	0	3	3	0	1	2	2	1	0	0
Eskort Heidelberg	4	4	1	2	5	3	2	2	3	4	7
Frey's Cato Ridge	4	2	2	0	3	2	2	1	4	4	0
Lynca	0	0	0	0	0	0	0	0	0	0	12
Winelands Pork	0	2	2	2	0	2	2	2	0	0	0
Total	8	8	8	7	8	8	8	7	8	8	19

The carcasses were halved and the right side was cut up into different wholesale cuts, namely: shank, leg, chump, loin, belly, thick rib and rib, as described by Bruwer (1992). Wholesale cuts were dissected into skin, bones, fat and lean meat (and trimmings where applicable). The weights were determined at each stage of the cutting up and dissection. The head and kidney fat was removed.

3.2 Carcass Processing

The head was weighed and calculations were made both with and without the head, trotters, tail, kidney and kidney fat. A back fat (BF), fat and *M. longissimus lumborum* muscle sample was taken from each pig and stored at -18°C until they were analysed.

Figure 3.1 shows the sampling point where the two chops (30 cm) were cut from the *M. longissimus lumborum* muscle and used for colour and drip loss/purge analyses.

3.3. Meat Quality Analyses

3.3.1 Colour Determination

One chop was used to perform instrumental colour on fresh meat and fat with a Minolta colour meter (Model CR200, Osaka, Japan) following the CIE colour convention (CIE,

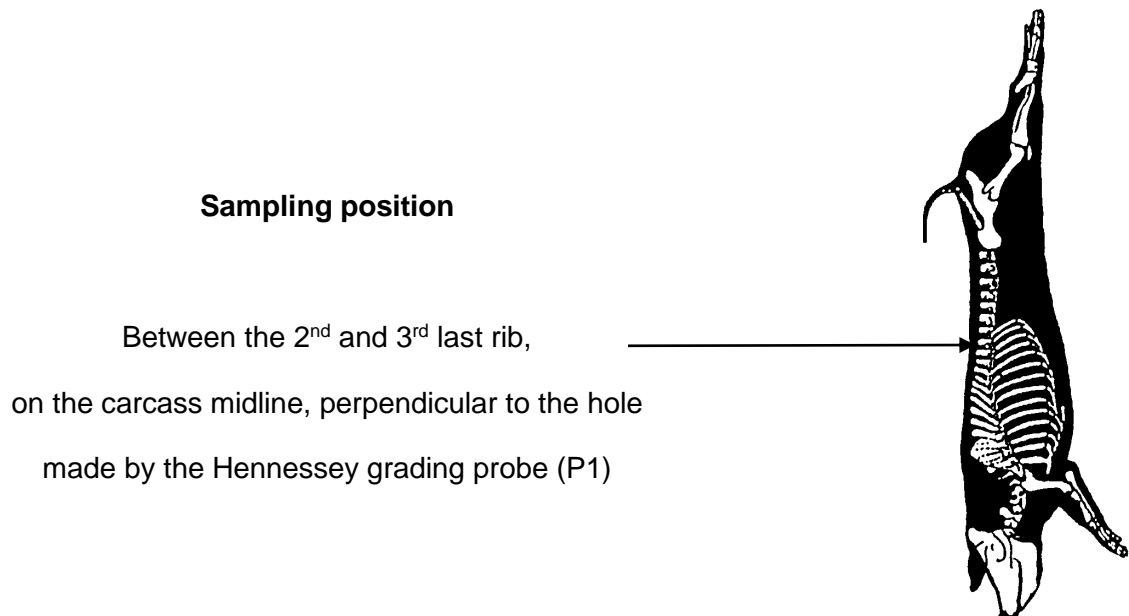


Figure 3.1: Schematic representation of a pig carcass, showing the sampling position.

1986), where the three fundamental outputs are L^* , a^* and b^* . L^* is lightness on a scale of 0 (all light absorbed) to 100 (all light reflected); a^* represent red to green which spans from +60 (red) to -60 (green) and b^* represent yellow to blue spanning from +60 (yellow) to -60 (blue) (MacDougall, 1977).

The hue angle is defined as $\tan^{-1}(b/a)$ and describes the fundamental colour of a substance and chroma or saturation index (SI) which is related to colour intensity of meat and describes the vividness (MacDougall, 1977), was calculated according to the formula: $SI = (a^{*2} + b^{*2})^{0.5}$ for muscle. Hue angle was calculated according to the formula $\tan^{-1}(b^*/a^*)$ (Ripoll, Joy, & Muñoz, 2011). Values for chroma (S) higher than 20 relate to the bright red colour of bloomed meat and $S=18$, $S=14$ and $S<12$, as dull, distinctly brown and brown to grey-greenish brown respectively (MacDougall, 1977).

3.3.2 Drip Loss Determination

A 30 cm chop was cut from the *M. longissimus lumborum* and sliced into 3cm x 3cm x 3cm cubes. Each cube was weighed and hung onto a pin, secured to the cap, inside a sample bottle (200 ml), ensuring that the meat did not touch the sides of the bottle.

This was done in triplicate for each pig and the average drip loss of the three pieces of meat was used to determine the drip loss of that specific pig. The samples were stored for 3 days at $4\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$. The amount of drip loss was measured as the difference between the sample mass before and after the three day storage period. Drip loss was expressed as a percentage of the starting mass.

3.4 Lipid Analyses

3.4.1 Lipid Extraction

Total lipid from approximately 1 g of BF and 5 g from the *M. longissimus lumborum* was quantitatively extracted, according to the method of Folch, Lees, & Sloane-Stanley (1957), using chloroform and methanol in a ratio of 2:1. An antioxidant, butylated hydroxytoluene was added at a concentration of 0.001 % to the chloroform:methanol mixture. A rotary evaporator was used to dry the fat extracts under vacuum and the extracts were also dried overnight in a vacuum oven at 50°C , using phosphorus pentoxide as moisture adsorbent.

Total extractable fat content (EFC) was determined by weighing and expressed as %fat (w/w) per 100 g tissue. The fat free dry matter (FFDM) content was determined by weighing the residue on a pre-weighed filter paper used for Folch extraction after drying. By determining the difference in weight, the FFDM could be expressed as %FFDM (w/w) per 100 g tissue.

The moisture content of the BF was determined by subtraction ($100 - \% \text{fat} - \% \text{FFDM}$) and expressed as %moisture (w/w) per 100 g tissue. The extracted fat was stored in a polytop (glass vial, with push-in top) under a blanket of nitrogen and frozen at -20°C until further analyses.

3.4.2 Iodine Value and Refraction Index Determination

A sample of 0.5 g lipid, extracted by the Folch et al. (1957) method, was used to determine the Hanus iodine value (IV; AOAC, 2005; method nr. 920.158) of backfat. Iodine value was expressed as the number of grams iodine absorbed by 100 g fat, which indicates the unsaturation of the fat.

Extracted fat was also used to determine the refraction index value (RI; AOAC, 2005; method nr. 921.08), with an Atago 5000a Refractometer (Atago Co. Ltd, Japan). Three drops of extracted fat (from Folch extraction) were placed on the glass surface in the sample chamber by means of a disposable glass Pasteur pipette. The glass surface of the machine was cleaned with ethanol and dried with a clean piece of tissue paper in between each reading. Triplicate readings of RI-values were made at a temperature of 40 °C and an average value was obtained for each sample.

3.4.3 Fatty Acid Analysis

Approximately 25 mg of total lipid (from Folch extraction) was transferred into a teflon-lined screw-top test tube by means of a disposable glass Pasteur pipette. Fatty acid methyl esters (FAME) were prepared for GC analysis by methylation of the extracted fat, using methanol-BF₃ (Slover & Lanza, 1979; Alfaia, Castro, Martins, Portugal, Alves, Fontes, Bessa & Prates, 2007). Fatty acid methyl esters were quantified using a Varian 430 flame ionization GC, with a fused silica capillary column, Chrompack CPSIL 88 (100 m length, 0.25 mm ID, 0.2 mm film thickness).

Column temperature was 40–230°C (hold 2 minutes; 4°C/minute; hold 10 minutes). Fatty acid methyl esters in hexane (1 µl) were injected into the column using a Varian CP 8400 Autosampler with a split ratio of 100:1. The injection port and detector were both maintained at 250°C. Hydrogen, at 45 psi, functioned as the carrier gas, while nitrogen was employed as the makeup gas. Galaxie Chromatography Software recorded the chromatograms. Fatty acid methyl ester samples were identified by comparing the relative retention times of FAME peaks from samples with those of standards obtained from SIGMA (189-19). Fatty acids were expressed as the relative percentage of each individual FA as a percentage of the total of all FA present in the sample.

Fatty acid data was used to calculate the following ratios of fatty acids: C18:0/C18:2; total MUFA;; total SFA; total PUFA; PUFA/MUFA; PUFA/SFA; the ratio of omega-6 to omega-3 (n-6)/(n-3) fatty acids. Double bond index (DBI) was calculated as: $DBI = \sum (\% \text{ of UFA} \times \text{number of double bonds of each UFA})$ (Alam, & Alam, 1986). Peroxidizability index (PI) was calculated as: $PI = [(\% \text{ Monoenoic} \times 0.025) + (\% \text{ Dienoic} \times 1) + (\% \text{ Trienoic} \times 2) + (\% \text{ Tetraenoic} \times 4) + (\% \text{ Pentaenoic} \times 6) + (\% \text{ Hexaenoic} \times 8)]$

(Pamplona, Portero-Otín, Riba, Ruiz, Prat, Bellmut, & Barja, 1998). Atherogenicity index was calculated as: $AI = (C12:0 + 4 \times C14:0 + C16:0)/(MUFA + PUFA)$ (Chilliard, Ferlay, Rouel, & Lambere, 2003).

3.5 Reagents

All other reagents and solvents were of analytical grade and obtained from Merck Chemicals (Pty, Ltd, Halfway House, Johannesburg, South Africa).

3.6 Hennessy Grading Probe Calculations

The regression model developed by Bruwer in 1992 to predict lean meat is as follows:

$$\text{Lean meat \%} = 72.5114 - 0.46118 X1 + 0.0547X2$$

Where X1 and X2 = fat thickness and muscle thickness between 2nd and 3rd last rib, 45 mm from the midline.

Accuracy of the HGP to sort carcasses into P, O and R was tested against actual meat yield. Distribution of correct, underscored and over scored carcasses based on actual determination of meat yield were calculated and related to weight classes.

Regression analyses were used to determine the accuracy of the current regression formula (P, O and R as x variables) to predict true meat yield (y). The true fat and muscle thickness values for the warm carcass as measured by the HGP was obtained and this was used to generate a possible regression to predict meat yield.

3.7 Statistical Analysis

Pearson's correlation analysis was performed between selected meat quality parameters and predicted meat yield by HGP and actual meat yield by dissection to determine which yield expression method is the best correlated with meat quality characteristics (NCSS, 2016). Multiple regression (XLSTAT, 2018) with Y = % meat yield by dissection and fat thickness and muscle thickness as x₁ and x₂ respectively was performed to develop a new formula to predict lean meat content with the HGP.

Scatterplots (XLSTAT, 2018) of % actual meat predicted by dissection versus % meat predicted with old and new HGP equations were constructed. One-way Analysis of

Variance (ANOVA) was performed to determine significant differences in meat quality parameters in yield classes and weight classes (NCSS, 2016).

The Tukey-Kramer multiple comparison test ($\alpha = 0.05$) was carried out to identify significant differences between the treatment means (NCSS, 2016). It was not possible to statistically analyze the interaction between yield groups and weight groups since pork carcasses of all weight groups was not available within each yield group. Selected meat and fat quality parameters of yield groups were visualized in a 2-dimensional space by principal component analysis (PCA) (XLSTAT, 2018).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Relationship between meat yield by HGP, meat yield by dissection, carcass classification measurements and meat quality parameters

Pearson correlation coefficients between carcass classifications measurements are indicated in Table 4.1 and it was found that carcass mass was positively, although weakly, correlated with FT by HGP ($r = 0.5422$; $p < 0.001$) and with muscle thickness by HGP ($r = 0.2561$; $p < 0.05$), this means that as the carcass mass increased, the FT and muscle thickness by HGP increased. Carcass mass was negatively correlated with % meat yield by HGP ($r = -0.3736$; $p < 0.01$) and % true meat yield by dissection ($r = -0.5374$; $p < 0.001$). This means that as the carcass mass increased the predicted meat yield by HGP and % true meat yield by dissection decreased. The correlation coefficient between carcass mass and % true meat yield by dissection was better than between carcass mass and % meat yield by HGP (Table 4.1).

Table 4.1: Pearson correlation coefficients between carcass classification measurements.

	Carcass Mass (kg)	Fat Thickness by HGP(mm)	Muscle Thickness by HGP(mm)	% Predicted Meat yield by HGP	% True meat yield by dissection
Carcass Mass (kg)	1.0000	0.5422***	0.2561*	-0.3736**	-0.5374***
Fat Thickness by HGP(mm)		1.0000	0.3190**	-0.7895***	-0.7199***
Muscle Thickness by HGP (mm)			1.0000	0.3297**	-0.2643*
% Predicted Meat yield by HGP				1.0000	0.5447***
% True meat yield by dissection					1.000

* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

Table 4.1 shows that there was a positive correlation between FT by HGP and muscle thickness by HGP ($r = 0.3190$; $p < 0.01$) and there was a strong, negative correlation between FT by HGP and % meat yield by HGP ($r = -0.7895$; $p < 0.001$) and % true meat yield by dissection ($r = -0.7199$; $p < 0.001$). This means that as the FT by HGP increased, the muscle thickness by HGP increased and the % predicted meat yield by HGP and % true meat by dissection decreased. Muscle thickness by HGP was positively correlated with % predicted meat yield by HGP ($r = 0.3297$; $p < 0.01$) and

negatively correlated with % true meat by dissection ($r = -0.2643$; $p < 0.05$). This means that as the muscle thickness by HGP increased, the % predicted meat yield by HGP increased and the % true meat yield by dissection decreased. This observation can probably be ascribed to the over prediction of the meat yield by the HGP.

The WHC of meat can be defined as the ability of the meat to retain water when external pressures are applied to it. One of the most common pork quality defects are high moisture loss or drip loss. The complete system of pork production and the handling of the carcass through initial chilling and the storage and handling of the meat play a very important role in influencing the amount of drip loss from the meat products (Kauffman, Cassens, Scherer, & Meeker, 1992).

From Table 4.2 it is clear that the drip loss from the muscle was negatively correlated ($r = -0.3974$; $p < 0.001$) with the muscle thickness by HGP. In other words, the thicker the muscle is, the less drip loss there will be. This may be due to the muscle taking longer to cool down and therefore there is less protein denaturation and thus less drip loss (Ngapo, Babare, Reynolds, & Mawson, 1999). However, the drip loss was positively correlated ($r = 0.3644$; $p < 0.01$) with % true meat yield by dissection. This indicates that there was more drip loss when the carcass yielded more meat, which is in contrast with the negative correlation between drip loss and muscle thickness by HGP, this indicates that muscle thickness is not linked to drip loss. Meat colour parameters were not significantly correlated with any of the meat classification parameters.

Intramuscular fat was positively correlated ($r = 0.3596$; $p < 0.01$) with the FT by HGP, implicating that the more fat there is according to the HGP, the more IMF there will be (Table 4.2). The IMF was negatively correlated with the % meat yield by HGP ($r = -0.3391$; $p < 0.01$) and with the % true meat yield by dissection ($r = -0.4649$; $p < 0.001$), this implicates that as the % of meat in the carcass increased, the % of IMF decreased. Pietruszka, Jacyno, Kawecka & Biel (2015) also found that pigs which had a high amount of IMF had a significantly lower percentage of lean meat.

Table 4.3 indicates Pearson correlation coefficients between carcass classification measurements and proximate composition and chemical and physical properties of backfat. Highly significant correlations ($p < 0.001$) were observed between all the

Table 4.2: Pearson correlation coefficients between carcass classification measurements and selected meat quality parameters.

	Carcass mass (kg)	Fat thickness by HGP (mm)	Muscle thickness by HGP (mm)	% Meat yield by HGP	% True meat yield by dissection
Drip loss from muscle (%)	0.0019 ^{NS}	-0.1427 ^{NS}	-0.3974 ^{***}	-0.1163 ^{NS}	0.3644 ^{**}
Muscle colour: L*	-0.0440 ^{NS}	0.0517 ^{NS}	-0.1438 ^{NS}	-0.1440 ^{NS}	0.1270 ^{NS}
Muscle colour: a*	0.0585 ^{NS}	0.0841 ^{NS}	0.0847 ^{NS}	-0.0287 ^{NS}	0.0050 ^{NS}
Muscle colour: b*	0.0525 ^{NS}	0.1457 ^{NS}	-0.0507 ^{NS}	-0.1778 ^{NS}	0.0163 ^{NS}
Muscle colour: Chroma	0.0589 ^{NS}	0.1175 ^{NS}	0.0223 ^{NS}	-0.1025 ^{NS}	0.0109 ^{NS}
Muscle colour: Hue	0.0039 ^{NS}	0.0702 ^{NS}	-0.2585 [*]	-0.2373 ^{NS}	0.0784 ^{NS}
Intramuscular fat (%)	0.2572 [*]	0.3596 ^{**}	0.0283 ^{NS}	-0.3391 ^{**}	-0.4649 ^{***}

^{NS} = Not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

parameters and the % true meat yield by dissection. The extractable fat was negatively correlated with % meat yield by HGP ($r = -0.4263$; $p < 0.001$) and % true meat yield by dissection ($r = -0.7552$; $p < 0.001$). This means that the higher the meat yield, the lower the % of extractable fat. The % FFDM, % Moisture, IV and RI all had a negative correlation with carcass mass and FT by HGP and positive correlations with % meat yield by HGP and % true meat yield by dissection.

Table 4.3: Pearson correlation coefficients between carcass classification measurements and proximate composition and chemical and physical properties of backfat.

	Carcass mass (kg)	Fat thickness by HGP (mm)	Muscle thickness by HGP (mm)	% Meat yield by HGP	% True meat yield by dissection
Proximate analysis:					
% Extractable Fat	0.5170 ^{***}	0.5042 ^{***}	0.1139 ^{NS}	-0.4263 ^{***}	-0.7552 ^{***}
% Fat Free Dry Matter	-0.5029 ^{***}	-0.4144 ^{***}	-0.1367 ^{NS}	0.3225 ^{**}	0.5388 ^{***}
% Moisture	-0.4015 ^{***}	-0.4310 ^{***}	-0.0709 ^{NS}	0.3817 ^{**}	0.6825 ^{***}
Chemical and physical properties of backfat:					
Iodine value	-0.2417 [*]	-0.4928 ^{***}	-0.3548 ^{**}	0.2605 [*]	0.5575 ^{***}
Refraction index	-0.3127 ^{**}	-0.5272 ^{***}	-0.3173 ^{**}	0.3193 ^{**}	0.6923 ^{***}

^{NS} = Not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

Pearson correlation coefficients between carcass classification measurements and prominent fatty acids in BF in Table 4.4 shows that some FA such as C14:0, Oleic acid (C18:1 c 9), linoleic acid (C18:2) and Alpha (α) - linolenic acid (C18:3 n -3), had more significant correlations with the % true meat yield by dissection, in comparison to the % meat yield by HGP. However, in some cases like C16:0, C18:0 and arachidonic acid (C20:4) there were strong, significant ($p < 0.001$) correlations between the

carcass classification measurements and both the % meat yield by HGP and % true meat yield by dissection.

In some cases such as the and C18:1c9 and C18:2, there were no significant correlation between the classification measurements and the % meat yield by HGP, but there were strong and significant correlations between the classification measurements and the % true meat yield by dissection (Table 4.4). There are however some exceptions, such as palmitoleic acid (C16:1c9) and vaccenic acid (C18:1c7), where the correlations between the classification measurements and % meat yield by HGP were significant ($p < 0.05$) but they were not significant for the % true meat yield by dissection, but these correlations were not very strong.

The same scenario was observed when looking at the fatty acid ratios in Table 4.5. There were more significant correlations between carcass classification measurements and % meat yield by dissection in comparison to the % meat yield by HGP when it came to the PUFA/SFA, $n-6/n-3$ and C18:0/C18:2 ratios and the DBI. The total PUFA, total omega-6 ($n-6$) FA, PUFA/MUFA ratio and the peroxidizability index had strong correlations with the % true meat yield by dissection ($p < 0.001$), but the correlations with the % meat yield by HGP were not significant.

Table 4.1 to Table 4.5 shows us that in general the % true meat yield by dissection gave better correlations with most of the parameters in comparison with the % meat yield predicted by the HGP, which was an indication that the HGP predictions of meat yield are no longer a good predictor of meat quality. This confirmed that it was time to urgently revisit the formula used to predict the meat content of pig carcasses.

