

Effects of increased slaughter weight of pigs on pork production

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Declaration

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature:

Date: 5 November 2005

Abstract

The South African pork industry is characterised by low slaughter weights when compared to the rest of the world. This inevitably leads to a smaller number of kilograms produced per unit fixed cost and subsequently the efficiency of production is reduced. A study was conducted with 189 pigs representing three sex types (boar, gilt and castrate) and five commercial genotypes. Pigs entered into the trial at an age of 10 weeks and an average live weight of 27.5 ± 2.5 kg. Treatments were according to slaughter weight ranging between 62 and 146 kg. Production and carcass characteristics, meat quality and processing characteristics and sensory attributes were assessed.

Production characteristics assessed included live weight gains, intake, P2 backfat thickness and feed conversion ratio. Main observed effects were associated with slaughter weight and its interaction with sex type. Rates of change in parameters measured were described. Growth and feed conversion ratio were described using linear models while cumulative feed intake was described using 2nd order polynomials. Carcass characteristics assessed included carcass weight, dressing percentage, carcass length, ham length, ham circumference, chest depth, backfat thickness measurements, muscle depth, eye muscle area, subcutaneous fat area, intramuscular fat area as well as ratios of eye muscle to subcutaneous and intramuscular fat area. The main statistical differences observed were for slaughter weight. Significant sex type differences were observed for dressing percentage and some fat and muscle depth measurements. Meat quality characteristics assessed included colour measurements, tenderness, drip loss and water holding capacity. Main differences observed were for slaughter weight. Carcass yields were assessed in terms of absolute and percentage yields of commercial cuts as well as yield of processable lean meat. In terms of the absolute and percentage yields of the commercial cuts, the main statistical differences observed were for slaughter weight. Changes in cut yield with

increased slaughter weight are described using regression analysis. In terms of yields obtained for processable lean meat, the main statistical differences observed were for slaughter weight.

Sex type differences were only observed for percentage belly and topside processable lean meat and percentage brine uptake of belly bacon, whole gammon ham and topside gammon. Genotypic differences were observed for percentage yield of processable lean meat of the neck and whole gammon and percentage fresh to smoke losses of back bacon and whole gammon ham. Sensory attributes were assessed using gammon ham, belly bacon and fresh loin. Observed slaughter weight differences were inconsistent and did not appear to change with an increase in slaughter weight. Once meat was processed, most sensory differences were no longer observed. Increased slaughter weight generally led to increased juiciness and decreased tenderness.

It is therefore concluded that the current South African pig genotypes have the ability to maintain high growth rates for a much longer time and therefore can be slaughtered at a higher weight without detrimental effect on production efficiency, carcass and meat quality characteristics, yields of commercial and processable lean meat, processing characteristics and ultimately sensory characteristics of the meat produced.

Opsomming

Die Suid-Afrikaanse varkbedryf word gekenmerk deur relatiewe lae slagmassas in vergelyking met die res van die wêreld. Dit lei onvermydelik tot 'n kleiner aantal kilogramme vleis geproduseer per eenheid vaste koste. 'n Studie is gevolglik gedoen met die doel om die tempo's van verandering van sekere produksie-, karkas-, vleis- en proseseringseienskappe te kwantifiseer ten einde die optimale slagmassa te bepaal wat vir alle rolspelers in die bedryf tot voordeel sal wees. Die studie is gedoen met 189 diere wat vyf kommersiële genotipes en drie geslagstipes (beer, sog en kaastraat) verteenwoordig het. Varke is op 'n ouderdom van 10 weke met 'n gemiddelde lewende massa van 27.5 ± 2.5 kg in die proef opgeneem. Behandeling was volgens slagmassa en het gevarieer van 62 tot 146 kg. Produksieparameters en karkas-, vleiskwaliteits-, en proseseringseienskappe sowel as sensoriese eienskappe, is geëvalueer.

Produksie-eienskappe wat geëvalueer is sluit in: groei, inname, P2 rugvetdikte en voeromset-verhoudings. Hoofeffekte wat waargeneem is, was vir slagmassa en interaksies van slagmassa met geslag. Tempo van verandering in die parameters gemeet, is beskryf. Groei en voeromset is beskryf deur die passing van 'n lineêre model terwyl kumulatiewe voerinnames beskryf is deur 'n 2^{de} orde polinoom. Karkaseienskappe wat geëvalueer is, sluit in: karkasmasse, uitslagpersentasie, karkaslengte, hamlengte, hamontrek, borsdiepte, rugvetdikte, spierdiepte, oogspieroppervlak, onderhuidse vet-, binnespiersoppervlak en verhoudings van oogspier- tot-vetoppervlakke. Die hoof statistiese effekte wat waargeneem is, was vir slagmassa. Betekenisvolle geslagsverskille is waargeneem vir uitslagpersentasie en sommige, vet- en spierdieptemetings. Genotipiese verskille is waargeneem vir sommige vetmetings. Vleiskwaliteiteienskappe wat beoordeel is, het kleur, drupverlies, waterbindingsvermoë en sagtheid ingesluit. Hoofeffekte waargeneem was vir slagmassa. Karkasopbrengste is geëvalueer in terme van

absolute en persentasie opbrengste van kommersiële snitte sowel as prosesseerbare maer vleis. In terme van absolute en persentasie opbrengste van kommersiële snitte, was meeste van die variasie beskryf deur slagmassa. Tempo van verandering in die persentasie opbrengste van die snitte word beskryf. In terme van opbrengste vir proseseerbare maer vleis is die hoof statistiese verskille waargeneem vir slagmassa. Geslagverskille is waargeneem vir persentasie streepspek en binneboud maer vleis opbrengs vir prosesering en persentasie pekelopname van streepspek, heel varkboud ham en binneboud ham. Genotipe verskille is waargeneem vir persentasie opbrengs van maer vleis vir prosesering van die nek en heelboud en persentasie vars-tot-klaar-gerook verliese van rugspek en heelboud hamme. Sensoriese eienskappe is evalueer vir twee geprosesseerde en een vars snit. Slagmassa-effekte was nie konstant nie en parameters het klaarblyklik nie verander soos slagmassa verander het nie. Sodra vleis geprosesseer is, het die meeste sensoriese verskille verdwyn. Beide sappigheid en taaiheid het toegeneem met 'n toename in slagmassa.

Dit kan dus aanvaar word dat, gegewe die huidige Suid Afrikaanse genotipes, dit moontlik is om swaarder karkasse te produseer sonder noemenswaardige nadelige effekte op karkas-, vleis-, opbrengste-, prosesering- en sensoriese eienskappe van varkvleis.

Format

This thesis is submitted in the form of manuscripts, using the Meat Science Journal format and some repetition is therefore unavoidable.

Presentations

Results from this thesis have been presented at conferences, symposia, lectures and in popular publications as shown below:

Conferences and symposia

- Pieterse, E., Hoffman, L.C., Gloy, E.L. & Siebrits, F.K., 2003. Sensory attributes of South African pork as influenced by genotype, sex type and age at slaughter – a comparison of fresh and processed cuts. In: Consistency of quality: abstracts and proceedings of the 11th International Meat Symposium, Centurion, South Africa, 29-30 January, 2003. 108-121.
- Gloy, E.L., Pieterse, E., Siebrits, F.K., Hoffman, L.C. & Coertze, R.J., 2003. Relationship between slaughter line measurements and processing yields in pigs. In: Consistency of quality: abstracts and proceedings of the 11th International Meat Symposium, Centurion, South Africa, 29-30 January, 2003.
- Swarts, I.C., Pieterse, E., Hoffman, L.C. & Gloy, E.L., 2003. Influence of porcine somatotropin on meat quality characteristics of South African pork. In: Consistency of quality: abstracts and proceedings of the 11th International Meat Symposium, Centurion, South Africa, 29-30 January, 2003.
- Gloy, E.L., Pieterse, E., Siebrits, F.K. & Hoffman, L.C., 2004. The effect of slaughter weight and sex type on meat quality and processing characteristics of pork. *Proceedings of the 40th National Congress of the South African Society of Animal Science*. Stellenbosch.
- Pieterse, E., Gloy, E.L., Hoffman, L.C., Siebrits, F.K., Mphuloane, A.K. & Hambrook, B., 2004. Slaughter weight, sex type, genotype and pig production efficiency. *Proceedings of the 40th National Congress of the South African Society of Animal Science*. Stellenbosch.

Lectures to Interest groups

Pieterse, E., 2003. Sensory attributes of SA Pork as influenced by Genotype, Sex type and Slaughter weight. Presentation to the Pig Abattoir Forum 14 January 2003.

Pieterse, E., 2003. Development of a model for the determination of optimum slaughter weight for pigs while considering economy of production, consumer preferences as well as carcass, meat and processing characteristics. Presentation to the Magalies Pig Study Group May 2004.

Pieterse, E., 2002. Slaughter weight model project – preliminary findings. Presentation to the Limpopo Pig Study Group November 2002.

Pieterse, E., 2004. Improving pig production efficiency – a research perspective. Presentation to the South African Pork Producers Organisation Annual General Meeting and Symposium. 9 September 2004. Villa Via, Gordons' Bay.

Pieterse, E., 2004. Improving pig production efficiency – a research perspective. Presentation to the Transvaal Pork Producers Organisation Annual General Meeting and Symposium. 11 Augustus 2004. Roodevallei, Pretoria.

Pieterse, E., 2004. Development of a model for the determination of optimum slaughter weight for pigs while considering economy of production, consumer preferences as well as carcass, meat and processing characteristics. Workshop of the South African Pork Producers Organisation. June 2004.

Popular publications

Pieterse, E., 2003. Causes, incidence and management of boar taint. *Porcus* 19(1), 22.

Pieterse, E., Loots, L.P. & Viljoen, J., 2000. The effect of slaughter weight on pig production efficiency. *Porcus* 15(7), 28-29.

Pieterse, E., Loots, L.P. & Viljoen, J., 2000. The effect of slaughter weight on pig production efficiency 2. Meat quality parameters, sensory evaluation and economics. *Porcus* 16(1), 14-15, 18.

Dedication

This thesis is dedicated to my family,
Jacques, Wilna, Elmay and Nelus
for your love, support and understanding

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	Page
Declaration	i
Abstract.....	ii
Opsomming	iv
Format.....	vi
Presentations	vii
Conferences and symposia.....	vii
Lectures to Interest groups.....	viii
Popular publications	viii
Dedication.....	x
Acknowledgements	xi
Table of contents	xv
Introduction	1
Aim of the study.....	3
 Chapter 1.....	 5
Literature review	5
Introduction	5
Production parameters	6
Carcass characteristics	7
Meat quality	9
Retail carcass yield and cut yield	11
Processing characteristics.....	12
Consumer acceptability and sensory characteristics	14
Incidence of taints and factors affecting it	15
References	18
 Chapter 2.....	 28
The effect of pig slaughter weight on production efficiency	28
Abstract.....	28
Key words	29

Table of contents

Introduction	29
Materials and methods	31
Results and discussion	34
Conclusion	40
References	41
Chapter 3.....	43
The effect of slaughter weight on the carcass characteristics of pigs... 43	43
Abstract.....	43
Key words:	43
Introduction	44
Materials and methods	46
Results and discussion	51
Conclusion	63
References	65
Chapter 4.....	69
The effect of slaughter weight on the meat quality characteristics of pork	69
.....	69
Abstract.....	69
Key words	70
Introduction	70
Materials and methods	73
Results and discussion	76
Conclusion	86
References	86
Chapter 5.....	90
The effect of slaughter weight on the retail carcass yield of pork.....	90
Abstract.....	90
Key words	90
Introduction	91

Table of contents

Materials and methods	92
Results and discussion	94
Conclusion	99
References	100
Chapter 6.....	102
The effect of slaughter weight on the deboning and processing yield as well as chemical composition of bacon and ham cuts from pork carcasses.....	102
Abstract.....	102
Key words	103
Introduction	103
Materials and methods	105
Results and discussion	109
Conclusion	123
References	124
Chapter 7.....	127
The effect of slaughter weight on the descriptive sensory characteristics of pork.....	127
Abstract.....	127
Key words	128
Introduction	128
Materials and methods	129
Results and discussion	132
Conclusion	139
References	140
Chapter 8.....	143
The prevalence of boar taint in relation to slaughter weight, sex type and South African genotype	143
Abstract.....	143

Table of contents

Key words	144
Introduction	144
Materials and methods	146
Results and discussion	151
Conclusion	156
References	156
Chapter 9.....	161
Discussion and conclusion	161
References	165
Chapter 10	166
Final conclusions and recommendations.....	166
Further research required:.....	168
Chapter 11	169
ADDENDUM A	169

Introduction

The pig industry in South Africa can be divided into two main sections with the one being a commercial intensive section, and the other an extensive sector mainly associated with emerging farmers. Commercial production takes place on approximately 350 units. With 40% of these units farming between 40 and 150 sows and the remaining 60% farming between 400 and 2500 sows. In total it is estimated that the national South African pig herd consists of 110 000 sows in commercial units and 20 000 sows in the emerging market.

Pigs produced are marketed on contract to abattoirs or on the open market. Contract prices are set on a three monthly or yearly basis and are based on input cost while open market prices fluctuate according to supply and demand. Slaughtering takes place at 46 registered abattoirs with the largest proportion of slaughtering in the Gauteng Province.

Efficiency of feed utilisation and optimal utilisation of capital invested is the chief decider of profitability. This means that the larger the unit the higher the profitability but also the higher the initial investment required and thus the more severe the barrier to entry.

Carcasses are taken into the fresh meat or value added market in a ratio of approximately 50:50. Carcasses destined for the fresh meat market have an average weight of 62kg while average carcass weight for the processing market is 76kg or heavier. There is a trend in South Africa to produce pigs with increased carcass weights. The heavier the carcass, the less would be the fixed cost per kilogram of carcass produced, as the variable cost remains approximately the same, resulting in the total profitability per kilogram produced increasing with increased carcass weight. The effect of this

increase in carcass weight on the commercial yield, meat and processing quality requires scientific clarification.

Note: Figures quoted in this section are extracted from the Pork Industry Strategy Framework compiled in 2004.

Aim of the study

The aim of this study was to determine the effect of increased slaughter weight of pigs from typical South African genotypes (n=5), representing three sex types (males, castrates and females) on the following:

- Production parameters of pigs in terms of growth rate, feed intake, P2 backfat thickness and feed conversion ratio.
- Carcass characteristics in terms of carcass weight, dressing percentage, carcass measurements, fat thickness measurements, eye muscle depth, eye muscle area, subcutaneous fat area, and ratios of subcutaneous and intra muscular fat areas to eye muscle areas.
- Meat quality characteristics in terms of drip loss, water binding capacity, colour and pH measurements.
- Yield of carcasses in terms of absolute and percentage yields of South African commercial cuts.
- Yield of processable lean meat and processing yields of cuts, brine uptake and final product yields.
- Sensory characteristics of fresh pork and value added products.

It must be borne in mind that the aim of the study was to determine which of the parameters measured changed with increased slaughter weight and then to describe the changes in these parameters. As sex type differences have been documented for these parameters by various authors, the trial was designed to accommodate three sex types i.e. boars, castrates and gilts. Data were subsequently analyzed for interactions of sex types with slaughter weight. As it was impossible to obtain all the animals needed for the trial from one farm, five genotypes were selected. These genotypes were selected with the assistance of the South African Pork Producers Organization in such a manner as to represent the majority of genotypes slaughtered in South Africa at the time. The genotypes included two synthetic breeds, a line containing

Aim of the study

50% Duroc genes, a commercial Landrace X Large White mother line utilizing a Pietrain terminal sire and a line originating from the Robuster, a locally developed breed. Due to a confidentiality agreement with the suppliers of the pigs, the allocation of genotype numbers can not be disclosed.

Chapter 1

Literature review

Introduction

In the highly competitive world of pork production, increased efficiency of production is often the only survival tool available to the producer. Increased efficiency can be achieved in a number of ways amongst which are increased slaughter weights and the production of intact males instead of females or castrates (barrows). Optimum slaughter weight has been defined by various authors. Ellis & Horsfield (1988) defined optimum slaughter weight for the pig industry as a whole, as the weight at which the margin between the costs of producing the pig and processing the carcass, on the one hand, and the value of saleable products, on the other, is maximized. Optimum slaughter weight is an inter-relationship between live weight, feed efficiency and lean content which is largely dependant on the lean tissue growth potential of the animal which in turn, is determined by genotype and sex type (Fowler, Bichard & Pease, 1976).

The South African pork market consists mainly of two sections i.e. the fresh meat market and the processed (value added products) market. Pork usage in these markets is approximately equal. Until recently the average carcass weight of pigs slaughtered was below 70kg. There is, however, a trend in South Africa for the production of pigs with increased carcass weights. This was brought about by a producer drive for higher profitability because, if the cost of producing a piglet is seen as a fixed cost, the heavier the carcass, the less the fixed cost per kilogram of carcass produced. As the variable costs remain approximately the same per kilogram weight produced, the total profitability per kilogram produced would be increased.

Production parameters

Disadvantages associated with increased slaughter weight are related to reduced pig performance; especially reduced feed conversion efficiency and excessive fat thickness at slaughter (Cisneros, Ellis, Mc Keith, McCaw & Fernando, 1996). However, various authors have noted positive changes in genotypes in terms of their potential lean growth rates (Cisneros *et al.*, 1996) and overall carcass fatness (Blanchard, Willis, Warkup & Ellis, 2000) as the slaughter weight increased.

Another difference that does exist and which has a major effect on efficiency of production and optimum slaughter weight is sex type. Although boars have been shown to have higher growth rates than gilts, they have similar feed intakes, and thus better feed efficiencies (Blanchard, Ellis, Warkup, Chadwick & Willis, 1999a). However, Channon, Kerr & Walker (2004) showed that males and females grew at the same average daily rate up to 157 days of age while Bonneau (1998) reported reduced growth in castrates and therefore increased cost of production for this gender.

Latorre, Lázaro, Valencia, Medel & Mateos (2004) compared growth, feed intake and feed efficiency for different slaughter weights and found that castrates had a higher average daily gain and average daily feed intake than gilts but that the gain:feed ratio was the same up to 116kg live weight. Between 116 and 133kg live weight, castrates had higher gains, feed intake and feed conversion ratio. The authors further reported that the rates of change in gain:feed was 0.01kg for every 10kg above 116kg body weight ($R^2=0.61$; $P\leq 0.001$) while average daily gain decreased by 38g/day for every 10kg above 116kg body weight ($R^2=0.59$; $P\leq 0.01$). Earlier studies done by Huiskes, Binnendijk & Van Trigt (1996) and Ellis & Avery (1994) reported inconsistent results pertaining to growth rate but they found that increased live weight consistently led to decreased efficiency of feed utilization. In studies where pigs were grown to 110, 135 and 155kg body weight, significant differences were

observed for average daily gain and feed conversion ratio (Huiskes *et al.*, 1996). However, Ellis & Avery (1994) found that animals grown to 90, 110 and 130kg body weight showed no differences in growth rate but a steady decline in efficiency of feed utilization. Differences between these studies and the magnitude of differences reported might be due to genetic and/or environmental differences.

Castration has recently been questioned in terms of animal welfare. When considering all these factors, the production of heavy males becomes very tempting but other factors associated with boar production should be considered i.e. the possibility of increased fighting between animals and the subsequent losses associated with injuries, dominance, carcass bruising and rejections as well as the possibility of the appearance of boar taint (should certain determining factors come into play). Generations of selection for lean growth resulted in an indirect selection for increased mature body weight and possibly delayed puberty. This might offer the opportunity to utilize the growth and carcass characteristics of boars up to a heavier slaughter weight. This weight will be determined by, amongst others, genotype (Latorre, Lázaro, Gracia, Nieto & Mateos, 2003).

Carcass characteristics

Carcass characteristics are factors that pose challenges to role players in the pork industry and were summarised by Kallweit, Kohler & Henning (2001) who noted that “In future production, swine carcasses should not only be lean but also homogeneous in weight and shape. Extreme conformation should be avoided.” Factors influencing carcass characteristics are in many ways linked to three main factors i.e. sex type, genotype and slaughter weight. Sex type manipulation is restricted to the choice between castrate and boar production while gilts remain a given. Genotype is a choice made by the producer and changing over from one genotype to another is often time consuming and costly. One easily manageable factor is slaughter weight. Sex type differences

do occur and it has been shown that gilts slaughtered at 105kg were generally superior to castrates for carcass quality parameters (Tibau, Gonzalez, Soler, Gispert, Lizardo & Mourot, 2003) having lower backfat thickness and subsequently higher percentage lean and protein content with more water and less lipid (Gonzalez, Soler, Gispert, Puigvert & Tibau, 2001; Tibau *et al.*, 2003). Channon *et al.* (2004) reported that gilt carcasses had 0.4% more intramuscular fat and also higher P2 backfat measurements at the same age and carcass weight than entire males, while Blanchard *et al.* (1999a) found no difference in P2 backfat thickness between boars and gilts. Latorre *et al.* (2004) reported increased backfat thickness in castrates as well as decreased dressing percentage but no differences in carcass and ham length but greater ham circumference in castrates, while Blanchard *et al.* (1999a) reported higher dressing percentage for gilts than boars. They further reported that boars had lower eye muscle depth but similar intramuscular fat content.

Genotypic differences have been observed for dressing percentage (Fabian, Chiba, Kuhlert, Frobish, Nadarajah & McElhenney, 2002; Latorre *et al.*, 2003), backfat thickness (Choi *et al.*, 2003a, Choi, Kim, Cho, Lee, Jeon & Cheong, 2003b; Gatlin, See, Hansen & Odle, 2003; Huang *et al.*, 2004), eye muscle depth (Gatlin *et al.*, 2003), level of intramuscular fat (Choi *et al.*, 2003a; Fabian *et al.*, 2002; Sencic, Speranda, Antunovic, & Speranda, 2003; Channon *et al.*, 2004) and abdominal fat firmness (Fabian *et al.*, 2002). Certain specific genetic factors have also been shown to influence carcass characteristics, for instance carriers of the stress gene (Nn) had higher eye muscle depth and decreased backfat thickness (Fabrega *et al.*, 2002) than normal (NN) pigs. Further quantitative trait loci have been identified for backfat thickness, carcass yield, loin muscle area, intramuscular fat content, carcass gain and lightness (L*) indicating definite genotypic differences for these characteristics (Sato *et al.*, 2003; Pierzchala, Blicharski & Kuryl, 2003).