The HGP was introduced in South African Abattoirs in 1992, based on research done by Bruwer (1992). The HGP takes carcass measurements between the 2nd and 3rd last ribs, 45mm from the back midline while the carcass is still hanging. The measurements are then used to calculate the %LM in the carcass. The problem we are facing is that the composition of pork has changed since 1992, but the formula used to predict meat content have remained the same (Siebrits, et al., 2012).

From the Pearson correlations and Table 4.6 it is evident that these formula is no longer valid. The pigs were dissected and reclassified based on the true LMC by dissection and it was found that in actual fact, from the 97 pigs that we collected, there were only 39 pigs that fell under classification group P, 38 pigs were O's and 20 pigs

were R's and there were in fact pigs which fell under the C, U, and S classification group. This shows us that only 25.7% of the pigs were correctly classified with the HGP. The HGP predictions are clearly no longer valid. The meat quality work for the rest of the project was therefore done on the new yield groups based on the dissection data rather than on the yield groups based on the old HGP predictions of yield, due to the fact that the old HGP formulas are no longer valid and accurate.

Table 4.6: Evaluation of the correctness of classification of pig carcasses in the different classification groups with the HGP.

Class	Number of pigs per class according to HGP	Number of pigs per class based on true lean yield by dissection	Number of pigs correctly classified	% Of pigs per class correctly classified with HGP
P	39	19	13	33.3
O	38	23	7	18.4
R	20	19	5	25.0
C	0	19	0	0
U	0	10	0	0
S	0	7	0	0
All pigs	97	97	25	25.7

4.2 Multiple Regression Analysis

Multiple regression with Y = % meat yield by dissection and fat thickness and muscle thickness as x_1 and x_2 respectively was performed (NCSS, 2016).

Multiple regression analysis produced the new equation as (Figure 4.1):

$$\% \text{ Meat} = 77.2281 - (0.9478 \times \text{fat thickness}) + (0.0263 \times \text{muscle thickness})$$

$$R^2 = 0.62; \text{RSD} = 2.26\%; n = 240$$

In contrast to the old 1992 equation calculated by Bruwer as:

$$\% \text{ Meat} = 72.5114 - (0.4618 \times \text{fat thickness}) + (0.0547 \times \text{muscle thickness})$$

$$R^2 = 0.71; \text{RSD} = 1.23\%, n = 97$$

Scatterplots of % actual meat predicted by dissection versus % Meat predicted with old and new HGP equations are depicted in Figure 4.1. From this Figure it is clear that the HGP over-predicts the lean yield with Bruwer's, 1992 equation. This clearly emphasize the necessity of a re-evaluation of the formula for % Lean Meat prediction.

Table 4.4: Pearson correlation coefficients between carcass classification measurements and fatty acid profile in backfat.

	Carcass mass (kg)	Fat thickness by HGP (mm)	Muscle thickness by HGP (mm)	% Meat yield by HGP	% True meat yield by dissection
Fatty acid composition					
C14:0	0.0800 ^{NS}	0.2243 ^{NS}	0.2512 [*]	-0.0601 ^{NS}	-0.2561 [*]
C16:0	0.3004 [*]	0.5683 ^{***}	0.2653 [*]	-0.3935 ^{***}	-0.6662 ^{***}
C16:1c9	-0.0234 ^{NS}	0.0501 ^{NS}	0.4589 ^{***}	0.2476 [*]	-0.0325 ^{NS}
C18:0	0.2509 [*]	0.3704 ^{**}	-0.1416 ^{NS}	-0.4606 ^{***}	-0.4398 ^{***}
C18:1c9	0.0637 ^{NS}	0.1552 ^{NS}	0.4944 ^{***}	0.1654 ^{NS}	-0.3542 ^{**}
C18:1c7	-0.0693 ^{NS}	-0.0239 ^{NS}	0.3829 ^{**}	0.2717 [*]	-0.1325 ^{NS}
C18:2c9,12 (n-6)	-0.2452 [*]	-0.4672 ^{***}	-0.4039 ^{***}	0.2036 ^{NS}	0.6522 ^{***}
C18:3c9,12,15 (n-3)	0.0254 ^{NS}	-0.2133 ^{NS}	-0.3898 ^{**}	-0.0399 ^{NS}	0.2815 [*]
C20:4c5,8,11,14 (n-6)	-0.3648 ^{**}	-0.5305 ^{***}	0.0303 ^{NS}	0.5479 ^{***}	0.7017 ^{***}

^{NS} = Not significant; ^{*} = p < 0.05; ^{**} p < 0.01; ^{***} p = < 0.001

Table 4.5: Pearson correlation coefficients between carcass classification measurements and fatty acid ratios in backfat.

	Carcass mass (kg)	Fat thickness by HGP (mm)	Muscle thickness by HGP (mm)	% Meat yield by HGP	% True meat yield by dissection
Fatty acid ratios with health implications:					
Total SFA	0.3148**	0.5566***	0.1162 ^{NS}	-0.4787***	-0.6522***
Total MUFA	0.0196 ^{NS}	0.1117 ^{NS}	0.5466***	0.2426*	-0.2956*
Total PUFA	-0.2366 ^{NS}	-0.4648***	-0.4119***	0.1959 ^{NS}	0.6437***
Total Omega- 6 Fatty Acids (n-6)	-0.2513*	-0.4738***	-0.4052***	0.2093 ^{NS}	0.6580***
Total Omega- 3 Fatty Acids (n-3)	0.0142 ^{NS}	-0.2297 ^{NS}	-0.3958***	-0.0275 ^{NS}	0.2941*
PUFA/SFA	-0.2792*	-0.5070***	-0.3331**	0.2889*	0.6660***
PUFA/MUFA	-0.2048 ^{NS}	-0.4004***	-0.4693***	0.0946 ^{NS}	0.5992***
n-6/n-3	-0.3427**	-0.3518**	-0.0388 ^{NS}	0.3249**	0.4570***
Atherogenicity index	0.2885*	0.5576***	0.2374 ^{NS}	-0.4010***	-0.6529***
Fatty acid ratios with technological implications:					
C18:0/C18:2	0.2453*	0.5159***	0.2484*	-0.3529**	-0.6552***
Double bond index	-0.2769*	-0.5261***	-0.3082*	0.3241**	0.6772***
Peroxidizability Index	-0.2339 ^{NS}	-0.4693***	-0.4047***	0.2051 ^{NS}	0.6452***

^{NS} = Not significant; * = p < 0.05; ** = p < 0.01; *** p = < 0.001

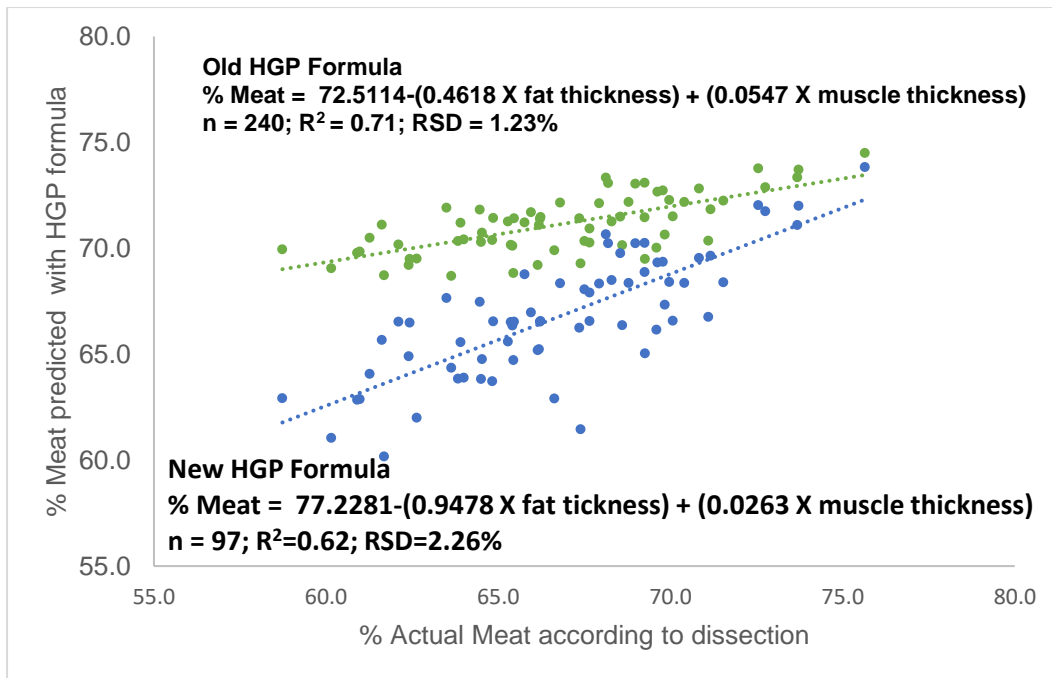


Figure 4.1: Scatterplots of % actual meat predicted by dissection versus % Meat predicted with old and new HGP equations.

According to the 1992 (Bruwer) equation, there is a 0.46 % units decrease in meat yield with every 1 mm increase in FT. According to the new recalculated equation, there is a 0.95 % units decrease in lean yield with every 1 mm increase in FT. The reason is the difference in the slope of the regression line. This is probably the reason why LMY is overpredicted with the use of Bruwer's 1992 equation on today's carcasses especially in fat carcasses. The new equation gives better predictions, but the specific point of measurement may need to change.

The old formula had an R^2 value of 0.71 compared to the R^2 value of 0.62 for the new formula. The reason for that is that Bruwer used 240 pigs in his 1992 study compared to the 97 pigs used in the current study and Bruwer included gender and genotype in his study. The over prediction of the meat by the HGP is due to the change in the carcass composition and this has led to the carcasses not falling within the acceptable range where the HGP can predict the meat yield correctly.

4.3 Yield Groups

Carcass composition and yields of different carcass cuts and parts according to yield class or classification after reclassification based on meat yield by dissection groups are shown in Table 4.7. The carcass weights of classification groups P and O were significantly ($p < 0.001$) lower than classification group R, C, and S when the head,

trotters, kidney, kidney fat and tail were included. A similar trend could be seen when the head, trotters, kidney, kidney fat and tail were excluded, the carcass weight of classification group P was significantly ($p < 0.001$) lower than classification group R, C, and S and classification group O only differed significantly ($p < 0.001$) from classification group S. Pig carcasses from the 55-69kg weight group of classification group R were excluded from the trial, due to a lack of availability of these carcasses, it was therefore expected that the R classification groups would have higher weights.

The kidney %, kidney fat %, belly %, loin %, fore shin %, leg % and fore trotter % were all significantly affected by yield class (Table 4.7). The kidney % decreased as the LM% decreased and the BFT increased. The kidney % of classification group P (0.40%) and O (0.39%) were significantly ($p = 0.003$) higher than classification group S (0.32%). The kidney fat % tends to increase as the LM% increased and the BFT increased. In other words, there is more fat surrounding the kidneys of heavier pigs. The kidney fat % of classification group P and O were significantly ($p < 0.001$) lower than that of classification group R, C, U, and S.

The belly % increased from classification group P (12.29%) to S (14.01%) (Table 4.7). This means that the % that the belly makes up of the carcass increased as the LM% decreased and the BFT increased. The belly % of classification group P and O was significantly ($p < 0.001$) lower than that of classification groups C, U, and S. The belly % of classification group R (12.75%) was significantly ($p < 0.001$) lower than that of groups U (13.90%) and S (14.01%). The loin % of classification group P (7.32%) was significantly ($p = 0.005$) lower than classification groups R (7.79%) and C (7.80%). The fore shin % of classification group P was significantly ($p < 0.001$) higher than the % fore shin of classification group R, U, and S.

The leg and thick rib made up the highest % of the pork carcasses in all the classification groups (Table 4.7). The loin, belly and leg are the most expensive cuts of the pig carcass (USDA, 2011), and it is interesting to note that the % belly increased and the % leg decreased as the LM % decreased and the BFT increased. Therefore it would be better for retailers to buy carcasses from the S classification group if they wish to make a profit from the belly cut and P classification group carcasses if they wish to make a profit from leg cut. The % leg of classification group P is significantly ($p < 0.001$) higher than the % leg of classification groups R, C, U, and S. The % leg of

Table 4.7: Carcass composition and yields of different carcass cuts and parts according to yield class.

	Yield class						Sign. level
	P (n = 19)	O (n = 23)	R (n = 19)	C (n = 19)	U (n = 10)	S (n = 7)	
Carcass weight (kg)¹	75.79 ^a ± 10.31	78.99 ^a ± 12.93	89.60 ^b ± 12.29	91.29 ^b ± 12.42	89.05 ^{ab} ± 10.67	92.65 ^b ± 8.73	p < 0.001
Head (%)	8.05 ± 0.48	7.73 ± 0.43	7.81 ± 0.53	7.70 ± 0.59	7.71 ± 0.43	7.79 ± 0.39	p = 0.283
Kidney (%)	0.40 ^b ± 0.06	0.39 ^b ± 0.05	0.38 ^{ab} ± 0.05	0.36 ^{ab} ± 0.06	0.35 ^{ab} ± 0.06	0.32 ^a ± 0.05	p = 0.003
Kidney fat (%)	1.11 ^a ± 0.22	1.20 ^a ± 0.21	1.45 ^b ± 0.29	1.59 ^b ± 0.38	1.68 ^b ± 0.31	1.60 ^b ± 0.06	p < 0.001
Tail (%)	0.24 ± 0.08	0.24 ± 0.07	0.23 ± 0.07	0.21 ± 0.05	0.24 ± 0.07	0.27 ± 0.06	p = 0.450
Belly (%)	12.29 ^a ± 1.00	12.63 ^a ± 0.60	12.75 ^{ab} ± 1.05	13.59 ^{bc} ± 0.83	13.90 ^c ± 1.13	14.01 ^c ± 1.18	p < 0.001
Rib (%)	9.44 ± 0.69	9.45 ± 0.57	9.51 ± 0.88	9.48 ± 0.58	9.87 ± 0.75	10.00 ± 0.74	p = 0.293
Loin (%)	7.32 ^a ± 0.42	7.57 ^{ab} ± 0.45	7.79 ^b ± 0.35	7.80 ^b ± 0.46	7.78 ^{ab} ± 0.44	7.79 ^{ab} ± 0.42	p = 0.005
Chump (%)	8.44 ± 0.53	8.45 ± 0.54	8.68 ± 0.59	8.49 ± 0.54	8.35 ± 0.41	8.50 ± 0.62	p = 0.643
Thick rib (%)	26.47 ± 1.16	26.40 ± 1.02	26.55 ± 0.98	25.86 ± 1.07	26.00 ± 1.06	25.82 ± 1.58	p = 0.271
Fore shin (%)	3.01 ^c ± 0.32	2.85 ^{bc} ± 0.29	2.69 ^{ab} ± 0.33	2.76 ^{abc} ± 0.29	2.64 ^{ab} ± 0.20	2.45 ^a ± 0.21	p < 0.001
Back shin (%)	1.74 ± 0.19	1.67 ± 0.19	1.69 ± 0.14	1.63 ± 0.19	1.65 ± 0.17	1.68 ± 0.12	p = 0.533
Leg (%)	19.20 ^c ± 0.66	19.00 ^{bc} ± 0.54	18.41 ^{ab} ± 0.75	18.27 ^a ± 0.85	17.80 ^a ± 0.79	17.79 ^a ± 0.73	p < 0.001
Fore trotters (%)	1.16 ^b ± 0.12	1.11 ^{ab} ± 0.10	1.05 ^a ± 0.09	1.05 ^a ± 0.11	1.01 ^a ± 0.05	0.99 ^a ± 0.08	p < 0.001
Hind trotters (%)	1.12 ± 0.15	1.09 ± 0.13	1.05 ± 0.16	1.02 ± 0.11	1.03 ± 0.10	1.07 ± 0.17	p = 0.199
Carcass weight (kg)²	66.61 ^a ± 9.40	69.62 ^{ab} ± 11.69	78.94 ^{bc} ± 11.11	80.26 ^{bc} ± 10.74	78.37 ^{abc} ± 9.57	81.55 ^c ± 7.50	p < 0.001

Carcass weight (kg)¹: Include head, trotters, kidney, kidney fat and tail

Carcass weight (kg)²: Exclude head, trotters, kidney, kidney fat and tail. Yield under classification regulation is expressed on this basis

Means with different superscripts in the same row differ significantly.

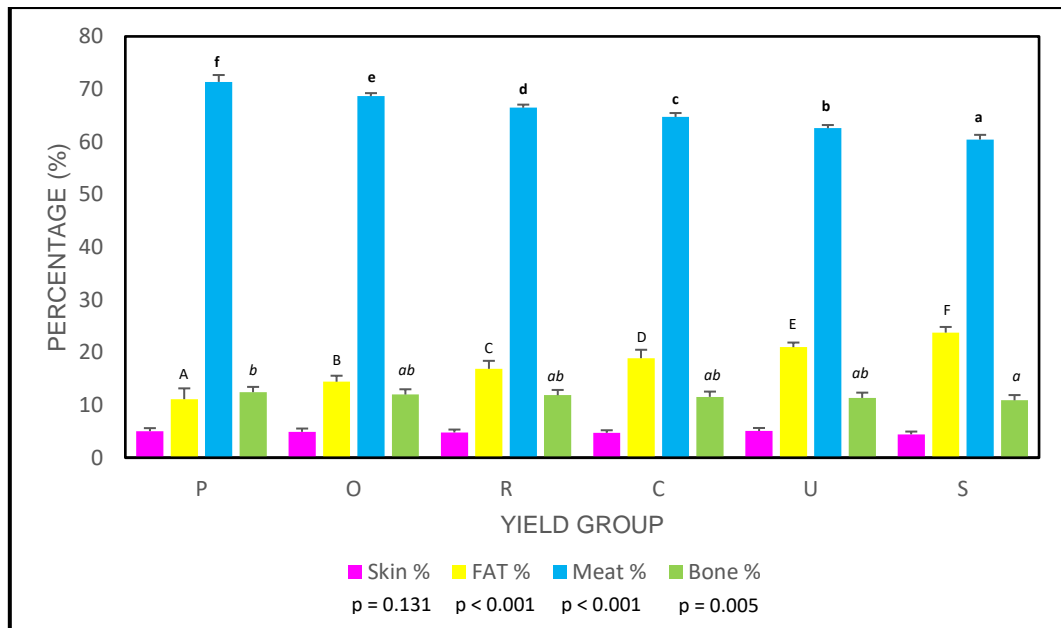
classification group O was significantly ($p < 0.001$) higher than that of classification groups C, U, and S.

The fore trotter % tends to decrease as the LM% decreased and the BFT increased (Table 4.7). The % that the fore trotter makes up of the whole carcass was significantly ($p < 0.001$) higher for classification group P than for classification groups R, C, U, and S. Although there were no significant differences between the classification groups when it came to the hind trotter %, there was a trend that showed a decrease in the % hind trotter from classification group P to C and an increase from classification group C to S.

Figure 4.2 confirms that heavier average carcass weights were found in lower yield classes and these classes had higher fat levels. Carcasses in classification group S had more than twice the amount of fat (23.76%) than carcasses in classification group P (11.12%). From classification group P to S the fat % increased and the meat % decreased and all the classification groups differ significantly ($p < 0.001$) from each other, as was expected. Bone % tends to decrease as yield class decreased. The bone % of classification group P (12.45%) was significantly ($p = 0.005$) higher than classification group S (10.90%). The skin % did not differ significantly ($p = 0.131$) between the classification groups.

The fat distribution across the different primal cuts of the carcass according to carcass yield is shown in Table 4.8. It is important to determine the fat distribution across the different cuts because processors have to know how much fat is in certain cuts, because this information is important for the end product they want to produce. The processor has to produce products according to the expectations of consumers.

From Table 4.8 it is clear that the % fat of each primal cut increased as the LM% decreased and the BFT increased. The % fat in the belly and rib seem to be the highest of all the primal cuts for all the classification groups. For the % of fat in the belly, classification group P was significantly ($p < 0.001$) lower than all the other classification groups and classification group O was significantly ($p < 0.001$) lower than classification group C, U, and S.



Skin % = Not Significant; Fat % = UPPERCASE Meat % = **lowercase bold**; Bone % = *lowercase italics*
Means with different superscripts in the same category differ significantly.
Expressed based on carcass weight excluding head, trotters, kidney, kidney fat and tail.

Figure 4.2: The % of skin, meat, fat and bone that make up primal cuts of carcasses from different classification groups.

The % fat in the rib for classification group P was significantly ($p < 0.001$) lower than the other classification groups (Table 4.8). There were no significant ($p > 0.05$) differences between classification group R (22.09%) and C (23.34%) and no significant ($p > 0.05$) differences between classification group U (28.32%) and S (30.46%). The % fat in the loin of classification group P was significantly ($p < 0.001$) lower than that of classification groups O, R, and C, but there were no significant ($p > 0.05$) differences between classification group U and S.

The % fat in the chump and thick rib of classification group P was significantly ($p < 0.001$) lower than the % fat in the chump and thick rib of classification groups O, R, and S, but there were no significant ($p > 0.05$) differences between classification group C and U (Table 4.8). The % fat in the fore shin of classification group P was significantly ($p < 0.001$) lower than the other classification groups. There were no significant ($p > 0.05$) differences between classification groups O, R, C, and U. The % fat in the fore shin of classification group O (8.29%) and R (8.76%) was significantly ($p < 0.001$) lower than that of classification group S (12.44%). The % fat in the hind shin of classification group P was significantly ($p < 0.001$) lower than the % fat in the hind shin classification groups R, C, U, and S and classification group O and R

Table 4.8: Fat distribution across the different primal cuts of the carcass according to yield class.

% Of total dissected fat in each cut	P (n = 19)	O (n = 23)	R (n = 19)	C (n = 19)	U (n = 10)	S (n = 7)	Sign. level
Belly	18.05 ^a ± 5.00	23.87 ^b ± 4.23	27.03 ^{bc} ± 4.07	30.45 ^{cd} ± 5.09	33.11 ^d ± 3.42	35.01 ^d ± 2.55	p < 0.001
Rib	13.99 ^a ± 2.40	17.71 ^b ± 2.23	22.09 ^c ± 2.60	23.34 ^c ± 3.32	28.32 ^d ± 3.31	30.46 ^d ± 2.74	p < 0.001
Loin	12.56 ^a ± 2.65	16.47 ^b ± 1.90	19.80 ^c ± 1.95	22.47 ^d ± 2.52	24.78 ^{de} ± 2.62	27.86 ^e ± 2.34	p < 0.001
Chump	13.08 ^a ± 2.59	16.82 ^b ± 1.68	19.79 ^c ± 3.10	22.12 ^d ± 2.55	24.15 ^d ± 1.82	27.63 ^e ± 2.05	p < 0.001
Thick Rib	8.34 ^a ± 1.62	10.84 ^b ± 0.96	12.27 ^c ± 1.44	13.70 ^d ± 1.71	15.10 ^d ± 1.55	17.71 ^e ± 1.13	p < 0.001
Fore shin	5.97 ^a ± 2.70	8.29 ^b ± 2.54	8.76 ^b ± 2.06	10.24 ^{bc} ± 2.54	9.05 ^{bc} ± 2.27	12.44 ^c ± 1.43	p < 0.001
Hind shin	13.84 ^a ± 2.36	15.75 ^{ab} ± 3.16	17.19 ^b ± 3.70	17.61 ^{bc} ± 2.67	18.39 ^{bc} ± 3.51	21.33 ^c ± 3.02	p < 0.001
Leg	8.06 ^a ± 2.00	10.37 ^b ± 1.45	12.21 ^c ± 1.60	13.56 ^{cd} ± 1.67	14.56 ^d ± 1.63	17.51 ^e ± 1.40	p < 0.001

Means with different superscripts in the same row differ significantly.

Table 4.9: Fat distribution across the different primal cuts of the carcass according to yield class (fat content of cut expressed as % of fat content of whole carcass).

Fat content of cuts as % of fat content of whole carcass	P (n = 19)	O (n = 23)	R (n = 19)	C (n = 19)	U (n = 10)	S (n = 7)	Sign. level
Belly	22.72 ± 4.52	23.69 ± 3.62	23.15 ± 3.15	24.49 ± 3.43	24.98 ± 2.52	24.08 ± 2.98	p = 0.528
Rib	13.64 ± 1.87	13.13 ± 2.04	13.90 ± 1.48	13.39 ± 2.20	15.13 ± 2.07	14.83 ± 2.49	P = 0.087
Loin	9.43 ^a ± 1.29	9.80 ^{ab} ± 1.08	10.42 ^{bc} ± 1.07	10.28 ^{bc} ± 1.21	10.75 ^c ± 1.42	10.47 ^{bc} ± 0.89	p = 0.026
Chump	11.38 ± 1.59	11.18 ± 0.99	11.77 ± 1.09	11.29 ± 1.10	10.90 ± 0.86	11.03 ± 1.12	P = 0.433
Thick Rib	22.17 ± 2.17	22.66 ± 1.54	22.00 ± 2.70	21.75 ± 1.92	21.27 ± 2.18	21.47 ± 1.90	p = 0.504
Fore shin	1.74 ^{ab} ± 0.60	1.88 ^b ± 0.55	1.59 ^{ab} ± 0.45	1.74 ^{ab} ± 0.44	1.29 ^a ± 0.32	1.43 ^{ab} ± 0.23	p = 0.028
Hind shin	2.55 ^b ± 0.62	2.11 ^a ± 0.55	1.95 ^a ± 0.44	1.74 ^a ± 0.34	1.65 ^a ± 0.38	1.76 ^a ± 0.37	p < 0.001
Leg	15.72 ± 2.09	15.49 ± 1.67	15.13 ± 1.61	14.90 ± 1.31	14.03 ± 1.46	14.91 ± 1.43	p = 0.147

Means with different superscripts in the same row differ significantly.

differed significantly ($p < 0.001$) from classification group S (Table 4.8). The % fat in the leg of classification group P was significantly ($p < 0.001$) lower than that of classification groups O, U, and S, but there were no significant ($p > 0.05$) differences between classification group R and C.

Consumers have a tendency to avoid meat with higher fat content for health reasons (Marcoux, Pomar, Faucitano, & Brodeur, 2007). Therefore from the study it is evident that, from a consumer's health point of view, meat from carcasses from the P classification group will be more suited to their needs. These carcasses have the least amount of fat in all the cuts of the carcass (Liu, Ford, Hu, Zelman, Mozaffarian & Kris-Etherton, 2017). However, from a processors point of view, carcasses from the C, U, and S groups would be better suited for products such as bacon and sausages which are preferred with a higher fat content and are better suited for processors who need fat to prepare certain products (Hugo & Roodt, 2015).

Fat distribution across the different primal cuts of the carcass according to yield class is (fat content of cut expressed as % of fat content of whole carcass) shown in Table 4.9. Although some variation across yield groups were noted, no clear patterns were observed. The belly, thick rib and leg had the most fat when it came to the fat content expressed as % of fat content of whole carcass. The % of fat in the loin cut of classification group P (9.43%) was significantly ($p = 0.026$) lower than that of classification groups R, C, U, and S. The % of fat in the fore shin cut of classification group U (1.29%) was significantly ($p = 0.028$) lower than that of classification groups O (1.88%). The % of fat in the hind shin cut of classification group P (2.55%) was significantly ($p < 0.001$) higher than all the other classification groups.

Pork is classified into 4 categories according to colour, texture or firmness, and exudation or drip loss (Warner, Kauffman, & Russel, 1993), normal pork, PSE, RSE (similar to PSE but with normal colour) and DFD. Denaturation of myofibrillar (in particular myosin) and sarcoplasmic proteins under unfavourable conditions causes drip loss, loss of structural integrity and paleness in colour. In pig meat drip loss is very important, due to its financial implications. High drip loss of meat leads to losses in terms of texture, appearance, loss of nutritional value and overall attractiveness. Therefore high drip losses compromise the quality of the fresh meat and in turn, its

processing (Otto, Roehe, Looft, Thoelking, & Kalm, 2004; Hughes, Oiseth, Purslow, & Warner, 2014).

Figure 4.3 shows that there was a significant decrease in drip loss as the LM% decreased and BFT increased. Meat from the P, O and R classification groups had significantly ($p = 0.05$) lower drip loss than meat from the C, U and S classification groups. The reason for this could be that there is a thicker layer of fat on these carcasses, which means that during the cooling process the carcass cools down at a slower rate due to the insulation effect of the fat and this acts as a protection mechanism against protein denaturation and therefore there will be less drip loss (Cheng & Sun, 2008). Kempster, et al. (1986) found that muscle colour and drip loss were not affected by the carcass weight groups, they also observed the trend that meat from leaner carcasses has a higher amount of drip loss but no effect on the muscle colour. This is in contrast to what we found. According to the study, although not significant, the lean carcasses had the highest amount of drip loss.

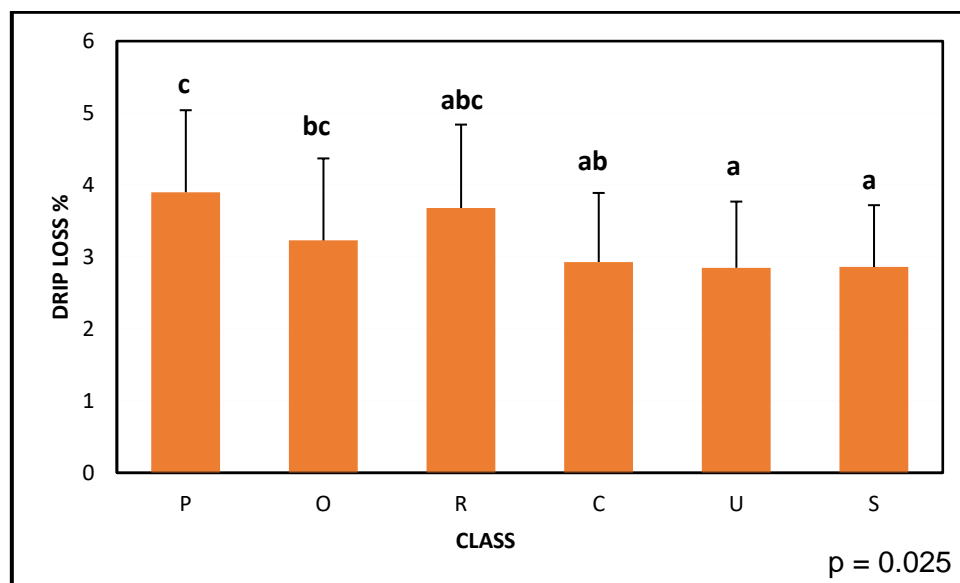


Figure 4.3: Drip loss of meat of backfat of pigs from different classification groups. Bars with different superscripts differ significantly.

Values for lightness (L^*) above 50 to 57 is regarded as PSE meat (Warner et al., 1993). Using this criteria, the carcasses used in this project were not PSE and neither weight class nor yield class had an effect on lightness of colour (pale vs. dark). Chroma describes the intensity of the typical colour of a substance, e.g. the brightness of red in meat, while hue angle refers to the deviation from the typical colour. Chroma and

Table 4.10: Carcass characteristics, chemical and physical composition of backfat and meat of pigs from different classification groups.

Class	P (n = 19)	O (n = 23)	R (n = 19)	C (n = 19)	U (n = 10)	S (n = 7)	Sign. level
Classification parameters:							
Carcass mass	75.79 ^a ± 10.31	78.99 ^a ± 12.93	89.60 ^b ± 12.29	91.29 ^b ± 12.42	89.05 ^b ± 10.67	92.65 ^b ± 8.73	p < 0.001
Fat thickness by HGP	11.07 ^a ± 2.65	11.40 ^a ± 1.22	14.58 ^b ± 1.84	15.07 ^{bc} ± 1.37	15.97 ^{bc} ± 2.46	17.37 ^c ± 2.01	P < 0.001
Muscle thickness by HGP	84.35 ^{ab} ± 14.58	79.32 ^a ± 11.25	94.23 ^{bc} ± 11.35	91.24 ^{abc} ± 15.90	83.42 ^{ab} ± 18.00	104.55 ^c ± 1.56	P < 0.001
% Meat content by HGP	72.01 ^c ± 1.72	71.58 ^{bc} ± 0.97	70.93 ^{ab} ± 0.74	70.54 ^a ± 0.82	69.71 ^a ± 0.66	70.21 ^a ± 0.97	P < 0.001
% Meat content by dissection	71.41 ^f ± 1.66	68.45 ^e ± 0.58	66.28 ^d ± 0.60	64.52 ^c ± 0.65	62.45 ^b ± 0.53	60.27 ^a ± 0.88	p < 0.001
Meat quality parameters:							
Muscle colour: L*	49.19 ± 2.28	48.23 ± 1.62	49.11 ± 1.56	47.97 ± 1.68	48.06 ± 1.75	48.57 ± 2.41	p = 0.203
Muscle colour: a*	8.81 ± 1.12	8.70 ± 1.49	8.28 ± 1.36	8.51 ± 1.29	8.84 ± 1.15	8.64 ± 1.40	p = 0.826
Muscle colour: b*	8.49 ± 1.03	8.24 ± 1.36	8.01 ± 1.01	8.14 ± 0.92	8.44 ± 0.95	8.33 ± 1.53	p = 0.819
Muscle colour: Chroma	12.25 ± 1.42	11.99 ± 1.98	11.41 ± 1.44	11.79 ± 1.52	12.23 ± 1.43	12.02 ± 1.98	p = 0.669
Muscle colour: Hue	44.34 ± 2.26	43.53 ± 1.95	44.51 ± 2.03	43.94 ± 2.33	43.79 ± 2.01	43.84 ± 2.86	p = 0.740
Fat quality parameters:							
% Fat Free Dry Matter	11.41 ^b ± 3.12	9.91 ^b ± 1.69	6.96 ^a ± 2.56	7.37 ^a ± 2.53	7.29 ^a ± 3.06	7.27 ^a ± 1.84	P < 0.001
% Moisture	23.79 ^d ± 4.09	19.80 ^c ± 3.07	17.51 ^{bc} ± 4.95	16.29 ^{bc} ± 4.15	13.82 ^{ab} ± 3.35	10.81 ^a ± 1.96	P < 0.001

Means with different superscripts in the same row differ significantly

hue angle are not normally interpreted in relation to colour acceptability of pork. There was also not much variation among yield classes since no significant differences were observed. (Table 4.10).

Intermuscular fat content has a high impact on consumer acceptability when it comes to pork. IMF is used by consumers as a visual cue in order to judge the quality of the meat (Monziols, et al., 2007; Frank, Joo, & Warner, 2016). The % of IMF of meat from this study is indicated in Figure 4.4. There was a trend that showed an increase in the % IMF as the LM% decreased and BFT increased. The % IMF of classification group P (1.99%) was significantly ($p = 0.003$) lower than S (2.56%).

Fernandez, et al. (1999) recommended that meat should contain levels of above 2.5% IMF, otherwise the meat tends to be dry. However, Barton-Gade and Bejerholm (1985) stated that the IMF levels in pork meat have to reach 2% before it can be detected that the sensory qualities have been affected. Only classification group S had more than 2.5% IMF, which means the meat from these pigs will have a good eating quality when considering the effect of muscle fat only. Classification groups C (2.49%) and U (2.44%) almost reach the recommended 2.5%, but classification groups P, O, and R contain much lower IMF than the recommended 2.5% and could be expected to be less palatable/dry.

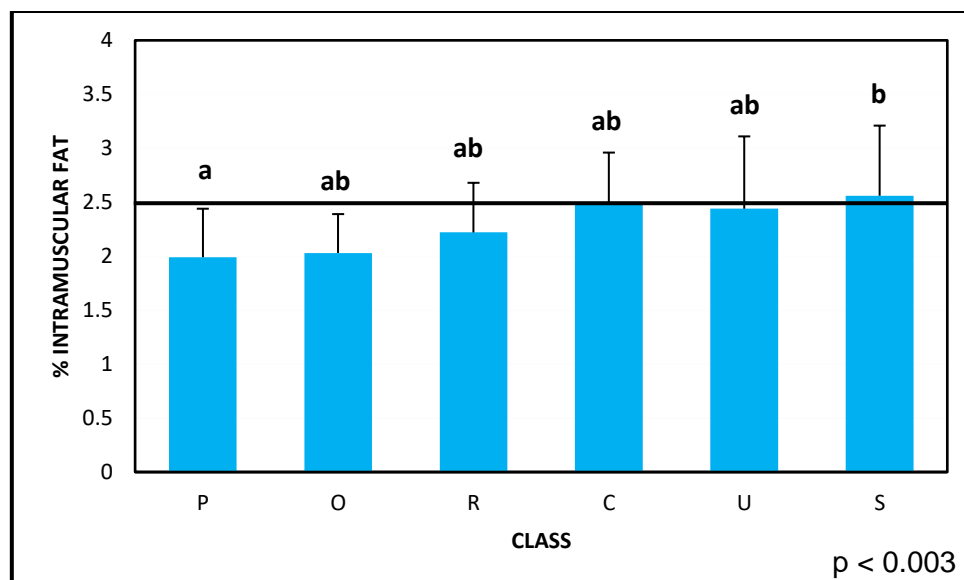


Figure 4.4: Percentage of intramuscular fat of meat of pigs from different classification groups. Bars with different superscripts differ significantly.

The quality of fat plays an important role in the production of meat products (Miklos, Xu, & Lametsch, 2011). The fat quality parameters from Table 4.10 indicates that the % FFDM and the % moisture in BF both showed a trend that they decrease as the LM% decreased and BFT increased. This is in agreement with previous findings (Barton-Gade, 1987; Babol, & Squires, 1995; Xue, Dial, & Pettigrew, 1997; Pauly, Kim, Lee, Jang, Kim, Lee, Jung, Kim, Seong, & Choi, 2009; Ferreira, 2014). The % FFDM of classification groups P and O was significantly ($p < 0.001$) higher than that of classification groups R, U and S. The % moisture of classification group P was significantly ($p < 0.01$) higher than the other classification groups and classification group O, R, and C differed significantly ($p < 0.001$) from classification groups U and S.

The % of EFC from BF is depicted in Figure 4.5. The % of EFC increased as the LM% decreased and BFT increased. The same results were obtained in a study done by Roodt in 2003. It has been previously reported that BF from heavier pigs have higher % EFC (Barton-Gade, 1987; Babol, & Squires, 1995; Xue, et al., 1997; Pauly, Spring, O'Doherty, Kragten, & Bee, 2009, Ferreira, 2014).

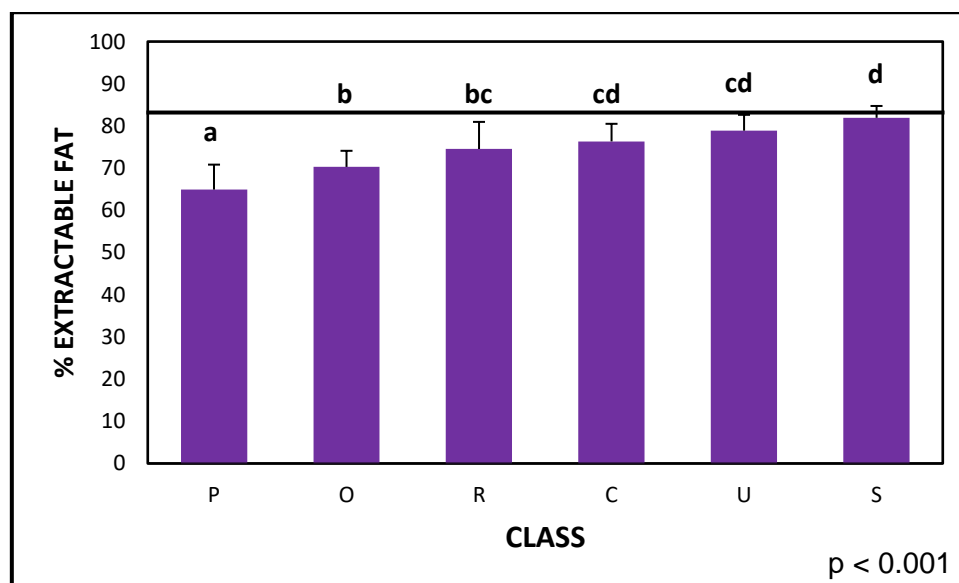


Figure 4.5: Percentage of extractable fat of meat of pigs from different classification groups. Bars with different superscripts differ significantly.

According to Barton-Gade (1983), the % EFC in pork is very important, especially when it comes to the production of lard. The depot fat should be more than 15% of the total fat content and there should be no “empty” fat tissues present, the fat tissue

should contain between 84-90% fat (EFC) (Prabucki, 1991). None of the classification groups had more than the recommended 84% extractable fat. Classification group S was significantly ($p < 0.001$) higher than classification groups P, O and R (Figure 4.5).

The iodine value (IV) gives an overall estimation of the unsaturation of FAs (Davenel, et al, 1999). Multiple authors have different recommendations of what the ideal IV of a good BF should be. According to Fischer (1989), BF used for the manufacturing of firm-cutting sausage is required to have an IV below 60. Warnants, et al. (1996) and Lea, et al. (1970) stated that it is critical from a quality point of view for BF to have an IV of below 65, whereas Barton-Gade (1983) proposed that a maximum IV of 70 would result in a firm fat. Houben & Krol (1983) indicated that if BF has an IV of 66 or higher, the BF will be soft and they suggested that the RI of BF should not be higher than 1.4598.