Increased slaughter weight leads to increased dressing percentage as the intestines of pigs are proportionally slower growing than the body of the pig as a whole (Whittemore, 1993; Ellis & Avery, 1994). Cisneros *et al.* (1996) and Latorre *et al.* (2004) reported linear increases in dressing percentage with increased slaughter weight. In a study to determine the influence of heavy slaughter weights (110kg) on growth and carcass characteristics of pigs, Ellis & Avery (1994) found that eye-muscle area increased with slaughter weight. Latorre *et al.* (2004) also reported a linear increase in backfat thickness, ham circumference and ham length.

Meat quality

Meat quality is becoming increasingly important to meat processors and consumers (Beattie, Weatherup, Moss & Walker, 1999). Meat quality has many different definitions. In some instances these definitions refer to factors exclusively associated with biochemical processes (Bruwer, 1992; Van der Wal, Engel & Hulsegge, 1997) while others define meat quality as a combination of physical and biochemical factors such as eye muscle area, ham shape, muscle quality and fat quality (Whittemore, 1993), all being characteristics that are closely related to carcass weight.

A longstanding problem in the pig industry is pale soft exudative (PSE) meat. This meat appears pale because of a high degree of light scattering caused by a low pH; it is soft because of free fluid between the muscle fibres and it is exudative due to its low water binding capacity at this low pH, resulting in weight loss by drip and evaporation (Lundström, Essen-Gustavsson, Rundgren, Edfors-Lilja & Malmfors, 1989). PSE meat is defined as meat with a drip loss in excess of 5% and an L* value above 50 (Warner, Kauffman & Greasar, 1977). Dark firm and dry meat (DFD) is the opposite condition to PSE. This condition results when animals are exposed to long-term stress and depletion of nutrients, primarily glycogen (Seideman, Cross, Smith & Durland, 1984).

Reported results suggested that pork quality may be improved when the slaughter weight of pigs is increased from 95 to 125kg (Moon, Mullen, Tory, Yang, Joo & Park, 2003). As slaughter weight increased, it was found that pH_u (ultimate pH) decreased but no differences were observed for carcasses slaughtered at 125kg or more, a decrease in cooking losses and an increase in shear force was also noted. The lightness (L^*) and redness (a^*) of the pork loin were increased with increasing slaughter weight (Moon *et al.*, 2003). Similarly, Kocwin-Podsiadla *et al.* (2002) found that an increase in hot carcass weight above 90kg had a positive effect on the rate and extent of *longissimus dorsi* muscle acidity measured 45 minutes and 24 hours post-mortem, resulting in higher water holding capacity, lower drip loss and lower losses from cured meat during cooking.

Differences in meat quality due to genotype have been reported by various authors. However, findings to date have not been conclusive with authors reporting contradicting effects. Lack of genotypic differences have been reported for water binding capacity, colour (Sencic *et al.*, 2003; Channon *et al.*, 2004) and pH_1 , measured 45 minutes post slaughter (Channon *et al.*, 2004) while genotypic differences for meat tenderness, colour (Latorre *et al.*, 2003) and pH_u (Channon *et al.*, 2004) were also reported. Genotype and sex type did not influence pH at 1, 3 and 6 hours *post mortem*. However, differences in pH_u were lower for Duroc and entire male carcasses with entire male carcasses showing pH_u 0.07 units higher than that of female carcasses (5.64 vs. 5.57) (Channon *et al.*, 2004). Latorre *et al.* (2004) further reported pH_1 and pH_u to be lower for gilts than for castrates while Bañon, Andreu, Laencina & Garrido (2004) reported no differences between males and castrates.

Pork tenderness is influenced by a number of factors. Latorre *et al.* (2004) found no effect of increased slaughter weight (age) on shear force values while the influence of sex type on shear force value is not conclusive. In a study by Latorre *et al.* (2004) it was found that the meat of castrates was more tender

than that of gilts while Blanchard, Warkup, Ellis, Willis & Avery (1999b) reported that the meat of intact males and females had the same shear force values while Channon *et al.* (2004) reported lower shear force values for females than for entire males.

Genetic (Bañon *et al.*, 2004), sex type (Channon, 2004; Nold, Romans, Costelli & Libal, 1999) and slaughter weight differences (Latorre *et al.*, 2004) have been reported for CIELab colour measurements by various authors and results are not always conclusive. For example, entire male carcasses were found to have lower L* values (thus darker meat) than females (Channon *et al.*, 2004) while Nold *et al.* (1999) reported higher L* values for castrates and boars in comparison with females. Similarly, Nold *et al.* (1999) reported lower a* and b* values for boars than for gilts and castrates whilst no differences in colour measurements were reported between gilts and castrates (Latorre *et al.*, 2004) and boars and castrates (Bañon *et al.*, 2004). Observed slaughter weight differences showed decreased L* and increased a* values (Latorre *et al.*, 2004). Colour differences observed are often linked to lack of pigmentation – especially in boar carcasses (Goerl, Eilert, Mandigo, Chen & Miller, 1995).

Retail carcass yield and cut yield

As carcass weight increases, profitability of production also increases (Ellis & Horsfield, 1988; Ellis, Web, Avery & Brown, 1996; Latorre *et al.*, 2004). This could however, be to the disadvantage of the processor as fat thickness increases with a concomitant reduction in percentage lean in the carcass (Ellis & Horsfield, 1988; Ellis *et al.*, 1996). However, the percentage lean in the carcass is not only of value to the processor, but also the yield of individual retail cuts since this represents the main raw material in their process.

A number of factors influence cut yield of pork. These include dietary lysine level (Unruh *et al.*, 1996), use of growth promoters (Crome, McKeith, Carr,

Jones, Mowrey & Cannon, 1996), sex type (Cisneros *et al.*, 1996; Latorre *et al.*, 2004), genotype (Unruh *et al.*, 1996; Fabrega *et al.*, 2002; Grzeskowiak, 2002) as well as slaughter weight (Cisneros *et al.*, 1996; Unruh *et al.*, 1996; Kawano, Tajima, Andou & Suzuki, 1997).

Documented sex type differences show gilt carcasses to have higher yields of ham and shoulder cuts than castrates (Latorre *et al.*, 2004). These differences were also reported by Cisneros *et al.* (1996) but were found to be small and probably of little commercial value. Genotypic differences are somewhat controversial with some authors reporting no genotypic differences in cut yield (Cisneros *et al.*, 1996) and others noting differences with lean type pigs yielding more processable lean meat, percentage wise, than fatter genotypes (Unruh *et al.*, 1997). Purebreds were also found to yield less in terms of ham, shoulder, loin and neck than commercial crossbreds (Grzeskowiak, 2002) while Pietrain sired animals yielded more in terms of leg and loin (Fabrega *et al.*, 2002). Observed increases in yields were mainly restricted to absolute yields (Kawano *et al.*, 1997). However, Cisneros *et al.* (1996) reported that percentage loin increased with increased slaughter weight but that percentage ham, shoulder and spare rib decreased.

Processing characteristics

Processing characteristics are largely dependant on meat quality characteristics, particularly water holding capacity and drip loss, since these two factors are the main determinants of processing yields/losses. Other factors associated with processing characteristics are factors associated with certain cuts. For example Persson *et al.* (2005) reported optimum belly thickness for production of belly bacon. Bellies thinner than 2 cm led to excessive losses during processing, especially slicing losses, while bellies 3 cm and thicker, although superior in terms of processing yields, did not appeal to consumers because of colour attributes and lean to fat ratio. The optimum belly thickness was deemed to be 2.5 cm. Similarly Brewer, Stites, McKeith, Bechtel,,

Movakosfski & Bruggen (1995) reported that, as belly thickness increased sensory assessment of lean to fat ratio decreased. Genotype differences were reported by Candek-Potokar, Monin & Zlender (2002) who found that Duroc crosses exhibited higher intramuscular fat content, marbling and intermuscular fat. Crossing with Duroc resulted in lower weight losses during ham processing. Observed sex type differences showed that castrates were fatter and had more intra- and intermuscular fat and lower ham processing weight losses than females (Candek-Potokar *et al.*, 2002). Dry hams from female pigs had higher total and non-protein nitrogen, but a drier, firmer texture and higher resistance to cutting force compared to dry hams from castrated pigs (Candek-Potokar *et al.*, 2002). Cisneros *et al.* (1996) reported small sex type differences, no genotypic differences but larger slaughter weight differences and noted that absolute yield of trimmed boneless cuts increased while percentage yields decreased with increased slaughter weight. They also noted that curing yields for the belly cut increased with increased slaughter weight up to 160kg live weight. Latorre *et al.* (2004) reported an increase in trimmed weight of ham and shoulder cuts with increased slaughter weight even though the percentage yields were not affected.

The chemical composition of carcasses is influenced by a number of factors. Differences exist for sex types (Wagner, Schinckel, Chen, Forrest & Coe, 1999; Gonzales, *et al.*, 2001; Tibau *et al.*, 2003) with gilts proving to have more protein, more water and less lipid than castrates (Gonzalez *et al.*, 2001; Tibau, *et al.*, 2003) while having higher lipid content and lower protein content than boars (Zullo, Barone, Colatruglio, Girolami & Matassino, 2003). Wagner *et al.* (1999) further reported significantly different changes in the ratio and composition of the tissues of barrows and gilts during growth.

Genotypic differences exist in terms of moisture content, protein, lipid and ash but these differences depended largely on sex type and live weight at slaughter. A recent study by Park, Kim, Jung, Park, Lee & Moon, (2005) however, showed

that no genotypic differences exist for chemical composition. However, the study of Zullo *et al.* (2003) showed that the genotypic differences observed were carried through to bacon in terms of dry matter content. They attributed this to differences observed in lipid and protein content of the initial product. Genotypic differences were summarized by Fabian *et al.* (2002) who concluded that “overall it can be said that pigs with distinct genotypes exhibit differences in growth rate, metabolite and hormonal profiles and ultimately body composition”.

Ellis & Avery (1994) found that dissection of carcasses with increased slaughter weight led to the proportion of skin decreasing while the proportion of lean, fat and bone remained relatively constant. Increased slaughter weight leads to decreased ash levels (Zullo *et al.*, 2003) increased protein levels (Candek-Potokar *et al.*, 1997; Wagner *et al.*, 1999; Gonzalez *et al.*, 2001; Zullo *et al.*, 2003), increased lipid levels (Candek-Potokar *et al.*, 1997; Wagner *et al.*, 1999; Gonzalez *et al.*, 2001; Zullo *et al.*, 2003) and decreased moisture content (Candek-Potokar *et al.*, 1997; Wagner *et al.*, 1999). A study by Tibau, *et al.* (2003) showed that protein deposition followed a quadratic function, reaching a maximum at 70kg BW while lipid deposition increased linearly from 25 up to 140kg. The increase in intramuscular lipids and the decreased water to protein ratio, resulting from an elevation of both age and weight at slaughter, should be beneficial for meat quality (Candek-Potokar *et al.*, 1997).

Consumer acceptability and sensory characteristics

Methods used for increasing efficiency of pork production can often be in direct competition with processor and consumer preferences as an increase in age and live weight of, especially, male animals can correspond with an increase in the occurrence and intensity of taints (Bañon *et al.*, 2004). However, Ellis & Horsfield (1988) found that pork eating quality could be increased by increasing the age and weight of the pig at slaughter. Sensory attributes of pork are closely related to the consumer's willingness to purchase the product again in the near future. A number of attributes are associated with these sensory traits

and the most important of these, according to Channon *et al.* (2004), are flavour and juiciness. Level of intramuscular fat is frequently associated with tenderness and levels of between 2 and 3% were shown to be detectable and to have a positive influence (Bejerholm & Barton-Gade, 1986). Genotypic differences also exist, with Durocs being juicier than other breeds (Channon *et al.*, 2004) whilst the same investigation noted that differences for tenderness, odour, flavour and overall liking were not influenced by genotype. Sex type differences observed show males to have higher shear force values than females (Channon *et al.*, 2004). However, tenderness is influenced by a number of factors including sex type and diet but not, as is often believed, fatness level (Wood, Mottran & Brown, 1981). Observed sex type differences showed bacon from boars to be more tender than that of castrates (Mottran, Wood & Patterson, 1982) while increasing maize in the diet led to increased tenderness and better flavour (Castaing, Caxette, Coudure & Peyhorgu, 1995).

Comparisons of sensory results across studies are, however, difficult due to variations in sample preparation, ageing time of meat, cut used and the statistical method used (Rødbotten, Kubberød, Lea & Ueland, 2004).

Incidence of taints and factors affecting it

Boar taint refers to the presence of urine and faeces like off-odours and off-flavours found mostly, but not exclusively, in meat from entire males. Boar taint is caused mainly by α -androst-16-en-3-one (androstenone) and 3-methylindole (skatole) (Jeremiah, Squires, & Sather, 1999).

Androstenone acts as a pheromone and is released from the salivary gland (Booth & Signoret, 1992) after synthesis in the boar testes (Brooks & Pearson, 1989). Androstenone causes urine like off odour, is hydrophobic and therefore accumulates in adipose tissue (Bonneau, 1982). Levels of androstenone in fat from entire males range between 0 and 5 ppm and depend amongst others, on

pig weight (Bonneau, 1982), stage of sexual maturity and genotype (Jonsson, 1985). Zamaratskaia, Babol, Andersson, Andersson & Lundström (2005a), however, reported that intact males slaughtered between 90 and 115kg did not differ in terms of androstenone levels in fat while Zamaratskaia, Madej, babol, Squires & Lundström (2005b) showed increased levels of androstenone after week 26.

Sinclair & Squires (2005) reported that levels of the sulfoconjugated form of androstenone present in peripheral plasma influence the accumulation of androstenone in fat. The level of the sulfoconjugated form of androstenone is governed by an enzyme, hydroxysteroid sulfotransferase. Animals with a decreased ability to sulfoconjugate 5α -androstenone will have increased circulating unconjugated 5α -androstenone available for accumulation in fat, potentially leading to the development of boar taint.

Androst-16-ene steroids are not generally affected by the environment and the control thereof has therefore not been very successful. Methods of control include immunization (Brooks, Pearson, Hogberg, Pestka & Gray, 1986; Hazas, Horn, Feher & Sandor, 1993; Turkstra *et al.*, 2002) inhibition of synthesis, blocking of metabolic pathways (Squires, 1989) and genetic selection (Jonsson, 1985; Sellier, Bonneau & Gruand, 1993).

Skatole is a product of bacterial degradation of tryptophan in the hind gut (Claus, Lösel, Lacorn, Mentschel & Schenkel, 2003). This tryptophan is, at least partially, produced by apoptosis of colon crypt cells (Claus *et al.*, 2003). This skatole is absorbed from the gut, metabolised in the liver, partially excreted in the urine and partially deposited in fatty tissue (Agergaard & Laue, 1993). It produces a faecal-like odour and a bitter taste (Hansson, Lundström, Fjellkner Modig & Persson, 1980). Although similar skatole concentration in the gut and faeces of males and females have been reported (Agergaard & Jensen, 1993),

skatole levels in back fat were reported to be positively correlated with testosterone levels given certain dietary conditions (Zamaratskaia *et al.*, 2005a) as well as with free oestrone levels.

Cytochrome P450 2A6 (CYP2A6) has further been shown to be a key enzyme in the liver metabolism of skatole with the activity of CYP2A6 negatively correlated to accumulated skatole levels in fat. A single base deletion in CYP2A6 results in a frame shift in the coding region resulting in a non-functional enzyme and thus increased skatole levels in fat (Lin, Lou & Squires, 2004).

Skatole levels can be reduced by slaughtering at a lower weight (Zamaratskaia *et al.*, 2005a,b), dietary supplementation with linseed (Matthews, Homer, Thies & Calder, 2000; Kouba, Enser, Whittington, Nute, & Wood, 2003) as well as supplementation with raw potato starch (Zamaratskaia *et al.*, 2005a). The decrease in skatole levels with the use of raw potato starch was shown to be dose dependant (Lösel & Claus, 2005). It is further hypothesised that the raw potato starch leads to increased butyrate formation in the colon, thereby contributing to reduced epithelial cell apoptosis, thus leading to reduced skatole formation and absorption (Claus *et al.*, 2003).

As skatole levels in fat are further strongly related to the environment, it can be reduced through wet feeding, *ad lib* access to water, cleanliness and ventilation, low fibre diet, addition of feed additives like bicarbonate, antibiotics (Lundström *et al.*, 1988; Kjeldsen, 1993; Hansen, Larsen, Jensen, Hansen-Møller & Barton-Gade, 1993; Claus, Weiler & Herzog, 1994) and fructo-oligosaccharide (Xu, Hu & Wang, 2003).

Other compounds which can also have an effect on boar taint but which are considered of less importance are 5α -androst-16-en-3 α -ol (androstenol)

(Brennan, Shand, Fenton, Nichols & Aherne, 1986; Brooks & Pearson, 1989) and another tryptophan derivative, indole (Garcia-Regueiro & Diaz, 1989).

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Chapter 2

The effect of pig slaughter weight on production efficiency

Abstract

A study was conducted with 192 pigs of five genotypes and three sex types. Pigs entered the trial at an age of 10 weeks and an average live weight of 27.5 ± 2.5 kg and were slaughtered between 62 and 146 kg live weight. Live weight, P2 backfat thickness, feed intake and conversion ratio and growth rate were determined weekly. Rates of change in parameters measured were described using regression analysis. Main effects were associated with slaughter weight and its interaction with sex type. With increased slaughter weight, growth remained essentially linear ($R^2 > 0.91$). Cumulative feed intake was described using a 2nd order polynomial regression ($R^2 > 0.95$) which, upon differentiation, showed rate of change of castrates to be faster than for gilts and gilts and castrates faster than for boars. Changes in feed conversion ratio was estimated by fitting a linear model ($R^2 > 0.81$) that showed the rate of deterioration to be fastest for castrates and gilts followed by boars but, that the overall efficiency of gilts and boars were better than castrates. P2 Backfat thickness showed gilts and boars to be leaner than castrates ($P \leq 0.05$) and Genotype 5 to be leaner ($P \leq 0.05$) than the other genotypes. This characteristic showed a constant increase with increased slaughter weight. It is therefore concluded that the current genotypes produced commercially in South Africa have the ability to maintain high growth rates for a longer period than was previously assumed by the industry. These genotypes can therefore be slaughtered at a higher weight but the effect of increased backfat thickness and feed conversion efficiency should be kept in mind in order to determine optimal slaughter weight. The higher efficiency of boars should also be exploited while bearing in mind the possibility of the negative effects associated with boar production.

Key words

Pork, slaughter weight, average daily gain, feed conversion ratio, P2.

Introduction

Various authors have defined optimum slaughter weight for pigs. Ellis & Horsfield (1988) defined optimum slaughter weight for the pig industry as a whole, as the weight at which the margin between the costs of producing the pig and processing the carcass, on the one hand, and the value of saleable products, on the other, is maximized. Optimum slaughter weight is an inter-relationship between live weight, feed efficiency and lean content which is largely dependant on the lean tissue growth potential of the animal which in turn is determined by genotype and sex type (Fowler, Bichard & Pease, 1976).

Disadvantages associated with increased slaughter weight are related to reduced pig performance especially reduced feed conversion efficiency and excessive fat thickness at slaughter (Cisneros, Ellis, McKeith, McCaw & Fernando, 1996). However, various authors have noted dramatic positive changes in genotypes in terms of their potential lean growth rates (Cisneros *et al.*, 1996) and overall carcass fatness (Blanchard, Willis, Warkup & Ellis, 2000).

Another factor that exists and has a major effect on efficiency of production and optimum slaughter weight is sex type. However, the results reported are contradictory. For example, boars have been shown to have higher growth rates and similar feed intakes than gilts, thus resulting in better feed efficiency (Blanchard, Ellis, Warkup, Chadwick & Willis, 1999). However, it has also been noted that males and females grow at the same average daily rate up to 157 days of age (Channon, Kerr & Walker, 2004).

Latorre, Lázaro, Valencia, Medel & Mateos (2004) compared growth, feed intake and efficiency for different slaughter weights and found that castrates had higher average daily gain and average daily feed intake than gilts but that the gain:feed ratio was the same up to 116kg live weight. Between 116 and 133kg live weight, castrates had higher gains, feed intake and feed conversion ratio. The authors further reported rates of change in gain:feed of 0.01kg for every 10kg above 116kg while average daily gain decreased by 38g/day for every 10kg above 116kg. On the other hand, Bonneau (1998) reported reduced growth in castrates. Earlier studies by Ellis & Avery (1994) reported inconsistent results pertaining to growth rate but reported that increased live weight consistently led to decreased efficiency of feed utilization. Animals grown to 90, 110 and 130kg showed no differences in growth rate but a steady decline in efficiency of feed utilization.

Recently castration has been questioned in terms of animal welfare. When considering all these factors, the production of heavy males becomes very tempting but other factors associated with boar production should be considered i.e. the possibility of increased fighting between animals and the subsequent losses associated with injuries, dominance, carcass bruising and rejections as well as the possibility of the appearance of boar taint should certain determining factors come into play. Generations of selection for lean growth resulted in an indirect selection for increased mature body weight, thus the effect of androstenone could possibly only appear at a later stage. This might offer the opportunity to utilize the growth and carcass characteristics of boars up to a heavier slaughter weight. This weight will be determined by, amongst others, genotype (Latorre, Lázaro, Gracia, Nieto & Mateos, 2003).

For the purpose of this study production parameters refer to measurements taken on live animals (live weight, feed intake, ultra sound backfat thickness) and calculations (growth rate, feed conversion ratio) made from these. The aim

of this study was to determine the effect of pig genotype, sex type and slaughter weight on these production parameters in South Africa.

Materials and methods

The experiment was conducted at the Agricultural Research Council's – Animal Nutrition and Animal Products Institute at Irene (Gauteng Province) and RTV abattoir in Benoni (Gauteng Province).