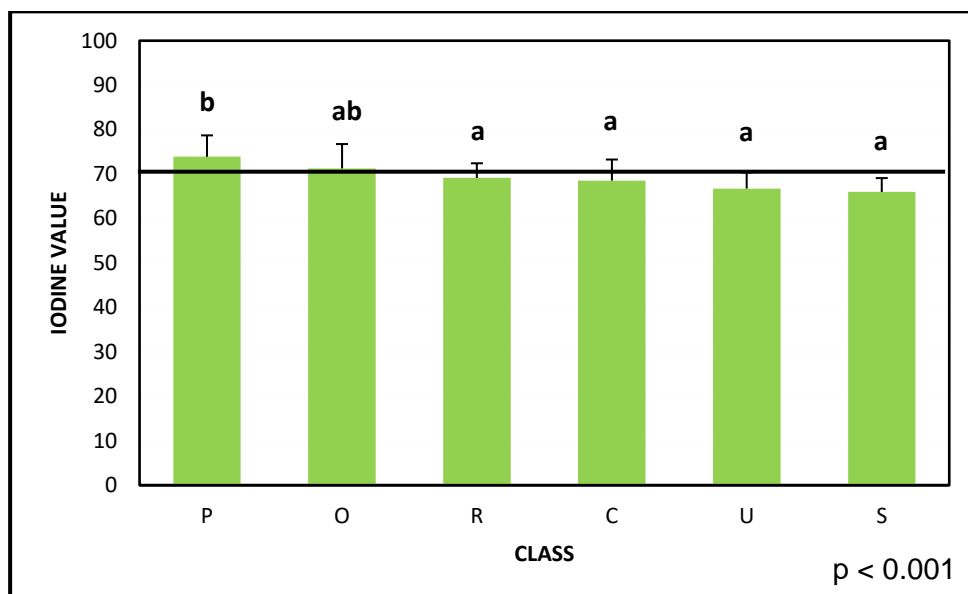


Figure 4.6: Iodine value of backfat of pigs from different classification groups. Bars with different superscripts differ significantly.

Figure 4.6 and 4.7 indicates that the IV and the RI decrease as the LM% decreased and BFT increased. This is in agreement with previous findings of Roodt (2003) and Ferreira (2014). This tells us that the technological quality of the fat increased as the LM% decreased and BFT increased. Classification groups R, C, U, and S all have an IV below 70. This indicates that the fat from these carcasses will be of a good quality. Only classification group S had an RI of less than 1.4598. The P classification group differed significantly ($p < 0.001$) from most of the other classification groups when it

comes to both the IV and the RI. This indicates that the leaner pigs have more unsaturated BF with poorer technological properties in comparison to the pigs which contain more fat.

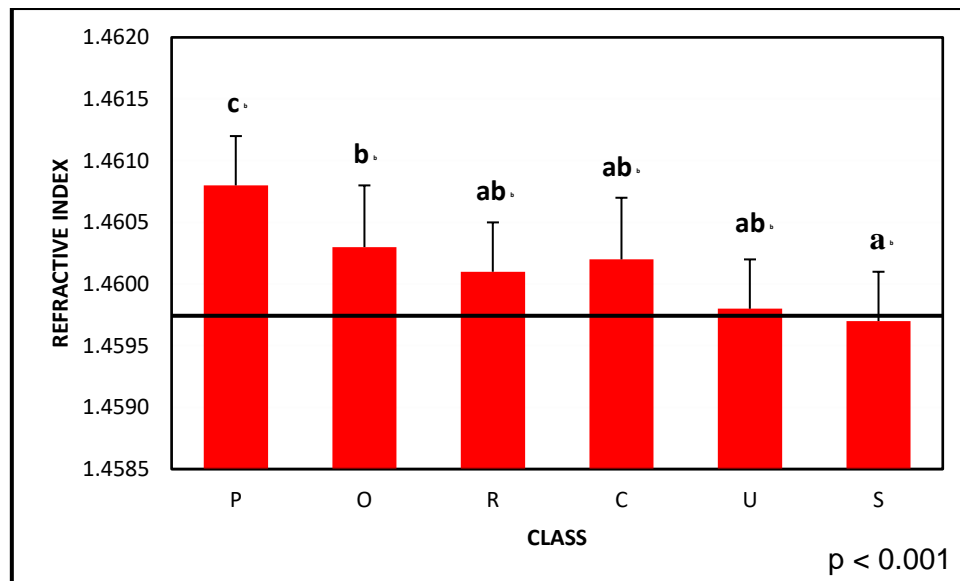


Figure 4.7: Refractive index of backfat of pigs from different classification groups. Bars with different superscripts differ significantly.

The fatty acid composition of BF of pigs from different classification groups is indicated in Table 4.11. The table indicates that classification group O (1.20%) and U (1.23%) contained the most C14:0 and classification group P contained significantly ($p = 0.011$) less C14:0 than classification groups O and U. There were high levels of C16:0 and C18:1c9, in both cases it was observed that there was a trend that showed that as the LM% decreased and BFT increased, the amount of the fatty acid present increased. Classification groups P and O contained significantly ($p < 0.001$) lower amounts C16:0 in comparison with the other classification groups.

Although not significant, there is a trend that demonstrates that as the LM% decreased and BFT increased, the % C18:0 increased (Table 4.11). This is in agreement with previous findings (Ferreira, 2014). Stearic acid is regarded as the most important FA in the regulation of BF consistency in pigs (Whittington, et al., 1986). Lizardo, van Milgen, Mourot, Noblet and Bonneau (2002) stated that a good quality fat should contain more than 12% C18:0. Only classification group U (12.08%) and S (12.05%) had more than the recommended 12% C18:0. The results show that the higher the C16:2 and C18:0 content of the BF is, the lower the IV and RI will be, the same results were found in a study done by Roodt (2003) on the BF quality of South African pigs.

According to Lizardo and co-workers, C18:1c9 constitutes more than 40% of total fat content, making this fatty acid the major component of pig adipose tissue. C18:1c9 has a low melting point, but Davenel, et al., (1999) suggests that its concentration is poorly related to the consistency of fatty tissue. From Table 4.11 it is clear that the % of C18:1c9 increased as the LM% decreased and BFT increased. Classification group P had significantly ($p < 0.001$) lower amounts of C18:1c9 than classification groups R, U, and S.

The BF consistency of pigs has been proven to be inversely correlated with the C18:2 concentrations (Whittington, et al., 1986). There is a decrease in the % of C18:2 as the LM% decreased and BFT increased (Table 4.11). Classification group P had significantly ($p < 0.001$) higher amounts of C18:2 in comparison with the other classification groups, and classification group O (16.99%) had significantly ($p < 0.001$) higher amounts of C18:2 than classification group S (13.32%). Whittington, et al., (1986) set the limit for C18:2 to be less than 15% in order for the fat to be of good quality and Lizardo, et al., (2002) suggested that a good technological quality BF should contain between 12 and 15% C18:2. Classification group U (14.11%) and S (13.32%) were the only two groups which had less than 15% C18:2.

Classification group P (1.49%) had significantly ($p = 0.010$) higher amounts of C18:3n-3 than classification group U (1.30%) (Table 4.11). Classification group P had significantly ($p < 0.001$) higher amounts of eicosadienoic acid (C20:2), Erucic (C22:1), eicosatrienoic (C20:3n-3) and C20:4 in comparison to the other classification groups. The only exception is in the % C20:3n-3, where classification group P was not significantly ($p = 0.002$) higher than classification group R, and C.

Fatty acid ratios of BF of pigs from different classification groups are indicated in Table 4.12. Madsen, Jakobsen, and Mortensen (1992) stated that SFA (C12:0 – C18:0), have a positive influence on firmness and cohesiveness of the carcass fat tissue. Saturated fatty acids have high melting points, and because of this, they have a strong influence on the solid fat content of lipids (Davenel, et al., 1999).

Table 4.11: Fatty acid composition of backfat of pigs from different classification groups.

Class	P (n = 19)	O (n = 23)	R (n = 19)	C (n = 19)	U (n = 10)	S (n = 7)	Sign. level
C12:0	0.01 ± 0.02	0.01 ± 0.02	0.01 ± 0.02	0.00 ± 0.01	0.02 ± 0.03	0.01 ± 0.01	p = 0.344
C14:0	1.03 ^a ± 0.13	1.20 ^b ± 0.24	1.13 ^{ab} ± 0.17	1.07 ^{ab} ± 0.12	1.23 ^b ± 0.19	1.14 ^{ab} ± 0.13	p = 0.011
C15:0	0.02 ± 0.03	0.03 ± 0.03	0.01 ± 0.02	0.01 ± 0.02	0.01 ± 0.02	0.00 ± 0.00	p = 0.086
C16:0	22.61 ^a ± 1.21	23.55 ^{ab} ± 1.33	24.41 ^{bc} ± 0.82	24.47 ^{bc} ± 1.61	25.38 ^c ± 0.76	25.60 ^c ± 1.19	p < 0.001
C16:1c9	1.71 ± 0.41	1.74 ± 0.39	1.91 ± 0.32	1.78 ± 0.34	1.84 ± 0.41	1.87 ± 0.35	p = 0.564
C17:0	0.31 ± 0.09	0.32 ± 0.12	0.32 ± 0.11	0.33 ± 0.11	0.28 ± 0.08	0.26 ± 0.07	p = 0.537
C17:1c10	0.05 ± 0.10	0.08 ± 0.13	0.08 ± 0.11	0.05 ± 0.09	0.10 ± 0.11	0.00 ± 0.00	p = 0.361
C18:0	10.92 ± 1.40	11.63 ± 1.90	11.67 ± 1.11	11.71 ± 1.11	12.08 ± 1.66	12.05 ± 1.00	p = 0.297
C18:1t9	0.01 ± 0.01	0.01 ± 0.02	0.01 ± 0.02	0.01 ± 0.01	0.01 ± 0.02	0.02 ± 0.02	p = 0.727
C18:1c9	36.04 ^a ± 1.07	37.25 ^{ab} ± 1.63	37.66 ^b ± 1.64	37.16 ^{ab} ± 1.22	38.02 ^b ± 1.79	38.57 ^b ± 1.38	p < 0.001
C18:1c7	4.62 ± 0.30	4.93 ± 0.31	4.92 ± 0.41	4.80 ± 0.43	4.96 ± 0.48	5.04 ± 0.31	p = 0.050
C18:2c9,12 (n-6)	20.06 ^c ± 2.21	16.99 ^b ± 3.08	15.66 ^{ab} ± 2.61	16.31 ^{ab} ± 2.77	14.11 ^{ab} ± 2.46	13.32 ^a ± 2.20	p < 0.001
C20:0	0.13 ± 0.03	0.13 ± 0.02	0.14 ± 0.02	0.14 ± 0.02	0.13 ± 0.01	0.14 ± 0.01	p = 0.726
C18:3c9,12,15 (n-3)	1.49 ^b ± 0.20	1.33 ^{ab} ± 0.28	1.32 ^{ab} ± 0.15	1.39 ^{ab} ± 0.21	1.20 ^a ± 0.14	1.30 ^{ab} ± 0.14	p = 0.010
C20:2c11,14 (n-6)	0.65 ^b ± 0.13	0.52 ^a ± 0.12	0.51 ^a ± 0.06	0.52 ^a ± 0.12	0.45 ^a ± 0.07	0.50 ^a ± 0.06	p < 0.001
C22:1c13	0.07 ^b ± 0.01	0.04 ^a ± 0.02	0.03 ^a ± 0.02	0.03 ^a ± 0.02	0.03 ^a ± 0.02	0.02 ^a ± 0.02	p < 0.001
C20:3c11,14,17 (n-3)	0.09 ^b ± 0.03	0.07 ^a ± 0.03	0.07 ^{ab} ± 0.02	0.08 ^{ab} ± 0.03	0.05 ^a ± 0.03	0.06 ^a ± 0.02	p = 0.002
C20:4c5,8,11,14 (n-6)	0.19 ^c ± 0.03	0.15 ^b ± 0.04	0.14 ^{ab} ± 0.03	0.14 ^{ab} ± 0.04	0.11 ^a ± 0.03	0.11 ^a ± 0.01	p < 0.001

Means with different superscripts in the same row differ significantly.

In order to obtain a good quality BF, Häuser and Prabucki (1990) suggested that the SFA content should be more than 41% of the total FAs. Table 4.12 indicates that as the LM% decreased and BFT increase the % of SFA increased. Classification groups P and O had significantly ($p < 0.001$) lower amounts of SFA in comparison to the other classification groups. None of the classification groups could conform to the quality parameter of more than 41% SFAs, but the quality of the BF increased as the LM% decreased and BFT increased.

Piedrafita, Christian and Lonergan (2001) discovered that as the total amount of UFAs in the BF increase, the firmness of the fat decreased. Häuser and Prabucki (1990) suggested that BF should contain less than 57% MUFAs in order to obtain a good quality BF. As the LM% decreased and BFT increased, the % of MUFAs increased (Table 4.12). Classification group P (42.49%) had a significantly ($p < 0.001$) lower amount of MUFAs in comparison to classification group R (44.61%), U (44.97%) and S (45.52%). All the classification groups had less than 57% MUFA.

Backfat consistency was found to decrease as the PUFA content increased (Warnants, van Oeckel & Boucqué, 1996). Therefore Warnants, van Oeckel and Boucqué (1996) set the limit for good fat quality at 19-21% and less PUFAs in BF. The % of PUFAs decreased as the LM% decreased and BFT increased, indicating that the BF consistency increased when moving from classification group P to S (Table 4.12). Classification group P (22.49%) had a significantly ($p < 0.001$) higher amount of PUFAs in comparison to the other classification groups, and was the only group which did not contain less than 21% PUFAs.

The fatty acid ratios in Table 4.12 indicate that from classification group P to S (as the LM% decreased) the total omega-6 ($n-6$) FAs decreased. Classification group P had significantly ($p < 0.001$) higher amounts of $n-6$ in comparison to the other classification groups and classification groups O (17.66%) had significantly ($p < 0.001$) higher amounts of $n-6$ than classification group S (13.92%). The total omega-3 ($n-3$) FAs followed a downward trend with decreased LMC. Classification group P (1.59%) had significantly ($p = 0.007$) higher amounts of $n-3$ than classification group U (1.25%).

Table 4.12: Fatty acid ratios of backfat of pigs from different classification groups.

Class	P (n = 19)	O (n = 23)	R (n = 19)	C (n = 19)	U (n = 10)	S (n = 7)	Sign. level
Total SFA	35.02 ^a ± 2.35	36.88 ^{ab} ± 3.29	37.69 ^b ± 1.69	37.73 ^b ± 2.41	39.12 ^b ± 2.09	39.20 ^b ± 2.05	p < 0.001
Total MUFA	42.49 ^a ± 1.46	44.06 ^{ab} ± 1.99	44.61 ^b ± 2.09	43.83 ^{ab} ± 1.72	44.97 ^b ± 2.40	45.52 ^b ± 1.46	p < 0.001
Total PUFA	22.49 ^c ± 2.46	19.06 ^b ± 3.41	17.70 ^{ab} ± 2.77	18.44 ^{ab} ± 3.09	15.91 ^{ab} ± 2.67	15.28 ^a ± 2.38	p < 0.001
Total n-6 FA	20.91 ^c ± 2.29	17.66 ^b ± 3.18	16.31 ^{ab} ± 2.66	16.97 ^{ab} ± 2.88	14.66 ^{ab} ± 2.53	13.92 ^a ± 2.26	p < 0.001
Total n-3 FA	1.59 ^b ± 0.23	1.40 ^{ab} ± 0.31	1.39 ^{ab} ± 0.16	1.46 ^{ab} ± 0.24	1.25 ^a ± 0.17	1.36 ^{ab} ± 0.15	p = 0.007
PUFA:SFA	0.65 ^b ± 0.10	0.53 ^a ± 0.14	0.47 ^a ± 0.09	0.49 ^a ± 0.11	0.41 ^a ± 0.08	0.39 ^a ± 0.08	p < 0.001
PUFA/MUFA	0.53 ^c ± 0.07	0.43 ^b ± 0.09	0.40 ^{ab} ± 0.08	0.42 ^{ab} ± 0.08	0.36 ^{ab} ± 0.08	0.34 ^a ± 0.06	p < 0.001
n-6/n-3 ratio	13.30 ^c ± 1.48	12.91 ^{bc} ± 2.53	11.77 ^{abc} ± 1.47	11.59 ^{ab} ± 0.96	11.72 ^{abc} ± 1.13	10.26 ^a ± 0.97	p < 0.001
Atherogenicity Index	0.41 ^a ± 0.04	0.45 ^{ab} ± 0.06	0.47 ^b ± 0.03	0.46 ^b ± 0.05	0.50 ^b ± 0.04	0.50 ^b ± 0.04	p < 0.001
C18:0/C18:2 ratio	0.56 ^a ± 0.13	0.72 ^{ab} ± 0.23	0.77 ^b ± 0.18	0.75 ^b ± 0.19	0.89 ^b ± 0.23	0.93 ^b ± 0.18	p < 0.001

Means with different superscripts in the same row differ significantly.

Table 4.13: A comparison between dissection of the left vs the right side of the carcass in terms of yield groups.

Real class according to dissection	P (n = 19)	O (n = 23)	R (n = 19)	C (n = 19)	U (n = 10)	S (n = 7)	Overall
Left side total weight no trotters	33.89 ± 4.79	35.42 ± 5.95	40.19 ± 5.80	40.90 ± 5.39	39.91 ± 5.24	41.77 ± 4.02	38.05 ± 6.06
Right side total weight no trotters	32.72 ± 4.70	34.21 ± 5.77	38.75 ± 5.36	39.36 ± 5.36	38.47 ± 4.36	39.79 ± 3.52	36.66 ± 5.74
Significance level	p = 0.452	p = 0.488	p = 0.432	p = 0.381	p = 0.513	p = 0.346	p = 0.102
Left side muscle weight no trotters	23.91 ± 3.05	24.33 ± 3.67	26.44 ± 3.85	26.17 ± 3.45	24.71 ± 3.17	24.84 ± 2.16	25.10 ± 3.48
Right side muscle weight no trotters	23.55 ± 3.11	24.02 ± 3.70	25.90 ± 3.68	25.59 ± 3.43	24.22 ± 2.83	24.31 ± 2.37	24.64 ± 3.41
Significance level	p = 0.719	p = 0.778	p = 0.664	p = 0.602	p = 0.719	p = 0.665	p = 0.360
Left side % Yield	70.50 ^a ± .48	67.74 ^a ± 0.89	65.78 ^a ± 0.93	64.00 ^a ± 1.27	61.96 ^a ± 1.11	59.53 ^a ± 1.14	65.98 ^a ± 3.39
Right side % yield	71.86 ^b ± 1.55	69.20 ^b ± 0.88	66.81 ^b ± 1.12	65.05 ^b ± 0.93	62.96 ^b ± 0.81	61.06 ^b ± 1.26	67.21 ^b ± 3.47
Significance level	p = 0.008	p = < 0.001	p = 0.004	p = 0.006	p = 0.034	p = 0.035	p = 0.013

Means with different superscripts in the same column differ significantly.

The PUFA/SFA ratio and PUFA/MUFA ratios both showed a decrease with increased BFT and decreased LM% (Table 4.12). The same was observed in work done by Roodt (2003). In both cases classification group P had significantly ($p < 0.001$) higher ratios than the other classification groups. The PUFA/MUFA ratios from Table 4.12 indicated that classification group O (0.43) had a significantly ($p < 0.001$) higher PUFA/MUFA ratio than classification group S (0.34).

The AI in Table 4.12 indicates the relationship between the sum of the main SFA and the main classes of UFA (the pro-atherogenic classes) (Ghaeni, Ghahfarokhi, & Zaheri, 2013). Ulbricht and Southgate (1991) suggested that the AI should be lower than 0.5 to lower the risk of lipids potentially causing the development of coronary diseases (Jankowska, *et al*, 2010). The AI increased as the LM% decreased and BFT increased.

The C18:0/C18:2 ratio increased as the LM% decreased and BFT increased (Table 4.12). Classification group P had a significantly ($p < 0.001$) lower C18:0/C18:2 ratio than classification groups R, C, U, and S. According to Enser (1983) and Honkavaara (1989) there is an important relationship between dietary C18:2 and the deposition of C18:0. If the C18:0/C18:2 ratio is above 1.2, the BF will be firm and if the ratio is below 1.2 the BF will be soft. None of the classification groups have a C18:0/C18:2 ratio above 1.2, this indicates that the fat from all the classification groups will be soft.