The trial was conducted with 192 pigs of three different sex types (boars, castrates and gilts) representing five South African (SA) genotypes deemed to be representative of the majority of commercial SA pig slaughtering. Animals within genotypes were randomly allocated to eight groups slaughtered at different weights. Pigs entered into the trial at an age of 10 weeks and an average live weight of 27.5 ± 2.5 kg. Upon arrival all pigs were weighed, tagged and treated for external and internal parasites. Pigs were then placed in their allotted pens and allowed to rest and adapt to the new environment and pen mates before the onset of the trial a week later.

The pigs were housed in commercial type grower houses with temperature controlled self-opening curtains. Each pen was equipped with a self feeder and automatic water nipple. Twenty-four pens in total were used for the study with eight pigs per pen and eight pens per sex type. This design rendered three pens, i.e. 24 pigs per slaughter weight with eight per sex type.

The main treatments were according to slaughter weight. Each sex type had eight slaughter groups of eight pigs. The first group of pigs was slaughtered when the average live weight of all pigs was 62kg and the following groups at two-weekly intervals. By using this design average live slaughter weights

ranging from 62 to 146kg were obtained. The slaughter group layout is shown in Table 2.1.

Table 2.1 Age at slaughter (days) and live weight at slaughter (kg) of group housed animals of three sex types representing five South African genotypes

Slaughter group	Age at slaughter (days)	Average live slaughter weight (kg)
1	112	61.93 ^a
2	126	77.99 ^b
3	140	86.04 ^c
4	154	102.37 ^d
5	168	112.70 ^e
6	182	128.39 ^f
7	196	133.10 ^f
8	210	145.45 ^g

Values in columns with different superscripts differ significantly ($P \leq 0.05$)

A commercial grower diet containing 18% crude protein (CP), 0.9% digestible lysine, 14 MJ/kg digestible energy and 10% oxytetracycline included at 2kg/ton were fed for the first 14 days after arrival. The same diet without medication was subsequently fed until an average live weight of 62kg. Thereafter a diet containing 16% crude protein, 0.81% digestible lysine and 13.5 MJ/kg digestible energy was fed until slaughter. Diets fed are shown in Table 2.2.

Table 2.2 Ingredient and calculated nutrient composition of diets fed to the pigs

	Diet 1	Diet 2	Diet 3
<i>Ingredient composition (%)</i>			
Yellow maize	68.97	68.82	67.44
Soya bean oilcake meal	11.61	12.73	11.86
Sunflower oilcake meal	3.38	3.20	11.30
Fishmeal	7.99	7.29	
Wheaten bran	5.00	5.00	5.00
Synthetic lysine	0.09	0.09	0.32
Synthetic methionine	-	-	0.04
Synthetic threonine	-	-	0.08
Monocalcium phosphate	0.94	1.01	1.68
Feed lime	1.18	1.20	1.49
Fine salt	0.24	0.26	0.39
Vitamin & Mineral premix	0.40	0.40	0.40
Oxytetracycline (10%)	0.20	-	-
<i>Calculated Nutrient composition</i>			
DE swine (MJ/kg)	14.00	14.00	13.50
Crude protein	18.00	18.00	16.00
Total lysine	1.03	1.03	0.92
Total methionine	0.38	0.37	0.34
TSAA	0.67	0.67	0.63
Total tryptophan	0.22	0.22	0.20
Total threonine	0.71	0.71	0.68
Digestible lysine	0.90	0.90	0.81
Digestible methionine	0.34	0.33	0.30
Digestible TSAA	0.57	0.56	0.53
Digestible tryptophan	0.18	0.18	0.16
Digestible threonine	0.59	0.59	0.57
Fat	3.80	3.74	3.18
Fibre	3.00	3.00	4.21
Calcium	0.90	0.90	0.90
Total Phosphorous	0.68	0.69	0.68
Available Phosphorous	0.40	0.40	0.40
Sodium	0.18	0.18	0.18

The following measurements and calculations were taken weekly:

- Live weight of individual animals.
- Feed was supplied *ad libitum* in automatic feeders and residues weighed back weekly for determination of group feed intake.
- Backfat thickness of individual animals using ultrasound, between the 2nd and 3rd last rib 45 mm from the midline.
- Average daily gain of individual animals and feed conversion ratio per pen were calculated.
- Rates of changes in the above were described using regression analysis.

Data obtained in this trial were subjected to analysis of variance for unbalanced design using GenStat (GenStat 5 release 4.2, 2000), testing for slaughter group effects alternating with genotype and sextype effects, as well as the interaction of slaughter weight by genotype and sextype. All requirements concerning homogeneity of treatment variances and normality were met. The trial was designed in such a manner as to have three sex types and five genotypes per slaughter group. Since each repetition was represented by a pen, and floor space had to be similar to that of commercial production systems the pens were filled to capacity by randomly allocating pigs of different genotypes within sextype to pens. This resulted in the trial being unbalanced for genotype. Further mortalities and removals resulted in the trial becoming unbalanced. Mortalities (3) were due to pneumonia and one to Hemorrhagic Enteritis while two animals were removed from the trial because of leg problems. A result was considered as highly significant at $P \leq 0.01$ and significant at $P \leq 0.05$. Percentage variance accounted for was calculated as the percentage ratio of the sum of squares of the individual parameter and the total.

Results and discussion

Presently, live weight at slaughter represents the main tool to the producer with which to select animals for the market. In the present trial, live weights at

slaughter increased, on average, from 62 to 146kg. This weight range is used throughout the document as comparison for slaughter weight effects.

Average daily gain (ADG) was estimated by fitting a linear model ($R^2 > 0.915$) to individual live weight data (Table 2.3). A second order polynomial fit did not significantly improve the fit as determined by the linear model. The distribution of R^2 values obtained by the linear fit showed 144 with a $R^2 > 0.99$, 36 with $0.95 \leq R^2 \leq 0.99$ and 9 with $0.91 \leq R^2 \leq 0.95$. The slope of this curve representing ADG, was used for further data analysis. Average daily gain showed highly significant differences ($P \leq 0.001$) for all main effects as well as slaughter weight sex X type interaction. Differences associated with slaughter weight accounted for most of the variance observed with slaughter weight describing 10% and slaughter weight X sex type 12.6%. The other main effects, genotype and sex type, described less than 10% of the variance. These results confirm the ability of modern genotypes to maintain high growth rates (Cisneros *et al.*, 1996; Blanchard *et al.*, 2000). As expected, observed sex type differences showed boars growing significantly faster than gilts and castrates these results are in accordance with that reported by Bonneau (1998), Blanchard *et al.* (1999) and Channon *et al.* (2004).

Table 2.3 Regression analysis ($y = a + bx$; $x = \text{slaughter weight}$) showing rates of change (b) in production parameters of group housed pigs of three sex types

Variable	a	b	R_a^2	F prob
Feed conversion ratio				
Boars	1.542	0.010 ^a	0.98	≤ 0.001
Castrates	1.541	0.013 ^b	0.97	≤ 0.001
Gilts	1.445	0.012 ^b	0.97	≤ 0.001
P2 at slaughter	4.081	0.088	0.98	≤ 0.001

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)
 $R_a^2 = \text{Adjusted } R^2$

Table 2.4 Means (\pm se) of backfat thickness, live weight at slaughter (kg) and average daily gain (g/d) of pigs of three sex types, five genotypes and eight slaughter weights

	P 2 – Back fat thickness at slaughter (mm)	Live weight at slaughter (kg)	Average daily gain (g/d)
Sex type			
Boar	11.0 ^a \pm 0.496	108.6 \pm 3.79	885.6 ^a \pm 11.2
Gilt	12.8 ^a \pm 0.479	102.4 \pm 3.66	819.7 ^b \pm 11.0
Castrate	15.0 ^b \pm 0.456	106.3 \pm 3.49	845.9 ^b \pm 10.6
Genotype			
1	13.6 ^{abc} \pm 0.599	100.1 ^b \pm 1.55	830.6 ^a \pm 13.8
2	12.8 ^{ab} \pm 0.609	109.5 ^a \pm 1.53	879.2 ^b \pm 13.8
3	13.8 ^{bc} \pm 0.661	111.2 ^a \pm 1.61	885.8 ^b \pm 15.4
4	14.8 ^c \pm 0.601	105.6 ^a \pm 1.50	848.2 ^{ab} \pm 13.6
5	12.0 ^a \pm 0.607	100.5 ^b \pm 1.54	812.5 ^a \pm 13.6
Slaughter weight (kg)			
62	9.6 ^a \pm 0.676	61.9 ^a \pm 1.93	775.8 ^a \pm 17.9
78	11.2 ^{ab} \pm 0.676	78.0 ^b \pm 1.94	876.7 ^{ef} \pm 17.4
86	11.9 ^b \pm 0.688	86.0 ^c \pm 1.97	831.5 ^b \pm 17.5
102	13.0 ^{bc} \pm 0.677	102.4 ^d \pm 1.94	883.9 ^f \pm 17.4
113	14.3 ^{cd} \pm 0.658	112.7 ^e \pm 1.88	861.2 ^{de} \pm 17.4
128	15.1 ^{de} \pm 0.621	128.4 ^f \pm 1.78	874.0 ^{ef} \pm 17.4
133	16.3 ^{ef} \pm 0.679	133.1 ^f \pm 1.94	854.0 ^{cd} \pm 17.2
146	16.3 ^{def} \pm 0.833	145.5 ^g \pm 2.38	839.4 ^{bc} \pm 18.4
Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)			

Cumulative intake was best described using a second order polynomial (Figure 2-1 and Equation 1, 2 and 3), which showed significant improvement in fit in comparison to a linear model.

Equation 1: $Y = a + bx + cx^2$

with: $Y =$ cumulative intake (kg)

$x =$ age in weeks

Then: dy/dx or dy/dt (t =time) would describe the change in y as age increase (time changes)

Equation 2: $dy/dx = (2)(b)x + c$

With: $dy/dx =$ change in cumulative intake at a certain x

$x =$ cumulative intake

$b =$ slope of the curve – describing the rate of change

Equation 3: Polynomial ($y = a + bx + cx^2$) for cumulative intake of boars.

$$Y = 5.365x^2 - 45.357x + 116.64 \quad (R^2 = 0.96)$$

Where $Y =$ cumulative intake of boars (kg)

and $x =$ age in weeks

So that $dY/dt = 10.73x - 45.357$

Equation 4: Polynomial ($y = a + bx + cx^2$) for cumulative intake of gilts.

$$Y = 6.3209x^2 - 57.88x + 145.57 \quad (R^2 = 0.97)$$

Where $Y =$ cumulative intake of gilts (kg)

and $x =$ age in weeks

So that $dy/dt = 12.64x - 57.88$

Equation 5: Polynomial ($y = a + bx + cx^2$) for cumulative intake of castrates.

$$Y = 158.31 - 63.445x + 6.9015 x^2 \quad (R^2 = 0.96)$$

Where Y = cumulative intake of castrates (kg)

and x = age in weeks

So that $dy/dt = 13.80 x - 63.445$

From these equations, the rate of change (b) in cumulative intake as the animal matures was highest for castrates, followed by gilts and then boars (Equation 3,4 & 5).