Figure 4.8 and Figure 4.9 represent the DBI and PI. The DBI and PI indicate the level of unsaturation (Roodt, 2003) and the PI can also be used as an indicator of the oxidative stability of fat (Pamplona, Portero-Otin, Riba, Ruiz, Prat, Bellmunt, & Barja, 1998). Prabucki (1991) suggested that a good quality BF should have a DBI of less than 80. Both the DBI and the PI decreased as the LM% decreased and BFT increases. As the DBI and PI increase, the IV and RI increase, and vice versa.

Only the U (78.26) and S (77.64) groups complied with the maximum DBI requirement of less than 80 and classification group P had significantly ($p < 0.001$) higher DBI than the other classification groups (Figure 4.8). The PI of classification group P was significantly ($p < 0.001$) higher than all the other groups (Figure 4.9). Classification group O (22.02) had a significantly ($p < 0.001$) higher PI than classification group S (18.09). The pigs in the S classification group, which are the heavier pigs, had a more saturated FA profile, a lower PUFA content and lower PI, which results in lower $n-6$

and *n-3* FAs and *n-6/n-3* ratio, these results were also found by Wood et al. (1998) and Ferreira (2014).

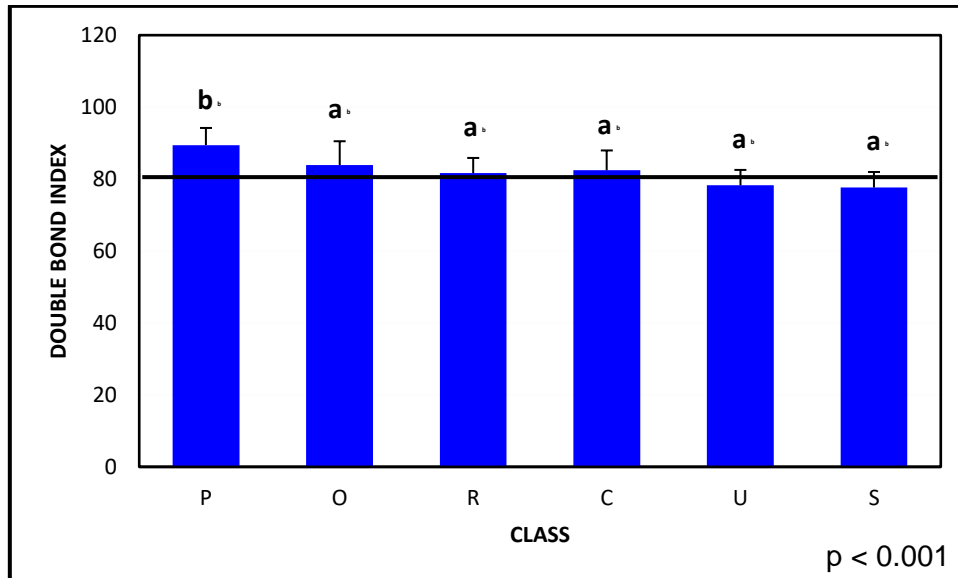


Figure 4.8: Double bond index of backfat of pigs from different classification groups. Bars with different superscripts differ significantly.

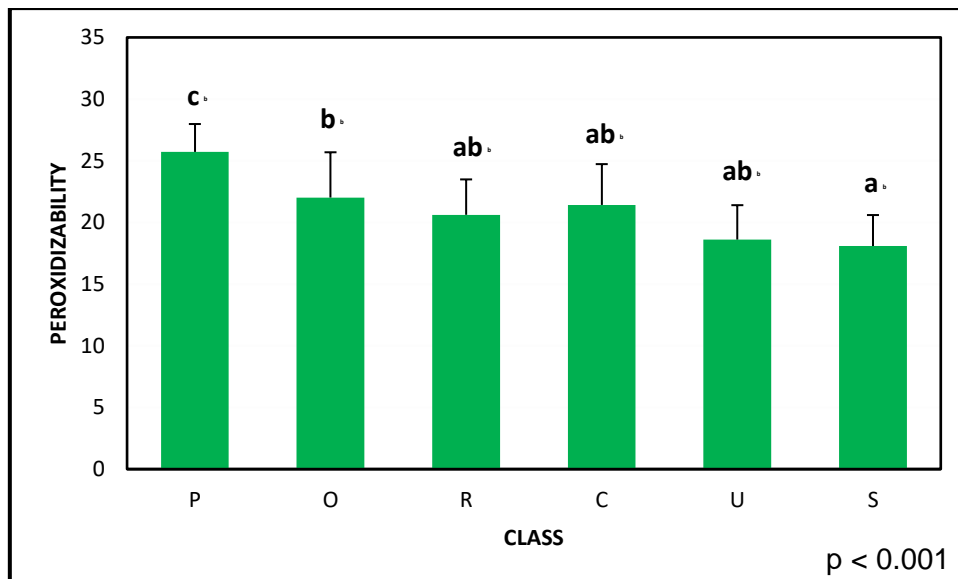


Figure 4.9: Peroxidizability index of backfat of pigs from different classification

Ulbricht and Southgate (1991) suggested that the PUFA/SFA ratio should be at least 0.4. Classification group S was the only classification group which did not have a PUFA/SFA ratio higher than 0.4 (Table 4.12), and this is not desired by consumers. In order to encourage human health, the *n-6/n-3* ratio should be quite low (Simopoulos, 2002). The *n-6/n-3* ratio showed a trend to decrease as the BFT increased and the

LM% decreased. Classification group P (13.30) had a significantly ($p < 0.001$) higher $n-6/n-3$ ratio in comparison to classification groups C (11.59) and S (10.26). The $n-6/n-3$ ratio indicates that the carcasses from classification group P are least likely to promote health. An increase in AI has a negative effect on the subcutaneous fat, from a FA profile point of view (Bothma, 2012).

The FA ratios from Table 4.12 indicate that from a health-conscious consumer point of view the pork carcasses from the P classification group will have the healthiest fat because of the higher amounts of $n-3$, the higher MUFA/SFA, PUFA/MUFA $n-6/n-3$ ratio and the lower AI. However, from the meat processors point of view the P classification group had the highest DBI, PI and the lowest C18:0/C18:2 ratio, which means that the fat from these carcasses will be soft and unsaturated, which is not ideal for meat processing due to the fat being highly oxidative.

In an attempt to determine whether it is necessary to dissect both carcass sides for future research a comparison was made between dissections of the left vs. the right side of the carcass in terms of yield group or classification groups (Table 4.13). There were no significant ($p = 0.102$) differences between any of the classification groups when the left side and right side of the carcass with no trotters were compared. The same was seen when the left side muscle and right side muscle was compared, with the trotters excluded.

However, when the left side % yield and the right side % yield was compared, it was found that for all the classification groups, the left side % yield were significantly ($p = 0.013$) lower than the right side % yield. This is due to the fact that the abattoirs split the carcasses differently and in some cases the tail could be found on the right side of the carcass and in other cases the tail could be found on the left side of the carcass and some carcasses were not split exactly in the middle and therefore one side could have more bone. If researchers plan to dissect only one side of the carcass in future research more attention will have to be paid to accurate splitting of carcasses in half.

4.5 Principal Component Analysis

Figure 4.10 shows the Principle Component Analysis (PCA) of meat and fat quality properties of pork as affected by different classification groups. Factor 1 explains 97% of the variation in the data. The PCA indicates that classification group P was associated with high IV, RI, DBI, PI, $n-6/n-3$ ratios and the PUFA: MUFA ratio. This indicates that the P classification group was associated with healthier fat from the consumer's point of view, but an inferior fat from the processor's point of view.

The S and U classification groups were associated with the total MUFA and SFA, % IMF, an unhealthy AI, and C18:0/C18:2 ratio, which are all very positive from the processors point of view. Therefore the S classification group was associated with the quality of fat that a processor desires. The O, R, and C classification groups were not correlated with any of the fat quality properties.

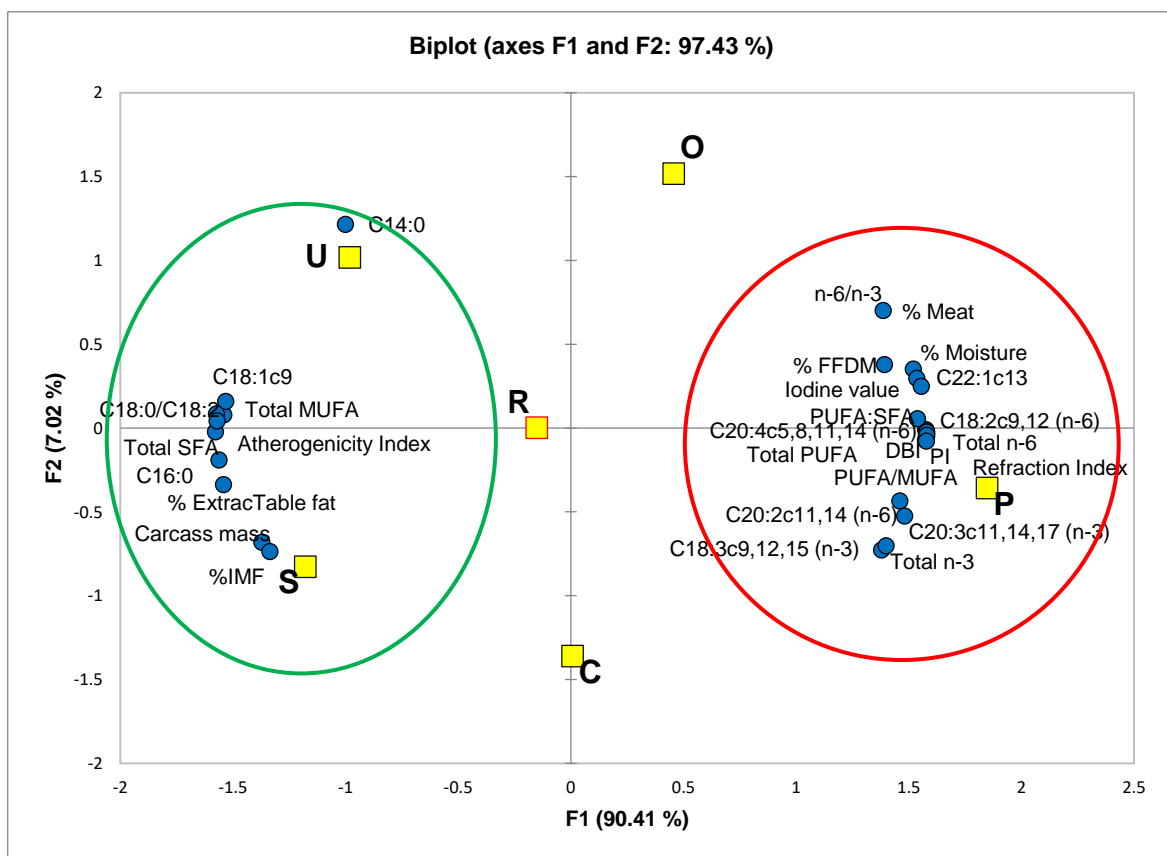


Figure 4.10: Principle Component Analysis of meat and fat quality properties of pork as affected by different classification group

4.4 Weight Groups

Although meat and fat quality parameters were generally better correlated with carcass yield than with carcass mass (Table 4.1 to 4.6) it was decided to also investigate the effect of carcass weight group on meat and fat quality parameters. The carcass composition and yields of different carcass cuts and parts according to weight class is shown in Table 4.14. The carcass weight of carcasses which included or excluded the head, trotters, kidney, kidney fat and tail showed the same trend. The head % tends to decrease as the carcasses became heavier, meaning that the % that the head makes up of the total carcass becomes smaller as the carcasses become heavier. The head % of weight group X (8.15%) was significantly ($p = 0.027$) higher than weight groups H (7.65%) and S (7.68%).

The kidney % increased from weight group X to W, and then decreased from weight group W to S (Table 4.14). Weight group W (0.42%) was significantly ($p < 0.001$) higher than weight group H (0.36%) and S (0.34%). The kidney fat % increased drastically as the carcasses became heavier (from weight group X to S). The kidney fat % of weight group X was significantly ($p < 0.001$) lower than that of weight groups V, H, and S. The % tail of weight group X was significantly ($p < 0.001$) higher than that of weight groups W, H, and S.

The belly % increased as the carcass weight increased (Table 4.14). Belly % of weight group X (12.27%) was significantly ($p < 0.001$) lower than that of weight group H (13.28%) and S (14.07%) and weight group W (12.50%) and V (12.90%) had a significantly ($p < 0.001$) lower % belly than weight group S. The fore shin % of weight group X was significantly ($p < 0.001$) higher than that of weight groups V, H, and S. The fore shin % decreased from weight group X to H and then increased from group H to S. The back shin % of weight group X was significantly ($p < 0.001$) higher than that of weight groups W, V, and H. The back shin % decreased from weight group X to V and then increased from group V to S.

The leg % decreased as the carcass becomes heavier (Table 4.14). Weight group S had a significantly ($p < 0.001$) lower % leg in comparison with the other weight groups. The fore trotter % decreased from weight group X to group V and increased from group V to group S. Weight group X was significantly ($p < 0.001$) higher than group V, H, and S. The hind trotter % decreased from weight group X to group H and increased from.

Table 4.14: Carcass composition and yields of different carcass cuts and parts according to weight class.

Weight Class	Weight class					Sign.level
	X (n = 16)	W (n = 16)	V (n = 24)	H (n = 22)	S (n = 19)	
Carcass weight (kg)¹	63.94 ^a ± 4.81	75.72 ^b ± 2.84	85.93 ^c ± 2.45	92.08 ^d ± 1.89	104.16 ^e ± 2.79	p < 0.001
Head (%)	8.15 ^b ± 0.47	7.78 ^{ab} ± 0.59	7.80 ^{ab} ± 0.43	7.65 ^a ± 0.48	7.68 ^a ± 0.41	p = 0.027
Kidney (%)	0.38 ^{ab} ± 0.07	0.42 ^b ± 0.04	0.38 ^{ab} ± 0.05	0.36 ^a ± 0.06	0.34 ^a ± 0.04	p < 0.001
Kidney fat (%)	1.07 ^a ± 0.19	1.32 ^{ab} ± 0.30	1.39 ^b ± 0.28	1.56 ^b ± 0.31	1.55 ^b ± 0.41	p < 0.001
Tail (%)	0.30 ^b ± 0.06	0.21 ^a ± 0.06	0.25 ^{ab} ± 0.08	0.20 ^a ± 0.06	0.22 ^a ± 0.05	p < 0.001
Belly (%)	12.27 ^a ± 0.67	12.50 ^{ab} ± 0.99	12.90 ^{ab} ± 0.98	13.28 ^{bc} ± 1.05	14.07 ^c ± 0.82	p < 0.001
Rib (%)	9.44 ± 0.57	9.81 ± 0.78	9.56 ± 0.63	9.64 ± 0.73	9.24 ± 0.75	p = 0.165
Loin (%)	7.49 ± 0.50	7.61 ± 0.52	7.66 ± 0.43	7.80 ± 0.44	7.62 ± 0.36	p = 0.348
Chump (%)	8.48 ± 0.40	8.33 ± 0.60	8.46 ± 0.50	8.54 ± 0.54	8.69 ± 0.62	p = 0.389
Thick rib (%)	25.91 ± 0.99	26.23 ± 1.13	26.57 ± 1.10	26.13 ± 1.08	26.27 ± 1.24	p = 0.434
Fore shin (%)	3.06 ^b ± 0.33	2.87 ^{ab} ± 0.31	2.66 ^a ± 0.27	2.65 ^a ± 0.26	2.75 ^a ± 0.31	p < 0.001
Back shin (%)	1.83 ^b ± 0.17	1.65 ^a ± 0.20	1.61 ^a ± 0.15	1.63 ^a ± 0.17	1.73 ^{ab} ± 0.11	p < 0.001
Leg (%)	19.03 ^b ± 0.85	18.97 ^b ± 0.68	18.58 ^b ± 0.83	18.51 ^b ± 0.81	17.77 ^a ± 0.55	p < 0.001
Fore trotters (%)	1.17 ^c ± 0.09	1.14 ^{bc} ± 0.12	1.02 ^a ± 0.10	1.03 ^a ± 0.11	1.06 ^{ab} ± 0.06	p < 0.001
Hind trotters (%)	1.13 ^b ± 0.13	1.13 ^b ± 0.13	1.04 ^a ± 0.13	1.02 ^a ± 0.16	1.03 ^a ± 0.09	p = 0.017
Carcass weight (kg)²	55.95 ^a ± 4.23	66.63 ^b ± 2.61	75.71 ^c ± 2.31	81.21 ^d ± 1.70	91.71 ^e ± 2.73	p < 0.001

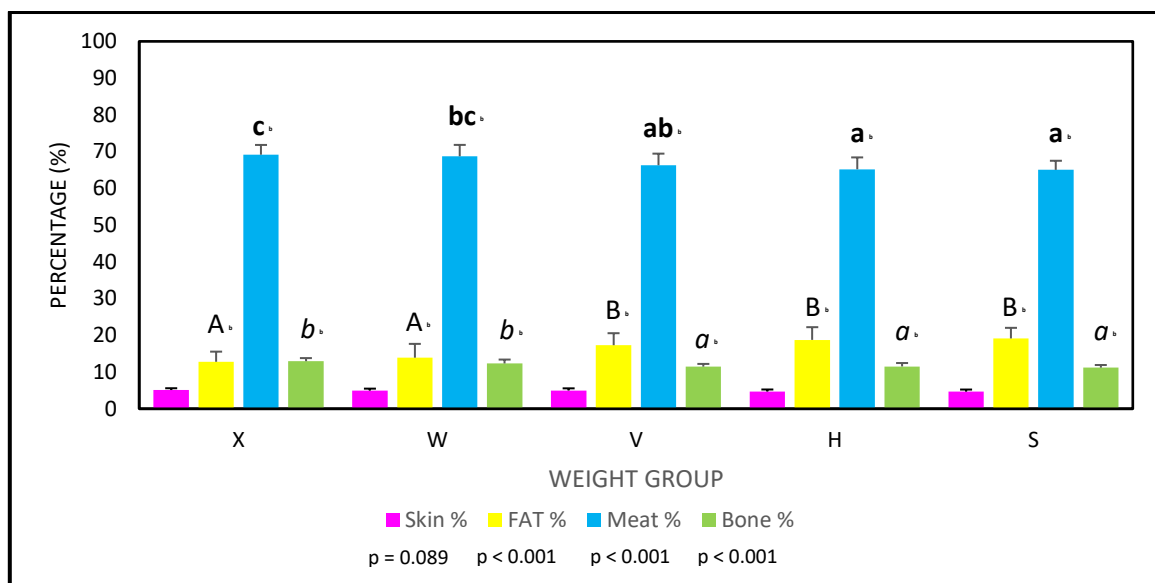
Carcass weight (kg)¹: Include head, trotters, kidney, kidney fat and tail

Carcass weight (kg)²: Exclude head, trotters, kidney, kidney fat and tail. Yield under classification regulation is expressed on this basis

Means with different superscripts in the same row differ significantly

group H to S. Weight group X and W were significantly ($p = 0.017$) higher than weight groups V, H, and S

Figure 4.11 shows the % of skin, meat, fat and bone that make up primal cuts of carcasses from different weight groups. Although not significant, the skin% tends to decrease as the carcass becomes heavier. The fat % increased as the carcass becomes heavier. The fat % of weight group X and W was significantly ($p < 0.001$) lower than that of weight groups V, H, and S. The meat % decreased as the carcass becomes heavier.



Skin % = Not Significant; Fat % = UPPERCASE Meat % = **lowercase bold**; Bone % = *lowercase italics*
 Means with different superscripts in the same category differ significantly.
 Expressed based on carcass weight excluding head, trotters, kidney, kidney fat and tail

Figure 4.11: The % of skin, meat, fat and bone that make up primal cuts of carcasses from different weight groups.

The meat % of weight group X was significantly ($p < 0.001$) higher than the meat % of weight groups V, H, and S (Figure 4.11). This proves once again that as the carcass becomes heavier, the higher the fat % and the lower the meat % that carcass will have. The bone % shows a trend that as the carcass becomes heavier, the % bone decreased. The bone % of weight group X and W were significantly ($p < 0.001$) higher than weight groups V, H, and S.

Table 4.15 shows the fat distribution across the different primal cuts of the carcass according to weight class. Once again it was clear that as in the case with the classification groups, the % fat of each primal cut increased as the carcass weight

increased. For the % fat in the belly, chump, thick rib and leg, weight group X and W had significantly ($p < 0.001$) lower % of fat in comparison to weight groups V, H, and S. For the % fat in the rib, loin and the hind shin, weight group X and W had a significantly ($p < 0.001$) lower % of fat in comparison to weight groups H and S. The % fat in the fore shin of weight group X (6.92%) was significantly ($p < 0.001$) lower than the % fat in the fore shin of weight groups H (9.53%) and S (10.57%) and weight group W (7.63%) had a significantly ($p < 0.001$) lower % of fat in the fore shin of weight group S (10.57%).