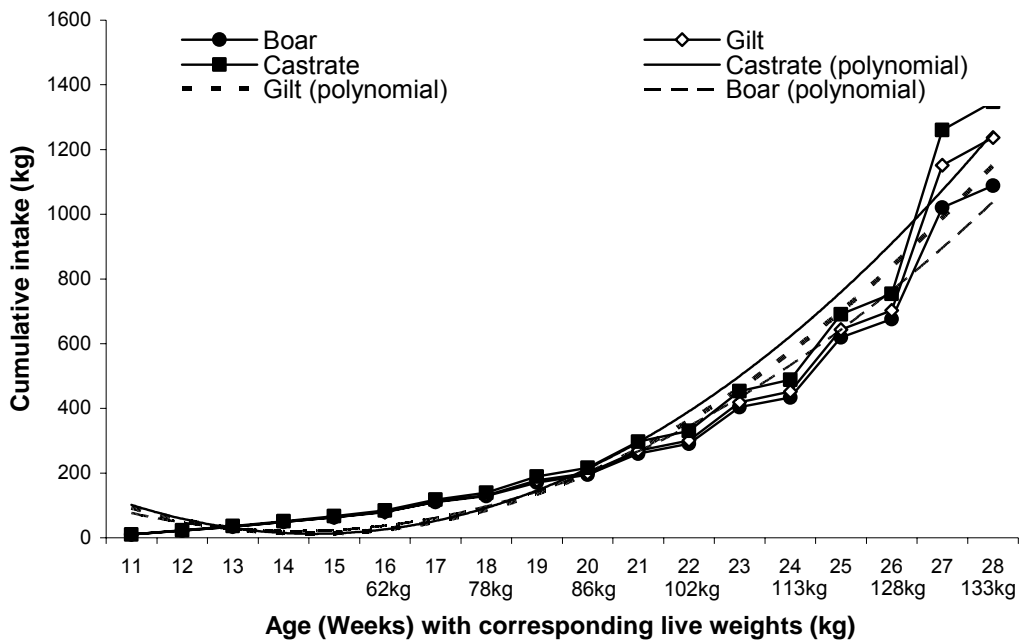


Figure 2-1 Cumulative intake of group housed pigs from 11 to 28 weeks of age of three sex types

Changes in feed conversion ratio (FCR) over time were estimated by fitting a linear model within sex type ($R^2 > 0.81$) to FCR data (Figure 2-2). A second order polynomial fit proved not to significantly improve on the linear model. Results obtained were used for further analysis. The distribution of R^2 values obtained by the fit showed 1 with a $R^2 > 0.99$, 16 with $0.90 \leq R^2 \leq 0.99$ and 7 with $0.80 \leq R^2 < 0.90$. The slope of this curve represents the average daily FCR change and was used for further data analysis. Average daily change in FCR showed significant differences ($P = 0.049$) with sex type describing 26% of the variance and slaughter group 71.5%. Similar results were reported by Huiskes, Binnendijk, & Van Trig (1996) and Chadd, Cole & Walters (1993). It can be concluded that FCR increased over time and the rate of change differed for the different sex types as initial differences observed show boars and gilts to be equally efficient but more efficient than castrates. From week 18 onwards, boars were more efficient than gilts and gilts more efficient than castrates ($P \leq 0.001$).

P2 backfat thickness showed castrates to have more backfat ($P \leq 0.05$) than boars and gilts and Genotype 5 to have the least backfat ($P \leq 0.05$), this genotype were also lighter (Table 2.4). Slaughter weight differences accounted for most of the observed variance and showed a constant increase with increase of 0.088mm per unit increase in slaughter weight (Table 2.3) ($R^2 = 0.98$; $P \leq 0.001$).

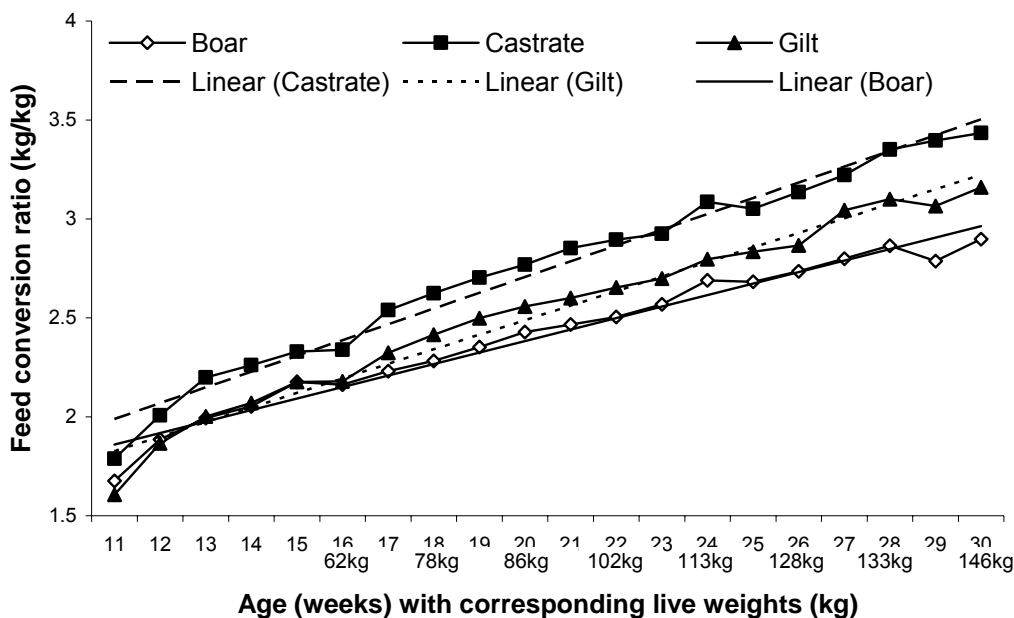


Figure 2-2 Feed conversion ratio (kg/kg) of group housed pigs from 11 to 30 weeks of age of three sex types

Conclusion

Average daily gain showed significant differences for all main effects and interactions tested. Most of the variance observed was however described by slaughter weight as well as sex type X slaughter weight interactions showing boars to grow faster than gilts and castrates. Growth rates, in all instances, were still linear ($R^2 > 0.91$). Cumulative feed intake showed different rates of change for sex types with increased live weight with castrates increasing feed intake more rapidly than gilts and boars. The faster growth rate and slower rate of increased feed intake observed for boars, or the opposite, slower growth rate and faster rate of increase in feed intake observed for castrates was reflected in the FCR. FCR worsened as slaughter weight increased with the rate at which this occurred being faster for castrates than for gilts and boars. Gilts and boars performed the same until 18 weeks of age but thereafter showed differences. It

is therefore concluded that the current genotypes farmed in South Africa have the ability to maintain high growth rates for a much longer period and that these genotypes can be slaughtered at a higher weight. The effect of increased slaughter weight of pigs on the carcass characteristics, meat quality and processing characteristics needs elucidation. The higher efficiency of boars should also be exploited while bearing in mind the possibility of the occurrence of taints.

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Chapter 3

The effect of slaughter weight on the carcass characteristics of pigs

Abstract

An investigation with 189 pigs of three sex types and five genotypes was conducted wherein the main treatment was slaughter weight (62 to 146kg). The main statistical differences observed were for the main effect of slaughter weight with significant ($P \leq 0.05$) and highly significant ($P \leq 0.01$) differences describing more than 10% of the variance observed. Significant sex type differences ($P \leq 0.05$) were also noted for dressing percentage, fat measurements and muscle depth measured between the 5th and 6th lumbar vertebrae. Sex type differences, in all instances, accounted for 10% or less of the observed variance except for subcutaneous fat:eye muscle area ratio (18.47%). Genotypic differences ($P \leq 0.05$) were observed for subcutaneous and intramuscular fat area, as well as certain Intrascop® (IS) and Hennessy Grading Probe® (HGP) fat depth measurements. Genotypic differences, in all instances, accounted for less than 10% of the variance observed. It was shown that although significant sex type and genotype differences ($P \leq 0.05$) do exist, slaughter weight had the largest effect on carcass characteristics in these experimental circumstances accounting for most of the observed variance.

Key words:

Pork, dressing percentage, carcass weight, fat thickness, muscle depth, eye muscle area, subcutaneous fat area, marbling.

Introduction

Carcass characteristics are factors that pose challenges to role players in the pork industry and were summarised by Kallweit, Kohler & Henning (2001) who noted that “In future production, swine carcasses should not only be lean but also homogeneous in weight and shape. Extreme conformation should be avoided.” Factors influencing carcass characteristics are in many ways linked to three main factors i.e. sex type, genotype and slaughter weight. Sex type manipulation is restricted to the choice between castrate and boar production while gilts remain a given. Genotype is a choice made by the producer and changing over from one genotype to another is often time consuming and costly. One easily manageable factor is slaughter weight. Sex type differences do occur, for example it was shown that gilts slaughtered at 105kg were generally superior to castrates for carcass quality parameters (Tibau, Gonzalez, Soler, Gispert, Lizardo & Mourot, 2003) and had lower backfat thickness and subsequently higher percentage lean and protein content with more water and less lipid than castrates (Gonzalez, Soler, Gispert, Puigvert & Tibau, 2001; Tibau, *et al.*, 2003). Similarly, Channon, Kerr & Walker (2004) reported that gilt carcasses had 0.4% more intramuscular fat and also thicker P2 backfat measurements at the same age and carcass weight than entire males, while Blanchard, Warkup, Ellis, Willis & Avery (1999) found no difference in P2 backfat thickness between boars and gilts. Latorre, Lázaro, Valencia, Medel & Mateos (2004) reported increased backfat thickness in castrates as well as decreased dressing percentage but no differences in carcass and ham length but greater ham circumference in castrates, while Blanchard *et al.* (1999) reported higher dressing percentage for gilts than boars. They further reported that boars had lower eye muscle depth but similar intramuscular fat content.

Genotypic differences have been observed for dressing percentage (Fabian, Chiba, Kuhlert, Frobish, Nadarajah & McElhenney, 2002; Latorre, Lázaro, Gracia, Nieto & Mateos, 2003), backfat thickness (Choi, Kim, Cho, Lee, Heon & Cheong, 2003a; Choi, Kim, Lee, Cho, Lee, Cho & Cheong, 2003b; Gatlin, See,

Hansen & Odle, 2003; Huang *et al.*, 2004), eye muscle depth (Gatlin *et al.*, 2003), level of intramuscular fat (Choi *et al.*, 2003a; Fabian *et al.*, 2002; Sencic, Speranda, Antunovic & Speranda, 2003; Channon *et al.*, 2004) and abdominal fat firmness (Fabian, *et al.*, 2002). Certain specific genetic factors have also been shown to influence carcass characteristics, for instance carriers of the stress gene (Nn) had higher eye muscle depth and decreased backfat thickness (Fabrega *et al.*, 2002) than normal (NN) pigs. Further quantitative trait loci have been identified for backfat thickness, carcass yield, loin muscle area, intramuscular fat content, carcass gain and muscle lightness (L*) indicating definite genotypic differences for these characteristics (Sato *et al.*, 2003; Pierzchala, Blicharski & Kuryl, 2003).

Increased slaughter weight leads to increased dressing percentage as the intestines of pigs are proportionally slower growing than the body of the pig as a whole (Whittemore, 1993; Ellis & Avery, 1994), Cisneros, Ellis, McKeith, McCaw & Fernando (1996) and Latorre *et al.* (2004) reported linear increases in dressing percentage with increased slaughter weight. In a study to determine the influence of heavy slaughter weights (110kg) on growth and carcass characteristics of pigs, Ellis & Avery (1994) found that eye-muscle areas increased with slaughter weight. Latorre *et al.* (2004) also reported a linear increase in backfat thickness, ham circumference and ham length.