The fat distribution across the different primal cuts of the carcass according to weight class (fat content of cut expressed as % fat content of the whole carcass) (Table 4.16) indicated that there were almost no significant differences between the weight groups. The only significant differences were observed in the hind shin cut, where fat content of weight group X (2.40%) was significantly ($p < 0.011$) higher than weight group V (1.81%) and H (1.89%).

Table 4.7 to Table 4.13 showed the carcass characteristics, fat quality parameters, fatty acid composition and fatty acid ratios of BF of pigs from different classification groups. Table 4.14 to Table 4.20 focuses on the BF from different carcass weight groups. In other words, the five weight groups under the different classification groups. Table 4.17 clearly demonstrated that the FT by HGP increased as the carcass weight increased from group X to group S. Carcass weight group X and W were significantly ($p < 0.001$) lower than the FT by HGP for weight group V, H and S.

The muscle thickness by HGP decreased from weight group X to V and then increased from group V to S (Table 4.17). A possible reason for this observation may be that the current formula used by the HGP was only calibrated for carcasses up to 90 kg. Carcasses from the H and S weight groups exceed this 90 kg maximum. Weight groups W and V are significantly ($p < 0.001$) lower than the other weight groups. A similar trend could be seen with the % meat content by HGP, a decrease could be seen from weight group X to V and then an increase from weight group V to S. The % meat of weight group X was significantly ($p < 0.001$) higher than all the other weight classes and group W (71.42%) was significantly ($p < 0.001$) higher than group V (70.37%). There was a clear decrease in % meat content by dissection from weight group X to S. Weight group X was significantly ($p < 0.001$) higher than group V, H and

Table 4.15: Fat distribution across the different primal cuts of the carcass according to weight class.

% Of total dissected fat in each cut	X (n = 16)	W (n = 16)	V (n = 24)	H (n = 22)	S (n = 19)	Sign. level
Belly	20.73 ^a ± 5.80	22.61 ^a ± 7.28	28.60 ^b ± 5.56	28.57 ^b ± 5.76	29.79 ^b ± 5.70	p < 0.001
Rib	16.98 ^a ± 4.06	17.80 ^a ± 5.30	21.07 ^{ab} ± 5.27	23.83 ^b ± 5.38	24.49 ^b ± 4.79	p < 0.001
Loin	15.16 ^a ± 4.41	16.68 ^{ab} ± 5.18	20.01 ^{bc} ± 4.25	21.51 ^c ± 5.01	21.79 ^c ± 3.95	p < 0.001
Chump	14.58 ^a ± 3.57	16.69 ^a ± 4.61	20.51 ^b ± 4.47	21.46 ^b ± 4.34	21.78 ^b ± 3.11	p < 0.001
Thick Rib	9.71 ^a ± 2.24	10.04 ^a ± 2.45	12.51 ^b ± 2.46	13.62 ^b ± 2.74	14.27 ^b ± 2.26	p < 0.001
Fore shin	6.92 ^a ± 2.12	7.63 ^{ab} ± 3.32	8.63 ^{abc} ± 2.94	9.53 ^{bc} ± 2.29	10.57 ^c ± 2.49	p < 0.001
Hind shin	13.78 ^a ± 2.16	14.76 ^{ab} ± 3.37	16.81 ^{bc} ± 3.73	18.40 ^c ± 2.73	19.32 ^c ± 2.55	p < 0.001
Leg	8.80 ^a ± 2.36	9.77 ^a ± 2.52	12.82 ^b ± 2.70	13.29 ^b ± 2.74	13.76 ^b ± 1.92	p < 0.001

Means with different superscripts in the same row differ significantly.

Table 4.16: Fat distribution across the different primal cuts of the carcass according to weight class (fat content of cut expressed as % of fat content of whole carcass).

Fat content of cuts as % of fat content of whole carcass	X (n = 16)	W (n = 16)	V (n = 24)	H (n = 22)	S (n = 19)	Sign. level
Belly	22.93 ± 4.36	22.93 ± 3.34	24.31 ± 3.22	23.23 ± 3.18	24.94 ± 3.75	p = 0.312
Rib	14.30 ± 1.51	13.98 ± 1.73	13.22 ± 2.09	14.19 ± 2.17	13.34 ± 2.40	P = 0.314
Loin	9.87 ± 1.34	10.14 ± 1.22	10.07 ± 1.17	10.46 ± 1.44	9.84 ± 0.91	p = 0.547
Chump	11.04 ± 1.01	11.71 ± 1.41	11.35 ± 0.92	11.20 ± 1.36	11.27 ± 1.14	P = 0.527
Thick Rib	21.91 ± 2.01	21.73 ± 1.95	21.99 ± 2.26	22.24 ± 2.24	22.27 ± 2.02	p = 0.935
Fore shin	1.95 ± 0.43	1.61 ± 0.54	1.59 ± 0.58	1.56 ± 0.40	1.74 ± 0.47	p = 0.129
Hind shin	2.40 ^b ± 0.66	2.12 ^{ab} ± 0.70	1.81 ^a ± 0.47	1.89 ^a ± 0.35	2.03 ^{ab} ± 0.46	p < 0.011
Leg	14.80 ± 1.71	15.31 ± 1.85	15.65 ± 1.67	15.15 ± 1.82	14.58 ± 1.22	p = 0.288

Means with different superscripts in the same row differ significantly.

Table 4.17: Carcass characteristics, chemical and physical composition of backfat of pigs from different carcass weight groups.

Carcass mass class:	X (n = 16)	W (n = 16)	V (n = 24)	H (n = 22)	S (n = 19)	Sign. level
Classification parameters:						
Carcass mass	63.94 ^a ± 4.81	75.72 ^b ± 2.84	85.93 ^c ± 2.45	92.08 ^d ± 1.89	104.16 ^e ± 2.79	p < 0.001
Fat thickness by HGP	10.89 ^a ± 2.05	11.80 ^a ± 2.35	13.81 ^b ± 1.99	14.63 ^b ± 2.85	15.58 ^b ± 2.24	p < 0.001
Muscle thickness by HGP	94.34 ^{bc} ± 2.98	79.68 ^a ± 15.75	77.42 ^a ± 14.58	91.34 ^b ± 13.61	103.78 ^c ± 2.69	p < 0.001
% Meat content by HGP	72.64 ^c ± 0.79	71.42 ^b ± 1.64	70.37 ^a ± 0.76	70.76 ^{ab} ± 1.17	70.99 ^{ab} ± 0.93	p < 0.001
% Meat content by dissection	69.29 ^c ± 3.06	68.54 ^{bc} ± 3.14	66.01 ^{ab} ± 3.11	65.04 ^a ± 3.19	64.90 ^a ± 2.50	p < 0.001
Meat quality parameters:						
Drip loss of meat (%)	3.55 ± 1.34	3.82 ± 1.17	3.24 ± 0.98	2.81 ± 1.13	3.33 ± 0.82	p = 0.070
Muscle colour: L*	48.86 ± 2.15	48.62 ± 1.91	48.53 ± 1.64	48.32 ± 2.13	48.47 ± 1.71	p = 0.941
Muscle colour: a*	9.00 ± 1.21	8.49 ± 1.36	8.88 ± 1.23	8.31 ± 1.35	8.32 ± 1.34	p = 0.328
Muscle colour: b*	8.44 ± 0.94	8.15 ± 1.35	8.50 ± 0.99	8.06 ± 1.04	8.04 ± 1.25	p = 0.543
Muscle colour: Chroma	12.20 ± 1.35	11.79 ± 1.86	12.30 ± 1.53	11.59 ± 1.60	11.59 ± 1.75	p = 0.468
Muscle colour: Hue	43.93 ± 1.78	43.86 ± 2.30	43.87 ± 1.96	44.64 ± 2.50	43.73 ± 2.29	p = 0.707
% Intramuscular fat	2.04 ± 0.45	2.01 ± 0.47	2.26 ± 0.52	2.41 ± 0.58	2.40 ± 0.43	p = 0.051
Fat quality parameters:						
% Extractable Fat	66.64 ^a ± 5.32	69.05 ^a ± 8.97	75.01 ^b ± 5.43	75.88 ^b ± 5.65	76.60 ^b ± 3.49	p < 0.001
% Fat Free Dry Matter	10.62 ^b ± 3.11	10.25 ^b ± 2.87	8.73 ^{ab} ± 2.39	6.91 ^a ± 2.97	7.12 ^a ± 2.10	p < 0.001
% Moisture	22.88 ^b ± 3.98	19.65 ^{ab} ± 5.69	16.26 ^a ± 4.59	17.21 ^a ± 5.59	16.27 ^a ± 3.66	p < 0.001
Iodine value	70.31 ± 5.16	71.03 ± 6.11	70.25 ± 5.28	67.79 ± 4.21	70.70 ± 4.02	p = 0.288
Refraction Index	1.46044 ± 0.00063	1.46037 ± 0.00060	1.46015 ± 0.00057	1.46005 ± 0.00047	1.46036 ± 0.00048	p = 0.156

Means with different superscripts in the same row differ significantly.

Table 4.18: Fatty acid composition of backfat of pigs from different carcass weight groups.

Carcass mass class:	X (n = 16)	W (n = 16)	V (n = 24)	H (n = 22)	S (n = 19)	Sign. level
C12:0	0.01 ± 0.02	0.02 ± 0.03	0.01 ± 0.01	0.01 ± 0.02	0.01 ± 0.01	p = 0.538
C14:0	1.17 ± 0.23	1.13 ± 0.27	1.14 ± 0.16	1.12 ± 0.11	1.06 ± 0.11	p = 0.567
C15:0	0.03 ^b ± 0.03	0.02 ^{ab} ± 0.02	0.01 ^{ab} ± 0.02	0.01 ^a ± 0.02	0.01 ^a ± 0.02	p = 0.009
C16:0	23.25 ^a ± 1.39	23.67 ^{ab} ± 1.59	24.44 ^{ab} ± 1.63	24.67 ^b ± 1.24	23.89 ^{ab} ± 1.38	p = 0.026
C16:1c9	1.76 ± 0.34	1.61 ± 0.40	1.80 ± 0.41	1.96 ± 0.33	1.84 ± 0.27	p = 0.062
C17:0	0.36 ± 0.06	0.32 ± 0.10	0.29 ± 0.13	0.30 ± 0.10	0.31 ± 0.08	p = 0.214
C17:1c10	0.07 ± 0.12	0.10 ± 0.13	0.05 ± 0.10	0.03 ± 0.07	0.09 ± 0.11	p = 0.362
C18:0	11.62 ± 2.01	11.51 ± 1.58	11.90 ± 1.45	11.64 ± 1.12	11.13 ± 1.07	p = 0.567
C18:1t9	0.01 ± 0.02	0.01 ± 0.01	0.01 ± 0.02	0.01 ± 0.01	0.01 ± 0.02	p = 0.826
C18:1c9	37.21 ± 1.52	37.17 ± 1.79	37.00 ± 1.65	37.91 ± 1.63	36.98 ± 1.24	p = 0.338
C18:1c7	4.99 ± 0.33	4.73 ± 0.38	4.89 ± 0.46	4.95 ± 0.37	4.68 ± 0.28	p = 0.070
C18:2c9,12 (n-6)	17.28 ± 3.14	17.29 ± 3.78	16.25 ± 3.63	15.22 ± 2.94	17.60 ± 2.08	p = 0.138
C20:0	0.12 ± 0.02	0.14 ± 0.02	0.14 ± 0.02	0.14 ± 0.02	0.13 ± 0.01	p = 0.052
C18:3c9,12,15 (n-3)	1.28 ± 0.24	1.41 ± 0.26	1.33 ± 0.23	1.31 ± 0.15	1.46 ± 0.17	p = 0.105
C20:2c11,14 (n-6)	0.54 ^{ab} ± 0.12	0.60 ^b ± 0.17	0.51 ^{ab} ± 0.11	0.49 ^a ± 0.07	0.56 ^{ab} ± 0.09	p = 0.027
C22:1c13	0.05 ^b ± 0.02	0.05 ^{ab} ± 0.03	0.03 ^a ± 0.02	0.03 ^a ± 0.02	0.04 ^{ab} ± 0.02	p = 0.004
C20:3c11,14,17 (n-3)	0.07 ± 0.03	0.08 ± 0.04	0.07 ± 0.03	0.06 ± 0.03	0.09 ± 0.02	p = 0.055
C20:4c5,8,11,14 (n-6)	0.17 ± 0.03	0.15 ± 0.05	0.14 ± 0.04	0.14 ± 0.05	0.14 ± 0.03	p = 0.239

Means with different superscripts in the same row differ significantly.

Table 4.19: Fatty acid ratios of backfat of pigs from different carcass weight groups.

Carcass mass class:	X (n = 16)	W (n = 16)	V (n = 24)	H (n = 22)	S (n = 19)	Sign. level
Total SFA	36.56 ± 3.46	36.81 ± 3.03	37.92 ± 2.77	37.89 ± 2.04	36.53 ± 2.22	p = 0.262
Total MUFA	44.09 ± 1.84	43.66 ± 2.25	43.78 ± 2.28	44.89 ± 2.03	43.64 ± 1.42	p = 0.272
Total PUFA	19.35 ± 3.48	19.53 ± 4.22	18.30 ± 3.93	17.22 ± 3.14	19.83 ± 2.29	p = 0.138
Total n-6 FA	17.99 ± 3.27	18.04 ± 3.96	16.90 ± 3.74	15.85 ± 3.01	18.29 ± 2.14	p = 0.133
Total n-3 FA	1.35 ± 0.27	1.49 ± 0.30	1.40 ± 0.26	1.37 ± 0.17	1.54 ± 0.19	p = 0.097
PUFA:SFA	0.54 ± 0.14	0.54 ± 0.15	0.49 ± 0.14	0.46 ± 0.10	0.55 ± 0.09	p = 0.140
PUFA/MUFA	0.44 ± 0.08	0.45 ± 0.11	0.42 ± 0.11	0.39 ± 0.09	0.46 ± 0.06	p = 0.155
n-6/n-3 ratio	13.51 ^b ± 2.64	12.07 ^{ab} ± 1.26	12.12 ^{ab} ± 1.95	11.55 ^a ± 1.53	11.93 ^{ab} ± 1.05	p = 0.022
Atherogenicity Index	0.44 ± 0.06	0.45 ± 0.06	0.47 ± 0.05	0.47 ± 0.04	0.44 ± 0.04	p = 0.233
C18:0/C18:2 ratio	0.71 ± 0.24	0.72 ± 0.27	0.78 ± 0.22	0.80 ± 0.20	0.65 ± 0.12	p = 0.205
Double bond index	84.48 ± 6.93	84.51 ± 7.31	82.05 ± 6.66	80.99 ± 5.06	85.13 ± 4.45	p = 0.172
Peroxidizability index	22.31 ± 3.75	22.55 ± 4.54	21.21 ± 4.15	20.14 ± 3.30	22.89 ± 2.47	p = 0.149

Means with different superscripts in the same row differ significantly.

Table 4.20: A comparison between dissection of the left vs the right side of the carcass in terms of weight groups.

Weight Class	X (n = 16)	W (n = 16)	V (n = 24)	H (n = 22)	S (n = 19)	Overall
Left side total weight no trotters	28.42 ± 2.09	33.91 ^b ± 1.50	38.55 ^b ± 1.28	41.34 ^b ± 0.69	46.85 ^b ± 1.59	38.05 ± 6.06
Right side total weight no trotters	27.52 ± 2.17	32.72 ^a ± 1.47	37.16 ^a ± 1.16	39.88 ^a ± 1.16	44.86 ^a ± 1.23	36.66 ± 5.74
Significance levels	p = 0.243	p = 0.021	p < 0.001	p < 0.001	p < 0.001	p = 0.102
Left side muscle weight no trotters	20.04 ± 1.70	23.00 ± 1.50	25.27 ± 1.46	26.61 ± 11.33	30.05 ± 1.50	25.1 ± 3.41
Right side muscle weight no trotters	19.67 ± 1.69	22.68 ± 1.50	24.70 ± 1.46	20.16 ± 11.33	29.47 ± 1.50	24.64 ± 3.41
Significance levels	p = 0.545	p = 0.542	p = 0.149	p = 0.380	p = 0.278	p = 0.360
Left side % Yield	68.58 ± 2.75	67.78 ± 3.08	65.80 ± 2.96	64.37 ± 3.33	64.15 ± 2.78	65.98 ^a ± 3.39
Right side % yield	69.47 ± 2.59	69.31 ± 3.39	66.65 ± 3.47	65.75 ± 3.25	65.69 ± 2.47	67.21 ^b ± 3.47
Significance levels	p = 0.354	p = 0.164	p = 0.310	p = 0.189	p = 0.099	p = 0.015

Means with different superscripts in the same column differ significantly.

S. This just proves once again that the HGP is not able to predict meat of heavy carcasses, because the HGP overpredicted the % of meat for every single weight class.

No significant trends were observed between the carcass weight groups when it came to drip loss and the colour of the meat (Table 4.17). Although not significant, the meat quality parameters indicated a trend that showed that as the % IMF increased from weight group X to S, as the carcass weight increased. None of the carcass weight groups complied with the recommended 2.5% IMF proposed for a better eating quality by Fernandez, et al., (1999).

The fat quality parameters (Table 4.17) indicated that the % EFC increased from weight group X to group S. Weight group X and W had a significantly ($p < 0.001$) lower % EFC than groups V, H, and S. Both the % FFDM and the % moisture showed the same trend, there was an increase from weight group X to V and then a decrease from group V to S.

For the % FFDM (Table 4.17), the BF of weight group X and W had a significantly ($p < 0.001$) lower % FFDM than the BF of group H and S. For the % moisture, the BF of weight group X had significantly ($p < 0.001$) higher % moisture than the BF of groups V, H and S. The BF of weight group H (67.79%) was the only one which had an IV below the recommended 70, none of the other weight groups complied with this recommendation and none of the weight classes have BF with a RI below the recommended 1.4598.

Few of the FA showed significant differences between the weight groups (Table 4.18). There were however significant differences between the weight groups when it came to pentadecylic acid (C15:0), C16:0, C20:2 and C22:1. The % C15:0 of weight group X was significantly ($p = 0.009$) higher than weight groups H and S. The % C16:0 of weight group X (23.25%) was significantly ($p = 0.026$) lower than the % C16:0 of weight groups H (24.67%). The % C16:0 increased from weight group X to H and then decreased from group H to S. The % C20:2 of weight group W (0.60%) was significantly ($p = 0.027$) higher than weight group H (0.49%). The % C22:1 of weight group X was significantly ($p = 0.004$) higher than the % C22:1 of groups V and H. No weight group as a whole could comply with the requirements of having more than 12% C18:0 and less than 15% C18:2.

C16:0, C18:1c9 and C18:2 were the FAs which made up most of the BF. According to Table 4.19, none of the weight groups had more than the recommended 41% SFA (Häuser & Prabucki, 1990), but all the weight groups had less than 57% MUFAs and less than 19-21% PUFAs. For the *n-6/n-3* ratio, weight group X (13.51) had a significantly ($p = 0.022$) higher ratio than weight group H (11.55). None of the weight classes as a whole had a DBI of lower than the recommended 80. The only group that came close to this was group H which had a DBI of 80.99.

Table 4.20 depicts the comparison between dissections of the left vs. right side of the carcass, but in terms of weight groups. This was done in order to determine if only one side of the carcass can be dissected for future research, in order to save a lot of time and money. The left side and right side of the total weight, without trotters, were compared for the weight groups and it was found that the left side for weight group W, V, H, and S, was significantly higher weights than the right side. No significant ($p = 0.360$) differences were found between the left side and right side muscle weight, without the trotters, between any of the weight groups.

There were no significant differences between the weight groups when the left side and right side % yield was compared, overall the right side % yield was significantly ($p = 0.015$) higher than the left side % yield (Table 4.20). As in the case with Table 4.13, Table 4.20 indicates that more attention should be given to halve the carcasses accurately in order to ensure that only one side of the carcass can be used for dissection and that the sides will be exactly the same.

It was not possible to statistically analyze the interaction between yield groups and weight groups since pork carcasses of all weight groups was not available within each yield group.

CHAPTER 5

GENERAL DISCUSSION AND CONCLUSIONS

Consumers today have gained more knowledge and awareness regarding the association between health and nutrition, and therefore their perception of meat quality is changing. The consumers are now demanding changes in their food products, because of the benefits a healthy diet provides (Grunert, 2006). Consumers have shown an increasing preference for products that contain high amounts of UFAs (Wood, et al., 2008). The meat industry has responded to consumer demands by producing heavier pigs which have more lean meat and more UFAs (Andersen, 2000; Peiretti, et al., 2015).

Pigs from very lean strains are frequently observed to have fat quality defects (Santoro, 1983). The leaner pork meat may be desired by the health-conscious consumers, but to meat processors, this meat creates a serious problem (Houben & Krol, 1983; Stiebing, et al., 1993; Warnants, et al., 1998; Teye, et al., 2006).

In order to gain more information about the food that consumers consume, they demand more information about the quality of the products they purchase, and this is why a classification system is required (Grunert, 2006; Strydom, 2011). The carcass classification system gives an indication of the meat quality and it is used to predict the amount of meat from the carcass that can be sold (Strydom, 2011). In South Africa, manually used probes such as the HGP or Intrascope are used to classify pig carcasses into one of the six classification groups, namely PORCUS. The probes take carcass measurements and these measurements are put into equations and the pigs are classified accordingly (Siebrits, et al., 2012).

The equations used by the probes were calculated by Bruwer in 1992. Since 1992, the composition of pigs has changed and the equations used by the probes have not been revised and therefore there was an urgent appeal from the meat industry for the pork classification system to be revised (Siebrits, et al., 2012). This study demonstrated that the HGP no longer classifies pigs correctly. Pigs were classified by the HGP and then reclassified based on the true meat yield by dissection and it was found that the

HGP classified only 26.8% of the pigs correctly. According to the HGP, there were no pigs that fell under the C, U, and S classification groups, but after reclassification based on the dissection data, it was found that there were 36 pigs that fell under these classification groups. This means that the retailer is paying more for the carcasses than they are worth.

The data clearly shows that the % true meat yield by dissections gives better correlations with most of the meat quality parameters, fatty acids and fatty acid ratios in comparison with the % meat yield predicted by the HGP. In fact, in some cases, the correlations are not significant when it comes to the % meat yield predicted by HGP but they show strong correlations when it comes to the % meat yield by dissection. This proves that the HGP predictions are no longer accurate.

Throughout the study it was found that the heavier carcasses were found in the lower yield classes and these classes also had higher levels of fat. As the % LMC decreased and the BFT increased, the % kidney, fore shin, leg and fore trotter decrease and the % kidney fat, belly and rib increase. The fat distribution across the different primal cuts show that from classification group P to classification group S, all the cuts show an increase in the % fat found in that specific cut.

All the way throughout the study, there is a constant contrast between classification group P and classification group S. According to the data, classification group P had the highest amount of drip loss and the lowest % IMF. This shows us that classification group P has a poor quality of meat from the processors point of view. The S classification group was in fact the only classification group that had more than the recommended 2.5% IMF and had the lowest amount of drip loss.

Lizardo, et al. (2002) stated that a good quality fat should contain more than 12% C18:0 and Whittington, et al. (1986) set the limit for C18:2 at less than 15%. The fatty acid analysis indicated that from all the classification groups only classification groups O and S had more than the recommended 12% C18:0 and less than 15% C18:2. It was also found that as the % LMC decreased and the BFT increased, the amounts of C16:0, C18:1c9 in the BF increased and the amount of C18:2 in the BF decreased. This indicates that the heavier carcasses will have BF with a better consistency and the fat quality increased as the BFT increased.

The data shows that there were significant differences in the BF quality of the different classification groups (PORCUS). Overall, from a processors point of view, the P and O classification groups could not comply with the international standards proposed for good quality BF. This is problematic because most of the pigs produced in South Africa fall under the P and O classification group. The increased BFT and decreased LMC can, therefore, be linked with increased fat quality. As the LMC decreased and the BFT increased, the SFA, MUFA, AI, and C18:0/C18:2 ratio increased, while the PUFA, *n*-6, PUFA: SFA, PUFA/MUFA, DBI, and PI decreased.

The most commonly used fat quality parameter is the IV. Barton-Gade (1983) proposed that an IV of less than 70 should be the cut-off point for a good quality fat. Classification group P and O had an unacceptable high IV, while classification groups R to S, had acceptable IV with good technological properties. The RI can also be used to determine fat quality. Classification group S was the only group that had a RI of lower than 1.4598. This indicates that pigs from classification group R, C, U, and S have the highest probability of having a good quality fat. Results show that the pigs in the S classification group have a more saturated FA profile, a lower PUFA content and lower PI, and this in turn results in lower *n*-6 and *n*-3 FA and *n*-6/*n*-3 ratios.

It is very unlikely that pig producers will start to produce more pigs in the C to S classification groups in order to improve the fat quality of their pigs. The South African payment system does not encourage the production of fat pigs because it has a lean meat rewarding strategy, meaning that they pay more per kg lean. Suppliers find it more economical to produce pigs in the P and O groups which have a high LMC and a low BFT (Roodt, 2003). Throughout the study the yield group has better correlations with fat quality than weight groups.

Multiple regression analysis indicated that the HGP over-predicts the lean yield with Bruwer's 1992 equation. The new recalculated equation, shows there is a much higher decrease in lean yield with every 1 mm increase in FT. The reason is the difference in the slope of the regression line and this is most likely why the % LMC is overpredicted with the use of Bruwer's 1992 equation on today's carcasses. The old formula has a better R^2 value than the new formula. The reason for that is that Bruwer used almost three times more carcasses in his 1992 study compared to the current study.

This study has shown that the formulas used by the HGP are no longer accurate, but the formulas cannot be changed based on the research done. Before the formulas can be changed officially, the study would have to be done on a much larger scale and under more controlled conditions. The pig samples would have to be more uniform. To achieve this the pigs would have to be fed the same feeds, they would have to be transported under the exact same conditions and for the same amount of time and the carcasses would have to be kept at the same temperature. Many more pigs would have to be used, and the same amount from each classification group should be used.

The meat processing industry plays an important role in the pig industry, therefore it will be more important to fulfil the needs of this industry (Bruwer, 1992). However, there is a conflict of interest regarding the fat quality as the meat processor requires saturated fat for good quality products whereas the consumers demand unsaturated, healthier fat (Warnants, et al., 1998). A solution to this could be for producers to produce pigs intended for the processing industry, while others could produce pigs for the fresh meat market. In order to do so, the feed of the pigs intended for processing would have to contain more SFAs, which would result in the pigs obtaining BF which consists of more SFA and this will lead to a better fat quality in meat products (Roodt, 2003). The feed of the pigs intended for the fresh meat market would have to be enriched with n-3 PUFA, which would satisfy the health-conscious consumers. To ensure that the quality of the pig carcasses does not deteriorate, there should be constant monitoring of the fat quality at abattoirs (Roodt, 2003).

CHAPTER 6

REFERENCES

- Adzitey, F., & Nurul, H. (2011). Pale soft exudative (PSE) and dark firm dry (DFD) meats: Causes and measures to reduce these incidences - a mini review. *International Food Research Journal*, 18, pp. 11-20.
- Affentranger P., Gerwig C., Seewer G. J. F., Schwörer D., Künzi N. (1996). Growth and carcass characteristics as well as meat and fat quality of three types of pigs under different feeding regimens. *Livestock Production Science*, 45, pp. 187-196.
- Alais, C., & Linden, G. (1991). *Food Biochemistry*. Chichester: Ellis Horwood. West Sussex.
- Alam, S. Q., & Alam, B. S. (1986). Effect of essential fatty acid deficiency on acyl group composition, membrane fluidity and adenylate cyclase activity in plasma membranes of rat submandibular salivary glands. *Journal of Nutrition*, 116, pp. 1620-1630.
- Alfaia, C. M. M., Castro, M. L. F., Martins, S. I. V., Portugal, A. P. V., Alves, S. P. A., Fontes, C. M. G. A., Bessa, R. J. B., Prates, J. A. M. (2007). Effect of slaughter season on fatty acid composition, conjugated linoleic acid isomers and nutritional value of intramuscular fat in Barrosã-PDO veal. *Meat Science*, 75, 44-52.
- AMSA. (2012). Meat colour measurement guidelines. American Meat Science Association. [Available on the internet:] www.meatscience.org, 5 May 2017.
- Andersen, H. J. (2000). What is pork quality? In C. Wenk, J.A. Fernandez, & M. Dupuis, *Quality of meat and fat in pigs as affected by genetics and nutrition*. Proceedings of the joint session of the EAAP commissions on pig production, animal genetics and animal nutrition (pp. 15-26). Zurich, Switzerland: Wageningen: Wageningen Pers.

- Arkfeld, E. K., Mohrhauser, D. A., King, D. A., Wheeler, T. L., Dilger, A. C., Shackelford, S. D., & Boler, D. D. (2017). Characterization of variability in pork carcass composition and primal quality. *Animal Science*, *95*, pp. 697-708.
- Association of Analytical Chemists. (2005). *Official Methods of Analysis (18th edition)*. Washington DC, USA: AOAC.
- Babol, J., & Squires, E. J. (1995). Quality of meat from entire male pigs. *Food Research International*, *28*, pp. 201-212.
- Barton-Gade, P. A. (1983). Some experience on measuring the quality of pork fat. In J. D. Wood, *Fat quality in lean pigs*, Meat Research Institute Special Report No. 2, Document number EUR 8901 EN, (pp. 47-52), CEC Workshop, Brussels, Belgium.
- Barton-Gade, P. A. (1987). Meat quality in boars, castrates and gilts. *Livestock Production Sciences*, *16*, pp. 187-196.
- Barton-Gade, P. A., & Bejerholm, A. C. (1985). Eating quality in pork. *Pig Farming*, *33*, pp. 56.
- Berg, F. (2006). Genetic Analysis of Fat Metabolism in Domestic Pigs and their Wild Ancestor. Acta Universitatis Upsaliensis. *Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Medicine 164*, Uppsala.
- Bernués, A., Olaizola, A., Corcoran, K. (2003). Extrinsic attributes of red meat as indicators of quality in Europe: an application for market segmentation. *Food Quality and Preference*, *14*, pp. 265-276.
- BFAP. (2013). Evaluating the South African pork value chain. Bureau for Food and Agricultural Policy. [Available on the internet:] www.bfap.co.za, 24 February 2018.
- BFAP. (2014). Evaluating the competitiveness of South African pork production within the global context. Bureau for Food and Agricultural Policy. [Available on the internet:] www.bfap.co.za, 24 February 2018.

- Bothma, C. (2012). The effect of dietary conjugated linoleic acid supplementation on the physicochemical, nutritional and sensory qualities of pork. Ph.D. Dissertation, University of the Free State, Bloemfontein, South Africa.
- Bredahl, L., & Andersson, M. (1998). What is pork quality? Results of a quantitative study. *Proceedings 44th international congress of meat science and technology*, (pp. 926-927). Barcelona, Spain.
- Brewer, M. S., (2012). Consumer attitudes towards colour and marbling of fresh pork. Pork Information Gateway. [Available on the internet:] www.porkgateway.org, 19 October 2018.
- Bruwer, G. G. (1992). The evaluation of pig carcasses for the development of a classification system. Ph.D. Dissertation, University of Pretoria, Pretoria, South Africa.
- Busk, H., Olsen, E. V., & Brøndum, J. (1999). Determination of lean meat in pig carcasses with the Autofom classification system. *Meat Science*, 52(3), pp. 307-314.
- Cameron, N. D., Warris, P. D., Porter, S. J., & Enser, M. B. (1990). Comparison of Duroc and British Landrace pigs for meat and eating quality. *Meat Science*, 27, pp. 227-247.
- Candek-Potokar, M., Zlender, B., Lefaucheur, L., & Bonneau, M. (1998). Effects of age and/or weight at slaughter on *longissimus dorsi* muscle: Biochemical traits and sensory quality in pigs. *Meat Science*, 48, pp. 287-300.
- Cheng, Q., & Sun, D. (2008), Factors affecting water holding capacity of red meat products: A review of recent research advances, *critical reviews in Food Science and Nutrition*, 48(2), pp. 137-159.
- Chilliard, Y., Ferlay, A., Rouel, J., & Lamberet, G. (2003). A review of nutritional and physiological factors affecting goat milk lipid synthesis and lipolysis. *Journal of Dairy Science*, 86(5), pp. 1751-1770.

- CIE. (1986). Commission Internationale de l'Eclairage, Recommendations on uniform colour spaces \pm colour differences equations, psychometric colour terms. Supplement no. 2 to CIE Publication no. 15 (E-1.3.1) 1971/ (TC-1-3). Paris.
- Davenel, A., Riaublanc, A., Marchal P., & Gandemer, G. (1999). Quality of pig adipose tissue: relationship between solid fat content and lipid composition. *Meat Science*, 51, pp. 73-79.
- Davids, M. P., Jooste, A., & Meyer, F. H. (2014). Evaluating the South African pork value chain. [Available on the internet:] www.ifama.org, 7 March 2017.
- De Lange, C. F., Morel, P. C., & Birkett, S. H. (2003). Modelling chemical and physical body composition of the growing pig. *Animal Science*, E159-E165.
- DOA. (2004) Red meat regulations. Department of Agriculture. The Meat Safety Act, 2000 (Act No. 40 of 2000). Government Gazette No. 26779, 17 September 2004. Regulation Gazette No. 8056.
- Dugan, M. E., Vahmani, P., Turner, D. T., Mapiye, C., Juárez, M., Prieto, N., Beaulieu, A. D., Zijlstra, R. T., Patience, J. F., & Aalhus, J. L. (2015). Pork as a source of omega-3 (n-3) fatty acids. *Clinical Medicine*, 4(12), pp. 1999-2011.
- Engel, B., Buist, W. G., Walstra, P., Olsen, E., & Daumas, G. (2003). Accuracy of prediction of percentage lean meat and authorization of carcass measurement instruments: Advance effects of incorrect sampling of carcass in pig classification. *Animal Science*, 76, pp. 199-209.
- Enser, M. (1983). The relationship between composition and consistency of pig backfat. In J.D. Wood, Fat quality in lean pigs, Meat Research Institute Special Report No. 2, Document number EUR 8901 EN, (pp.53-57). CEC Workshop, Brussels, Belgium.
- Extension. (2011). What causes dark, firm and dry (DFD) pork? [Available on the internet:] www.eXtension.org, 8 May 2017.
- FAO. (2009). How to feed the world in 2050. Food and Agriculture Organization. [Available on the internet:] www.fao.org, 5 February 2018.

- Fernandez, X., Monin, G., Talmant, A., Mourot, J., & Leuret, B. (1999). Influence of intramuscular fat content on the quality of pig meat – 2. Consumer acceptability of *M. Longissimus Lumborum*. *Meat Science*, 53, pp. 67-72.
- Ferreira, J. P. (2014). The effect of dietary conjugated linoleic acid supplementation on production efficiency and meat quality of pigs. Ph.D. Dissertation, University of the Free State, Bloemfontein, South Africa.
- Fischer, A. (1989) Requirements asked from and properties found in pig's fatty tissue: on the processing of fats from slaughter animals. Part II. *Die Fleischerei*, 9, pp. iii-v.
- Folch, J., Lees, M., & Sloane-Stanley, G. H. (1957). A simple method for the isolation and purification of total lipids from animal tissue. *Journal of Biological Chemistry*, 226, pp. 497-509.
- Fortin, A. (1986). Development of backfat and individual fat layers in the pig and its relationship with carcass lean. *Meat Science*, 18(4), pp. 255-270.
- Frank, D., Joo, S., & Warner, R. (2016). Consumer acceptability of intramuscular fat. *Korean Journal for Food Science of Animal Resources*, 36(6), pp. 699-708.
- Furman, M., Malovrh, S., Levart, A., & Kovac, M. (2010). Fatty acid composition of meat and adipose tissue from Krškopolje pigs and commercial fatteners in Slovenia. *Archiv Tierzucht*, 53, pp. 73-84.
- Garcia-Olmo, J., De Pedro, E., Garrido, A., Paredes, A., Sanabria, C., Santolalla, M., Salas, J., García-Hierro, J. R., Gonzalez, I., García-Cachan, M. D., & Guirao, J. (2002). Determination of the precision of the fatty acid analysis of Iberian pig fat by gas chromatography. Results of a mini collaborative study. *Meat Science*, 60, pp. 103-109.
- Genesis. (2016). Consumers and pork quality - Tenderness. [Available on the internet:] www.thepigsite.com, 15 May 2017.
- Ghaeni, M., Ghahfarokhi, K. N., & Zaheri, L. (2013). Fatty acid profile, atherogenic (IA), and thrombogenic (IT) health lipid indices in *Leiognathus bindus* and *Upeneaus sulphureus*. *Journal of Marine Science*, 3(4), pp. 1-3.

- Giorda, M. C., Bossi, L., Messina, E. (2014). Food and religion (in public food service). Consorzio Risteco, Turin, Italy. pp. 4-6
- Grau, R., & Hamm, G. (1953). "Eine einfache methode zur bestimmung der wasserbindung im muskel". *Die Naturwissenschaften*, 40, pp. 29-30.
- Gray, J. I., Gomma, E. A., & Buckley, D. J. (1996). Oxidative quality and shelf life of meats. *Meat Science*, 43, S111-S123.
- Griffiths, R. (2014). Importance of oxidative stability in the shelf life of foods and ingredients. [Available on the internet:] www.rssl.com, 11 May 2017.
- Grimbeek, P. J., Davids, T., & Human, M. (2014). South Africa: Challenges in an isolated industry. [Available on the internet:] www.pigprogress.net, 18 July 2017.
- Grunert, K. G. (2006). Future trends and consumer lifestyles with regard to meat consumption, *Meat Science*, 74, pp. 149-160.
- Häuser, A., & Prabucki, A. L. (1990). Ergebnisse eines "screenings" betreffend die Fettqualität bei mastschweinen in schweizerischen schlachthöfen. *Journal of Animal Physiology and Animal Nutrition*, 27, pp. 227-247.
- Hayenga, M. L., Grisdale, B. S., Kauffman, R. G., Cross, H. R., & Christian, L. L. (1985). A Carcass Merit Pricing System for the Pork Industry. *American Journal of Agricultural Economics*, 67(2), pp. 315–319.
- Hegsted, D. M., Gotsis, A., Stare, F. J., & Worcester, J. (1959). Interrelations Between the Kind and Amount of Dietary Fat and Dietary Cholesterol in Experimental Hypercholesterolemia. *The American Journal of Clinical Nutrition*, 7, pp. 5-12.
- Honikel, K. (1998). Reference methods for the assessment of physical characteristics of meat. *Meat Science*, 49(4), pp. 447-457.
- Honkavaara, M. (1989). Influence of porcine stress and breed on the fatty acid profiles of subcutaneous and intramuscular total lipids. *Meat Science*, 69(9), pp. 1429-1432.

- Houben, J. H., & Krol, B. (1983). Pig fats and the manufacture and storage of meat products. In J.D. Wood, *Fat quality in lean pigs*. Meat Research Institute Special Report No. 2, Document number EUR 8901 EN, CEC Workshop, Brussels, Belgium.
- Huff-Lonergan, E. (2010). Water-holding capacity of fresh meat. [Available on internet:] www.extension.org, 8 June 2017.
- Huff-Lonergan, E., & Lonergan, S. M. (2005). Mechanisms of water-holding capacity of meat: The role of post-mortem biochemical and structural changes. *Meat Science*, 71, pp. 194-204.
- Huff-Lonergan, E., Page, J. (2001). The role of carcass chilling in the development of pork quality. National Pork Producers Council. pp. 1-8.
- Hughes, J. M., Oiseth, S. K., Purslow, P. P., & Warner, R. D. (2014). A structural approach to understanding the interactions between colour, water-holding capacity and tenderness. *Meat Science*, 98(3), pp. 520-532.
- Hugo, A., & Roodt, E. (2007). Significance of porcine fat quality in meat technology: A review. *Food Reviews International*, 23, pp. 175-198.
- Hugo, A., & Roodt, E. (2015). Fat quality of South African pigs with different carcass classification characteristics. *Animal Science*, pp. 302.
- Ingr, I. (1989). Meat Quality. Defining the term by modern standards. *Fleischwirtschaft*, 69, pp. 1268-1270.
- Irie, M., & Sakimoto, M. (1992). Fat characteristics of pigs fed fish oil containing eicosapentaenoic and docosahexaenoic acids. *Animal Science*, 70(2), pp. 470-477.
- Jansons, I., Strazdina, V., Anenkova, R., Pule, D., Skadule, I., & Melece, L. (2016). Development of new pig carcasses classification formulas and changes in the lean meat content in Latvian pig population. *Agronomy Research*, 14(2), pp. 1306-1314.