The South African pork market consists mainly of two sections i.e. the fresh meat market and the processed (value added products) market. Pork usage in these markets is approximately equal. Until recently the average carcass weight of pigs slaughtered was below 70kg. There is, however, a tendency in South Africa to increase carcass weights. This was brought about by a perception by the producers that it is more economical to produce a heavier pig. If the cost of producing a piglet is seen as a fixed cost this would mean that the heavier the carcass the less the fixed cost per kilogram of carcass produced. As the variable cost remains approximately the same per kilogram produced the

total profitability per kilogram produced would be increased with increased carcass weight.

Earlier results (Chapter 2) have shown that growth rate of pig genotypes in South Africa remained constant at higher slaughter weights and the effects thereof on carcass characteristics require elucidation. The aim of this study was therefore to determine the effect of slaughter weight on the carcass characteristics of pork of different sex types and genotypes in terms of carcass weight, dressing percentage, fat thickness measurements, muscle depth, carcass measurements, eye muscle area, subcutaneous fat area, and ratios of subcutaneous and intra muscular fat to eye muscle area.

Materials and methods

For the purpose of this study carcass characteristics refer to measurements taken on carcasses on the slaughter line and during the following 24 hours prior to deboning and calculations made from these. It refers to dressing percentage, carcass weight, fat thickness, muscle depth, carcass length, ham length, chest depth, ham circumference, eye muscle area, subcutaneous fat area and percentage marbling.

The experiment was conducted at the Agricultural Research Council – Animal Nutrition and Animal Products Institute at Irene (Gauteng Province) and RTV abattoir in Benoni (Gauteng Province). The experimental outlay, housing and growth performance of the pigs have been described in detail in Chapter 2 and thus only the relevant information will be mentioned further. Slaughter information of pigs is shown in Table 3.1.

Table 3.1 Age at slaughter (days) and live weight at slaughter (kg) of group housed animals of three sex types representing five South African genotypes

Slaughter group	Age at slaughter (days)	Average live slaughter weight (kg)
1	112	61.93 ^a
2	126	77.99 ^b
3	140	86.04 ^c
4	154	102.37 ^d
5	168	112.70 ^e
6	182	128.39 ^f
7	196	133.10 ^f
8	210	145.45 ^g

Values in columns with different superscripts differ significantly ($P \leq 0.05$)

Care was taken to eliminate all unnecessary *ante mortem* stress that could influence meat quality. Pigs were weighed at approximately 06:00 in the morning, loaded onto a truck and transported 100 km to the abattoir where they were maintained in lairage for two hours prior to slaughter. Pigs were herded into a stunning cage, where they were stunned using an electrical stunner set at 220 Volts, with a current flow of 1.4 Amps for a period of four seconds. The electrodes were positioned at the base of each ear. Exsanguinations followed stunning within ten seconds after cessation of stunning. After 50 seconds the pig was shackled and hoisted, and bath scalding commenced five minutes after stunning. The same commercial abattoir and practises were used for all the slaughter groups. Thereafter the normal commercial dressing procedures were followed.

Warm carcass weight was determined using a commercial abattoir scale. The weight was determined approximately 90 minutes *post mortem* directly after Intrascop® (IS) and Hennessy Grading Probe® (HGP) measurements were completed. Carcasses were weighed complete with head, tail, trotters, kidneys and abdominal adipose tissues. Dressing percentage was calculated by determining the percentage ratio of the live weight of the animal at slaughter and the warm carcass weight.

Fat thickness measurements were taken on the right hand side of the carcass using both the Intrascop® (IS) and Hennessy Grading Probe® (HGP) at the following positions counted from the caudal end (Bruwer, 1992):

- Between the 2nd and 3rd last rib 45 mm from the dorsal midline.
- Between 5th and 6th lumbar vertebrae 45 mm from the dorsal midline.
- Between the 3rd and 4th lumbar vertebrae 45 mm from the dorsal mid-line.

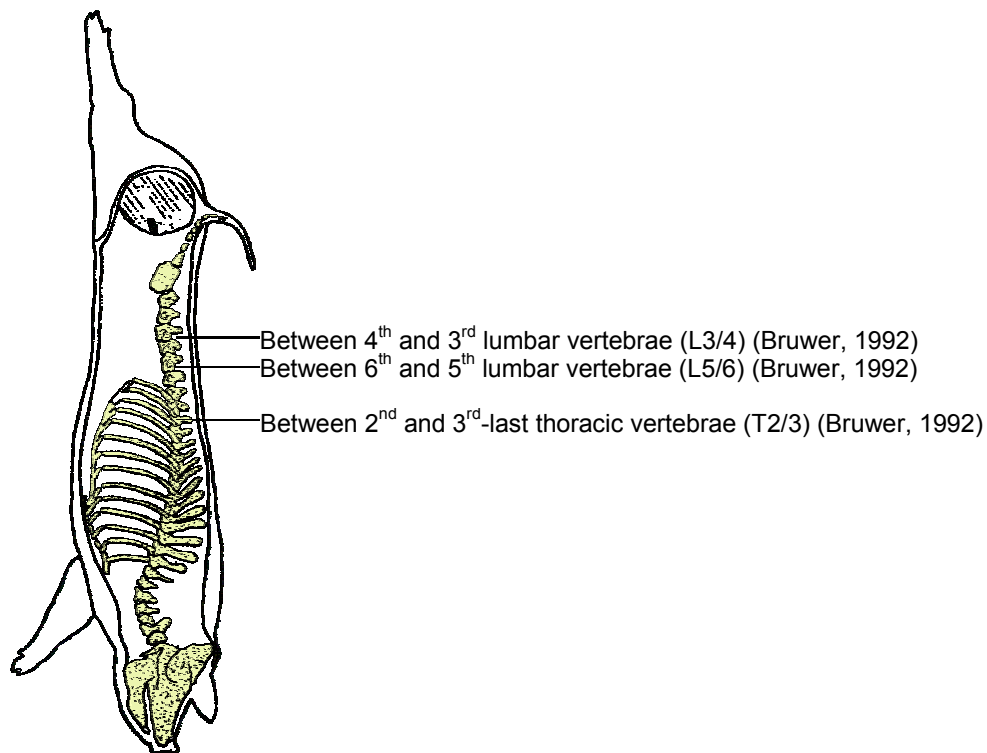


Figure 3-1 Figure showing the three measuring sites on the carcass (Adapted from Siebrits, 1984).

Muscle thickness measurements were recorded at the same position as fat thickness measurement using the HGP.

Carcass measurements were taken using a flexible tape measure with 1mm increments.

- Carcass length

The length of the carcass was measured from the cranial edge of the pubic symphysis to the cranial edge of the first rib at the angle of curvature.

- Ham length

Length of the ham was measured from the cranial edge of the pubic symphysis to the medio-distal point where the hind trotter was removed.

- Ham circumference

Ham circumference was measured around the thickest part of the ham.

- Chest depth

Chest depth was measured from the edge of the ribs across the widest section to the edge of the spinal column.

The left loin muscle (*longissimus lumborum*) was removed by cutting through the back between the vertebrae behind the last rib. The portion, including the muscle, subcutaneous fat, skin and bone from the first three lumbar vertebrae (approximately 15 cm) was removed. This portion was used for measuring of eye muscle area, subcutaneous fat area and intra muscular fat area (% marbling) using a Video Image Analyser (VIA) (Soft Imaging System Program: Analysis V 3.0). The total muscle area was measured while subcutaneous fat area was measured overlying the eye muscle (Figure 3-2).

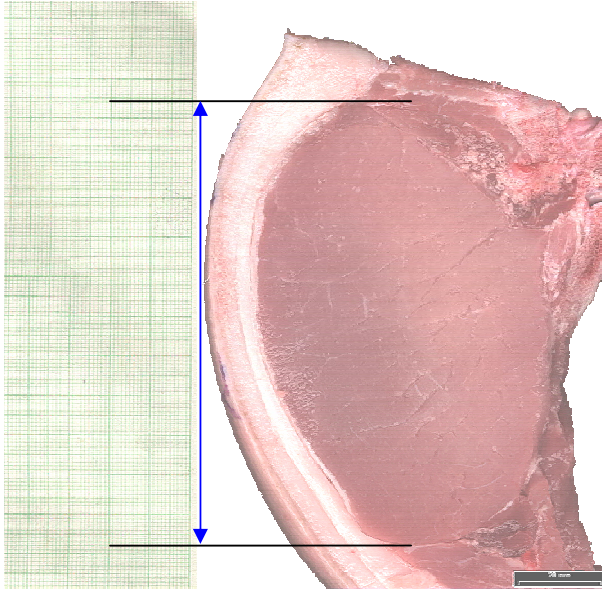


Figure 3-2 Video image analysis picture showing eye muscle area and area of subcutaneous fat measured

Data obtained in this trial were subjected to analysis of variance for unbalanced design using GenStat (GenStat 5 release 4.2, 2000), testing for slaughter group effects alternating with genotype and sextype effects, as well as the interaction of slaughter weight by genotype and sextype. All requirements concerning homogeneity of treatment variances and normality were met. The trial was designed in such a manner as to have three sex types and five genotypes per slaughter group. Since each repetition was represented by a pen and floor space had to be similar to that of commercial production systems the pens were filled to capacity by randomly allocating pigs of different genotypes within sextype to pens. This resulted in the trial being unbalanced for genotype. Further mortalities and removals resulted in the trial becoming unbalanced. Mortalities (3) were due to pneumonia and one to Hemorrhagic Enteritis while two animals were removed from the trial because of leg problems. A result was considered as highly significant at $P \leq 0.01$ and significant at $P \leq 0.05$. Percentage variance accounted for was calculated as the percentage ratio of the sum of squares of the individual parameter and the total.

Results and discussion

Live weight at slaughter is the only practical tool available to the producer for selecting animals that are ready for the market. In this investigation, live weight at slaughter varied from 61 to 146kg, this weight range is therefore used throughout as basis for comparison of variables.

Dressing percentage was calculated as a percentage ratio of the live weight of animals and warm carcass weight. Dressing percentage showed significant ($P \leq 0.05$) sex type differences and highly significant ($P \leq 0.001$) slaughter weight differences (Table 3.2). Sex type differences observed showed that dressing percentage for gilts and castrates were equal and higher respectively than that of boars, this difference accounted for 3.12% of the observed variance in the data. Blanchard *et al.* (1999) also reported a similar result while Latorre *et al.* (2004) found that gilts had a higher dressing percentage than castrates. Slaughter weight differences accounted for 19.76% of the variance and showed an increase of 0.4 percentage points for every 10kg increase in slaughter weight (Table 3.8). This linear increase was also reported by Latorre *et al.* (2004) at 0.6 percentage points for every 10kg. Studies by Cisneros *et al.* (1996) reported increases of 0.3 percentage points in dressing percentage (between 60 and 130kg live weight) per 10kg live weight gain. This increase in dressing percentage with increased slaughter weight can be attributed to the fact that the intestines of the pig are proportionally slower growing than the body of the pig (Gu, Schinckel & Martin, 1992; Whittemore, 1993).