- Jankowska, B., Zakes, Z., Zmijewski, T., & Szczepkowski, M. (2010). Fatty acid profile of muscles, liver and mesenteric fat in wild and reared perch (*Perca fluviatilis* L.). *Food Chemistry*, 118, pp. 764-768.
- Johnston, L. J., & Li, X. (2011). Fat hardness in swine products, dietary challenges and opportunities. *Meat Science*, pp. 191-200.
- Kasprzyk, A. (2007). Characteristics of genetic parameters and genetic gain in breeding herd of Polish Landrace pigs over 25-year breeding work period. *Archiv Tierzucht, Dummerstorf*, 50, Special Issue, pp. 107-115.
- Kasprzyk, A., Tyra, M., & Babicz, M. (2015). Fatty acid profile of pork from local and a commercial breed. *Animal Breed*, 58, pp. 379-385.
- Kauffman, R. G., Cassens, R. G., Scherer, A., & Meeker, D. L. (1992). Variations in pork quality; history, definition, extent, resolution. A National Pork Processors Council Publication. NPPC. Washington, D. C. USA.
- Keeler, J. (2010). *Understanding NMR Spectroscopy*. (2nd Ed). UK: John Wiley & Sons.
- Kemin. (2009). The interaction between meat quality, lipid oxidation and antioxidants in animal diets. [Available on the internet:] www.kemin.com, 5 May 2017.
- Kempster, A. J., Dilworth, A. W., Evans, D. G., & Fisher, K. D. (1986). The effects of FT and sex on pig meat quality with special reference to the problems associated with overleaness. *Animal Production*, 43, pp. 517-533.
- Kropf, D. H. (2003). Enhancing meat colour stability. *Proceeding of the 56th American Meat Association Reciprocal Meat Conference*, (pp. 73-75). Columbia, Missouri.
- Kühne, D. (1983). Fat quality in lean pigs. In J.D. Wood, *Fat quality in lean pigs*. Meat Research Institute Special Report No. 2, Document number EUR 8901 EN, CEC Workshop, Brussels, Belgium.
- Lea, C. H., Swoboda, P. A., & Gatherum, D. P. (1970). A chemical study of soft fat in cross bred pigs. *Agricultural Sciences*, 74(2), pp. 279-289.

- Lee, Y. B., & Choi, Y. I. (1999). PSE (pale, soft, exudative) pork: The cause and solutions - Review. *Animal Science*, 12(2), pp. 244-252.
- Lindahl, G. (2005). Colour characteristics of fresh pork. Ph.D. Dissertation, Swedish University of Agricultural Sciences, Uppsala. pp. 9-20.
- Lizardo, R., van Milgen, J., Mourot, J., Noblet, J. & Bonneau, M. (2002). A nutritional model of fatty acid composition in the growing-finishing pig. *Meat Science*, 75, pp. 167-182.
- Liu, A. G., Ford, N. A., Hu, F. B., Zelman, K. M., Mozaffarian, D., & Kris-Etherton, P. M. (2017). A healthy approach to dietary fats: understanding the science and taking action to reduce consumer confusion. *Nutritional Journal*, 16(53), pp. 1-15.
- Lui, L., Ngadi, M. O., Prasher, S. O., & Gariépy, C. (2010). Categorization of pork quality using Gabor filter-based hyperspectral imaging technology. *Journal of Food Engineering*, 99, pp. 287-293.
- MacDougall, D.B. (1977). Colour in meat. In: G.G. Birch, J.G. Brennan and K. Parker (Eds.), *Sensory properties of foods*. Applied Science Publishers, London, pp. 59.
- Madsen, A., Jakobsen, K., & Mortensen, H. P. (1992) Influence of dietary fat on carcass fat quality in pigs. A review. *Acta Agriculturae Scandinavica, section A. Animal Science*, 42, pp. 220-225.
- Majid, H. A. M. A., Shariff, S. N. F. A., Majid, M. A. A., Aszahar, N. F. F. C., & Omar, N. S. (2015). Nutritional labelling: awareness and its effects towards consumer behaviour in purchasing product. *Journal of Applied Environmental and Biological Sciences*, 5(6S), pp. 62-68.
- Marchello, J. A., & Dryden, F. D. (1968). While ideas differ... Meat quality is defined. *Progressive Agriculture in Arizona*. College of Arizona. pp. 14-15.
- Marcoux, M., Pomar, C., Faucitano, L., & Brodeur, C. (2007). The relationship between different pork carcass lean yield definitions and the market carcass value. *Meat Science*, 75(1), pp. 94-102.

- Maw, S. J., Fowler, V. R., Hamilton, M., & Petchey, A. M. (2003). Physical characteristics of pig fat and their relation to fatty acid composition. *Meat Science*, 63, pp. 185-190.
- McGlone, J. J. (2013). The future of pork production in the world: towards sustainable, welfare-positive systems. *Animals*, 3, pp. 401-415.
- Mckeith, R. O. (2010). Quality and composition traits in pork. M.Sc. Dissertation, University of Georgia, Athens, GA. pp. 1-27.
- Meat Suite. (2012). Weights and pricing. [Available on the internet] www.meatsuite.com, 9 June 2018.
- Metz, S. H. (1983). Genetic effects on fat deposition and fat quality in the growing pig. *Pig News and Information*, 6, pp. 291-294.
- Miklos, R., Xu, X., & Lametsch, R. (2011). Application of pork fat diacylglycerols in meat emulsions. *Meat Science*, 87, pp. 202-205.
- Mitchell, A., D., Scholz, A. M., & Pursel, V. G. (2003). Changes in body composition when young pigs are restricted to near maintenance dietary intake. *International Journal of Body Composition Research*, 1, pp. 123–128.
- Monziols, M., Bonneau, M., Davenel, A., & Kouba, M. (2007). Comparison of the lipid content and fatty acid composition of intramuscular and subcutaneous adipose tissue in pig carcasses. *Meat Science*, 76, pp. 54-60.
- Morrissey, P. A., Sheehy, P. J., Galvin, K., & Kerry, J. P. (1998). Lipid stability in meat and meat products. *Meat Science*, 49, S73-S86.
- NCSS. (2016). Statistical system for Windows. Number Cruncher Statistical Systems, Kaysville, Utah, USA.
- Ngapo, T. M., Babare, I. H., Reynolds, J., & Mawson, R. F. (1999). Freezing and thawing rate effects on drip loss from samples of pork. *Meat Science*, 53(3), pp. 149-158.
- Ngapo, T. M., Riendeau, L., Laberge, C., & Fortin, J. (2012). Marbling and aging - Part 1. Sensory quality of pork. *Food Research International*, 49, pp. 396-405.

- Ngapo, T.M., Martin, J.-F. & Dransfield, E. (2002). Consumer preferences of pork chops: an international cross-cultural comparison. *Proceedings 48th International Congress of Meat Science and Technology* pp. 150-151, Rome, Italy.
- NHF. (2016). Closer look at South African pork market shows. National Hog Farmer. [Available on internet:] www.nationalhogfarmer.com, 9 March 2018.
- Nürnberg, K., Fisher, K., Nürnberg, G., Kuechenmeister, U., Klosowska, D., Eliminowska-Wenda, G., Fiedler, I., & Ender, K. (2005). Effects of dietary olive and linseed oil on lipid composition, meat quality, sensory characteristics and muscle structure in pigs. *Meat Science*, 70, pp. 63-74.
- OECD. (2018). Meat consumption (indicator). Organisation for Economic Cooperation and Development. [Available on internet:] www.data.oecd.org, 9 June 2017.
- OMAFRA. (2016). Meat pH and pork quality. Ontario Ministry of Agriculture, Food and Rural Affairs. [Available on internet:] www.omafra.gov.on.ca, 19 October 2018
- Otto, G., Roehe, R., Looft, H., Thoelking, L., & Kalm, E. (2004). Comparison of different methods for determination of drip loss and their relationships to meat quality and carcass characteristics in pigs. *Meat Science*, 68, pp. 401-409.
- Pamplona, R., Portero-Otin, M., Riba, D., Ruiz, C., Prat, J., Bellmunt, M. J., & Barja, G. (1998). Mitochondrial membrane peroxidizability index is inversely related to maximum life span in mammals. *Journal of Lipid Research*, 39, pp. 1989-1994.
- Park, J. C., Kim, S. C., Lee, S. D., Jang, H. C., Kim, N. K., Lee, S. H., Jung, H. J., Kim, I. C., Seong, H. H., Choi, B. H. (2012). Effects of dietary fat types on growth performance, pork quality, and gene expression in growing-finishing pigs. *Animal Science*, 25(12), pp. 1759-1767.
- Pauly, C., Spring, P., O'Doherty, J. V., Kragten, S. A., & Bee, G. (2009). Growth performance, carcass characteristics and meat quality of group-penned surgically castrated, immunocastrated (Improvac®) and entire male pigs and individually penned entire male pigs. *Animal*, 3, pp. 1057-1066.

- Peiretti, P. G., Gai, F., Brugiapaglia, A., Mussa, P. P., & Meineri, G. (2015). Fresh meat quality of pigs fed diets with different fatty acid profiles and supplemented with red wine solids. *Food Science and Technology*, 35(4), pp. 633-642.
- Piedrafita, J., Christian, L. L., & Lonergan, S. M. (2001). Fatty acid profiles in three stress genotypes of swine and relationships with performance, carcass and meat quality traits. *Meat Science*, 57, pp. 71-77.
- Pietro Lo Fiego, D., Mocchioni, P. Minelli, G., & Santoro, P. (2010). Lipid composition of covering and intramuscular fat in pigs at different slaughter age. *Italian Journal of Animal Science*. 9(2), e39.
- Pietruszka, A., Jacyno, E., Kawecka, M., & Biel, W. (2015). The relationship between intramuscular fat level in the *Longissimus* muscle and the quality of pig carcasses and meat. *Animal Sciences*, 15(4), pp. 1031-1041.
- Pomar, C., Marcoux, M., Gispert, M., & Font i Furnols, M. (2009). Determining the lean content of pork carcasses. In: *Improving the sensory and nutritional quality of fresh meat*. pp. 493-518.
- Prabucki, A. L. (1991). Qualitätsanforderungen a Schweinefleisch. In *Schweinefleischqualitäts - Qualitätsschweinefleisch*, Tagungsbericht (pp. 5-10), 22 May 1991, Institut für Nutztierwissenschaften.
- Qiao, J., Ngadi, M. O., Wang, N., Gariépy, C., & Prasher, S. O. (2007). Pork quality and marbling level assessment using a hyperspectral imaging system. *Journal of Food Engineering*, 83, pp. 10-16.
- Raj, S., Skiba, G., Sobol, M., Pastuszewska, B. (2017). Effects of dietary fat on the saturated and monounsaturated fatty acid metabolism in growing pig. *Archives of Animal Nutrition*, 71(4), pp. 257-271.
- Ripoll, R., Joy, M., & Muñoz, F. (2011). Use of dietary vitamin E and selenium (Se) to increase the shelf life of modified atmosphere packaged light lamb meat. *Meat Science*, 87, pp. 88-93.
- Roodt, E. (2003). Backfat quality of South African pigs: A meat processing perspective. M.Sc. dissertation, University of the Free State, Bloemfontein, South Africa.

- Ros-Freixedes, R., & Estany, J. (2013). On the compositional analysis of fatty acids in pork. *Agricultural, Biological, and Environmental Statistics*, 19(1), pp. 136-155.
- SAMIC. (2006). South African Meat Industry Company. [Available on internet:] www.samic.co.za, 9 March 2018.
- Santoro, P. (1983). Fat Quality in pig meat with special emphasis on cured and seasoned raw hams. In J.D. Wood, Fat Quality in Lean Pigs, Meat Research Institute Special Report No. 2, Document number EUR 8901 EN, (pp.53-57). CEC Workshop, Brussels, Belgium.
- Sather, A P; Jones, S D.M; Robertson, W M; Zawadski, S. (1995). Sex effects on fat harness meter readings of market weight pigs. *Canadian Journal of Animal Sciences*, 75, pp. 509-515.
- Schinckel, A., Wagner, J. R., Forrest, J. C., & Einstein, M. E. (2001). Evaluation of alternative measures of pork carcass composition. *Journal of Animal Science*, 79(5), pp. 1093-1119.
- Schinckel, A., Richert, B., & Foster, B. (2005). Management of pigs in the pork production chain. *Proceeding of the 5th London Swine Conference* (pp.115-31), London, Ontario, Canada.
- Scollan, N. D., Dhanoa, M. S., Choi, N. J., Maeng, W. J., Enser, M., & Wood, J. D.. (2001). Bio hydrogenation and digestion of long chain fatty acids in steers fed on different sources of lipid. *Journal of Animal Science*, 136, pp. 345–355.
- Scollan, N. D., Hocquette, J. F., Nüernberg, K., Dannenberger, D., Richardson, R. I., & Maloney, A. (2006). Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality. *Meat Science*, 74, pp. 17-33.
- Seman, D. L., Barron, W. N., & Matzinger, M. (2013). Evaluating the ability to measure pork fat quality for the production of commercial bacon. *Meat Science*, 94, pp. 262-266.

- Siebrits, F. K., Hambrook, B. W., & Pieterse, E. (2012). Die Suid-Afrikaanse varkkarkas-klassifikasiesetel. *South African magazine for Natural Science and Technology*, 31 (1).
- Simopoulos, A. P. (1996). Omega-3 fatty acids. Part 1: Metabolic effects of omega-3 fatty acids and essentiality. In G. A. Spiller (Ed.), *Handbook of lipids in human nutrition* (pp. 51-73). New York: CRC Press.
- Simopoulos, A. P. (2002). The importance of the ratio of omega-6/omega-3 essential fatty acids. *Biomedicine and Pharmacotherapy*, 56 (8), pp. 365-379.
- Slover, H. T., & Lanza, E. (1979). Quantitative analysis of food fatty acids by capillary gas chromatography. *Journal of the American Oil Chemists' Society*, 56, pp. 933-943.
- Soji, Z., & Muchenje, V. (2017). Should the South African red meat classification system be revised or maintained? A review. *South African Journal of Animal Science*. 47 (No. 5)
- Sosnicki, A. (2010). Pork fat quality. Cutting Edge, First quarter. pp. 1-4.
- Sosnicki, A. A., Mathews, N., Fields, B., & Jungst, S. (2010). Pork Fat Quality. [Available on internet:] www.engormix.com, 26 April 2017.
- Stiebing, A., Kühne, D., & Rodel, W. (1993). Fettqualität: Einfluß auf die Lagerstabilität von schnittfester Rohwurst. *Fleischwirtschaft*, 73, pp. 1169-1172.
- Strydom, P.E. (2011). Quality related principles of the South African Beef classification system in relation to grading and classification systems of the world, *South African Journal of Animal Science*, 41, pp. 177-193.
- Taljaard, P. R., Jooste, A. & Afsaha, T. A. (2006). Towards a broader understanding of South African consumer spending on meat. *Agrekon*, 45, pp. 214- 224.
- Teye, G. A., Sheard, P. R., Whittington, F. M., Nute, G. R., Stewart, A., & Wood, J. D. (2006). Influence of dietary oils and protein level on pork quality. Effects on muscle fatty acid composition, carcass, meat and eating quality. *Meat Science*, 73, pp. 157-165.

- Thu, D. T. N. (2006). Meat Quality: Understanding of meat tenderness and influence of fat content on meat flavour. *Science and Technology Development*, 9(12), pp. 65-70.
- Tornberg, E. (1996). Biophysical aspects of meat tenderness. *Meat Science*, 43, S175-S191.
- Ulbricht, T. L., & Southgate, D. A. (1991). Coronary heart disease: seven dietary factors. *The Lancet*, 338, pp. 985-992.
- USDA. (2011). Wholesale pork pricing chart. United States Department of Agriculture. [Available on internet:] www.pork.org, 15 November 2018.
- USDA. (2017). The South African pork market. United States Department of Agriculture. [Available on internet:] www.fas.usda.gov, 9 March 2018.
- Veale, R., Quester, P., Karunaratna, A. (2006). The role of intrinsic (sensory) cues and the extrinsic of country of origin and price on food product evaluation. *Proceedings of the 3rd International Wine Business and Marketing Research Conference*, Monipellier, 6-8 July 2006.
- Visser, D. P., (2004). Structuring of breeding objectives in the pork supply chain in South Africa. Ph.D. Dissertation, University of Pretoria, Pretoria, South Africa.
- Warnants, N., Van Oeckel, M. J., & Boucqué, C. V. (1996). Incorporation of dietary polyunsaturated fatty acids in pork tissues and its implications for the quality of the end products. *Meat Science*, 4, pp. 1230-1240.
- Warnants, N., Van Oeckel, M. J., & Boucqué, C. V. (1998). Effects of incorporation of dietary polyunsaturated fatty acids in pork backfat on the quality of salami. *Meat Science*, 49, pp. 435-445.
- Warner, R. D., Kauffman, R. G, & Russell, R. L. (1993). Quality attributes of major porcine muscles: a comparison with the longissimus lumborum. *Meat Science*, 33, pp. 359-372.
- Webb, E. C. (2015). Description of carcass classification goals and the current situation in South Africa. *Animal Sciences*, 45(3), pp. 229-233.

- Webb, E. C., & O'Neill, H. A. (2008). The animal fat paradox and meat quality. *Meat Science*, 80, pp. 28-36.
- Wenk, C. (2000). Meat consumption and meat quality - How important is it? In C. Wenk, J.A. Fernandez, & M. Dupuis, *Quality of meat and fat in pigs as affected by Genetics and nutrition. Proceedings of the joint session of the EAAP commissions on pig production, animal genetics and animal nutrition* (pp. 7-12). Zurich, Switzerland: Wageningen: Wageningen Pers.
- Whittington, F. M., Prescott, N. J., Wood, J. D., & Enser, M. (1986). The effect of dietary linoleic acid on the firmness of backfat in pigs of 85 kg live weight. *Science of Food and Agriculture*, 37, pp. 753-761.
- Wood, J. D. (1984). Fat deposition and the quality of fat tissue in meat animals. In J. Wiseman (Ed.) *Fats in Animals Nutrition* (pp. 401-435). London: Butterworths.
- Wood, J. D., Enser, M. B., Fisher, A. V., Nute, G. R., Sheard, P. R., Richardson, R. I., Hughes, S. I., & Whittington, F. M. (2008). Fat deposition, fatty acid composition and meat quality: A review. *Meat Science*, 78, pp. 343 - 358
- Wood, J. D., Holder, J. S., & Main, D. C. (1998). Quality assurance schemes. *Meat Science*, 49, S191-S203.
- Wood, J. D., Jones, R. C., Francombe, M. A., & Whelehan, O. P. (1986). The effect of FT and sex on pig meat quality with special reference to the problems associated with overleaness. *Animal Production*, 43, pp. 535-544.
- XLSTAT. (2018). Data Analysis and Statistical Solution for Microsoft Excel. Addinsoft, Paris, France.
- Xue, J., Dial, G. D., & Pettigrew, J. E. (1997). Performance, carcass, and meat quality advantages of boars over barrows: A literature review. *Journal of Swine Health and Production*, 5, pp. 21-28.

CHAPTER 7

SUMMARY

The main objective of this study was to investigate whether the current formulas used in the pork classification system (PORCUS) is still suitable for predicting meat yield over different carcasses yield and weight classes. Ninety seven pork carcasses from different weight categories classed as P, O, and R classification groups were sampled at 4 major South African abattoirs and these pigs were then dissected into different wholesale cuts. These cuts were then dissected into skin, bone, meat and fat. The dissected portions were then weighed and these weights were used to determine true lean yield, which in turn was used to reclassify the carcasses. Pearson correlations coefficients indicated that the % true meat yield by dissection gives better correlations with most of the meat quality parameters in comparison with the % meat yield predicted by the HGP. Only 26.8% of the carcasses were classed correctly with the HGP. For most classes the yield was over predicted by the HGP. There is a general perception that pig carcasses are becoming heavier and leaner, 36 of the selected 97 carcasses that were supposed to yield P, O, and R, recorded actual yields of C, U, and S.

From the multiple regression analysis it was clear that the 1992 Bruwer equation over predicts the LMY of the carcasses and in turn this causes the HGP to incorrectly classify the pork carcasses.

The old HGP formula used by the HGP is as follows:

$$\% \text{ Meat} = 72.5114 - (0.4618 \times \text{fat thickness}) + (0.0547 \times \text{muscle thickness})$$

The new proposed formula is as follows:

$$\% \text{ Meat} = 77.2281 - (0.9478 \times \text{fat thickness}) + (0.0263 \times \text{muscle thickness})$$

The fat quality parameters, including fatty acid composition and fatty acid ratios, of pigs from different classification groups indicated that as the LM% decreased and the BFT increases, the % IMF, %EFC, AI and C18:0/C18:2 ratio increase and the % FFDM, % moisture, drip loss, IV, RI, DBI, PI, the amount of n-6, MUFA/SFA ratio, PUFA/MUFA ratio and n-6/ n-3 ratio all decreased. There is a constant contrast

between classification group P and classification group U and S. Classification group P pigs are associated with healthier fat from a consumer's point of view, but is seen as an inferior fat from a processors point of view, whereas pigs from classification group S are associated with the quality fat that the processor desires but consumers wish to avoid for health reasons.

Key words: pigs, meat quality, fat quality, South Africa, classification, PORCUS, Hennessey Grading Probe