Video image analysis (VIA) of eye muscle area, subcutaneous fat area and intramuscular fat area were used to calculate ratios of subcutaneous and intramuscular fat areas to muscle area (Table 3.3 and Table 3.4). The lack of observed sex type differences in intramuscular fat area can probably be ascribed to the low overall intramuscular fat areas observed. However, significant differences were reported by Channon *et al.* (2004) who found female pigs to have 0.4% more intramuscular fat than entire males. In this

investigation, no significant sex type differences ($P>0.05$) were observed for any parameter except for the subcutaneous fat area, and subcutaneous fat to eye muscle area ratio ($P\leq 0.001$). Observed sex type differences show subcutaneous fat area (mm^2) in boars and gilts to be statistically equal and lower than that of castrates. Since no significant differences ($P>0.05$) were observed for eye muscle area (mm^2) the differences observed for subcutaneous fat:eye muscle (Boars = gilts \leq castrates) can be ascribed to the difference observed in the subcutaneous fat area.

Genotypic differences observed included differences ($P\leq 0.05$) for eye muscle area, subcutaneous fat area and intramuscular fat area as well as differences for subcutaneous fat:eye muscle area ($P\leq 0.01$) and intramuscular fat:eye muscle area (Table 3.4).

Observed genotypic differences ($P\leq 0.05$) for eye muscle area showed Genotype 3 to have a larger eye muscle area than Genotype 1 and 2 but statistically equal ($P>0.05$) to Genotype 4 and 5 (Table 3.4). Differences for subcutaneous fat area showed Genotype 5 to have the smallest and Genotype 4 to have the largest subcutaneous fat area with other genotypes being intermediate or equal to either of the two. Genotype 5 and 1 had the lowest slaughter weight (Chapter 2) and this would probably have had an effect on subcutaneous fat depth, although this effect was not observed for Genotype 1. In terms of subcutaneous fat:eye muscle area Genotype 5 proved to be superior to all other genotypes while Genotype 1 proved to be inferior to all other genotypes except Genotype 4. The order of these ratios were the same as for subcutaneous fat area with Genotype 5 having the smallest and Genotype 4 the largest ratio with other genotypes intermediate and or statistically equal to these (Table 3.4).

The effect of slaughter weight on the carcass characteristics of pigs

Table 3.2 Means and standard errors of carcass characteristics of group housed pigs of three sex types, five genotypes and eight slaughter weights

Variable	Live weight at slaughter (kg)	Warm carcass weight (kg)	Dressing percentage (%)
Sex type			
Boar	108.61±3.79	83.88±3.09	77.00 ^a ±0.325
Gilt	102.44±3.66	80.15±2.98	77.97 ^b ±0.311
Castrate	106.26±3.49	83.70±2.87	77.92 ^b ±0.300
Genotype			
1	101.05±4.59	79.55±3.73	78.76±0.394
2	109.41±4.66	84.57±3.79	77.21±0.396
3	112.99±5.06	88.95±4.12	77.23±0.442
4	108.85±4.60	84.85±3.74	78.24±0.390
5	97.85±4.65	75.74±3.78	77.30±0.394
Slaughter weight (kg)			
62	61.93 ^a ±1.93	46.96 ^a ±1.56	75.12 ^a ±0.476
78	77.99 ^b ±1.94	60.52 ^b ±1.56	77.59 ^{bc} ±0.465
86	86.04 ^c ±1.97	66.82 ^c ±1.59	77.76 ^{bc} ±0.471
102	102.37 ^d ±1.94	78.96 ^d ±1.56	77.13 ^b ±0.465
113	112.70 ^e ±1.88	88.20 ^e ±1.52	78.28 ^{bc} ±0.453
128	128.39 ^f ±1.78	100.87 ^f ±1.44	78.57 ^c ±0.427
133	133.10 ^f ±1.94	105.47 ^g ±1.57	78.37 ^{bc} ±0.476
146	145.45 ^g ±2.38	114.67 ^h ±1.92	79.01 ^c ±0.572
Values in columns within groups with different superscripts differ significantly (P≤0.05)			

The effect of slaughter weight on the carcass characteristics of pigs

Table 3.3 Eye muscle, subcutaneous fat and intramuscular fat areas measured on loin chops of group housed pigs of three sex types, five genotypes and eight slaughter weights

Variable	Eye muscle area (mm²)	Subcutaneous fat area (mm²)	Intramuscular fat (mm²)
Sex type			
Boar	5081±141	1155 ^a ±97	14.87±2.02
Gilt	5035±133	1246 ^a ±91	15.35±1.91
Castrate	4703±127	1757 ^b ±88	14.52±1.82
Genotype			
1	4779 ^a ±111	1539 ^{bc} ±114	11.95 ^a ±2.39
2	4708 ^a ±110	1297 ^{ab} ±118	19.24 ^b ±2.46
3	5134 ^b ±115	1512 ^{bc} ±130	19.57 ^b ±2.64
4	4984 ^{ab} ±109	1632 ^c ±116	11.80 ^a ±2.43
5	4920 ^{ab} ±111	1061 ^a ±116	12.61 ^{ab} ±2.42
Slaughter weight (kg)			
62	3323 ^a ±138	733 ^a ±118	9.78 ^{ab} ±2.66
78	4062 ^b ±142	942 ^{ab} ±121	25.34 ^d ±2.73
86	4439 ^b ±143	897 ^{ab} ±125	25.88 ^d ±2.74
102	5172 ^c ±139	1179 ^{bc} ±118	19.85 ^{cd} ±2.66
113	5639 ^d ±135	1437 ^c ±115	13.86 ^{bc} ±2.59
128	5450 ^{cd} ±127	1803 ^d ±108	6.62 ^a ±2.45
133	5433 ^{cd} ±139	1992 ^d ±119	10.86 ^{ab} ±2.68
146	5729 ^d ±171	2394 ^e ±146	8.05 ^{ab} ±3.29
Values in columns within groups with different superscripts differ significantly (P≤0.05)			

Table 3.4 Ratios of subcutaneous and intramuscular fat to eye muscle area measured in pork chops of group housed pigs of three sex types, five genotypes and eight slaughter weights

Variable	Subcutaneous fat:eye muscle area (%)	Intramuscular fat:eye muscle area (%)
Sex type		
Boar	22.62 ^a ±1.75	0.309±0.047
Gilt	24.65 ^a ±1.65	0.335±0.045
Castrate	36.94 ^b ±1.59	0.320±0.043
Genotype		
1	31.89 ^b ±2.07	0.278 ^{ab} ±0.049
2	27.13 ^{ab} ±2.13	0.411 ^{bc} ±0.049
3	29.53 ^{ab} ±2.35	0.428 ^c ±0.051
4	32.71 ^b ±2.10	0.269 ^a ±0.048
5	21.58 ^a ±2.09	0.252 ^a ±0.049
Slaughter weight (kg)		
62	21.64 ^a ±2.78	0.278 ^{ab} ±0.061
78	23.40 ^a ±2.85	0.634 ^c ±0.063
86	21.15 ^a ±2.95	0.582 ^c ±0.063
102	24.13 ^a ±2.78	0.398 ^b ±0.061
113	27.73 ^{ab} ±2.71	0.249 ^{ab} ±0.060
128	33.95 ^{bc} ±2.55	0.126 ^a ±0.056
133	37.40 ^c ±2.80	0.199 ^a ±0.062
146	42.35 ^c ±3.44	0.142 ^a ±0.076
Values in columns within groups with different superscripts differ significantly (P≤0.05)		

Genotypic differences observed for intramuscular fat area showed Genotype 2 and 3 to have more intramuscular fat than Genotype 1 and 4 with Genotype 5 being intermediate and statistically equal to all genotypes (Table 3.3). Genotypic differences observed for intramuscular fat:eye muscle area (Table 3.4) show Genotypes 2 and 3 to have the highest ratio of intramuscular fat:eye

muscle area and confirms results obtained by Wood (1993) and Channon *et al.* (2004) showing these genotypes to have higher marbling.

In all the above VIA measurements, differences observed for sex type and genotype accounted for less than 10% of variance except for the sex type differences observed for subcutaneous fat:eye muscle area where it accounted for 18.47% of variance. Slaughter weight accounted for 21.74% of the variance. Although slaughter weight accounted for most of the variance, the effect of slaughter weight and sex type were similar for subcutaneous fat:eye muscle area indicating that, if subcutaneous fat:eye muscle area is of importance to the consumer (Dransfield, 2001), the sex and slaughter weight of the pigs should be considered. As no significant interactions ($P>0.05$) between sex type and slaughter weight were observed for any of the loin parameters measured, the rates of change of these parameters with increased slaughter weight would be statistically the same for all sex types.

Highly significant ($P\leq 0.01$) slaughter weight differences were observed for all variables measured, in all instances these differences described more than 20% of the variance observed. Changes in loin characteristics in relation to increased slaughter weight were determined using linear regression analysis (Table 3.8). These regressions indicate that the rate of increase in the advantageous parameters i.e. percentage marbling and eye muscle area, is faster than the rate of increase in the undesirable parameter, subcutaneous fat area (29.21mm^2 vs. 20.92mm^2) (Table 3.8).

Backfat depth was measured using the Intrascop® (IS) and Hennessy Grading Probe® (HGP). Results obtained are shown in Table 3.5 and Table 3.6. No significant interactions ($P>0.05$) of the main effects were observed for any fat depth measured. Highly significant ($P\leq 0.01$) sex type differences were observed for all IS and HGP measurements showing gilts and boars to be

statistically equal with thinner backfat than castrates at all sites. The present results are similar to that reported by Blanchard *et al.* (1999) while Channon *et al.* (2004) reported gilts to have higher backfat thickness than boars.

Significant ($P \leq 0.05$) and highly significant ($P \leq 0.01$) genotypic differences were observed for IS and HGP measurements (Table 3.5 & Table 3.6). These differences show Genotype 5 to have thinner backfat than the other genotypes, these observed results are similar to that for subcutaneous fat area (Table 3.3) and although this genotype proved to have had a lower slaughter weight than all genotypes except genotype 1 the assumption that lower slaughter weight led to this lower backfat thickness does not hold true for Genotype 1 proving that Genotype 4 was superior to, at least Genotype 1, for parameters relating to back fat thickness and subcutaneous back fat area. Genotypic differences related to backfat thickness have been reported by various authors (Choi *et al.*, 2003a,b; Gatlin *et al.*, 2003; Huang *et al.*, 2004).

Highly significant ($P \leq 0.001$) slaughter weight differences were observed for all IS and HGP measurements (Table 3.5 & 3.6). Rates of change in these measurements with increased slaughter weight were determined using regression analysis (Table 3.8). These regressions show IS fat measurements to increase at a rate of 0.122 mm, 0.136 mm and 0.152 mm ($P \leq 0.001$; $R^2 > 0.90$) and HGP fat measurements to increase at a rate of 0.124 mm, 0.130 mm and 0.140 mm ($P \leq 0.001$; $R^2 > 0.86$) at the three measuring sites *viz* between the 2nd and 3rd last rib, between the 5th and 6th lumbar vertebrae and between the 3rd and 4th lumbar vertebrae.

Genotype and sex type differences accounted, in all instances, for 10% or less of the variance observed in the measured backfat thickness while slaughter weight accounted for >25%. This indicates that, although genotype and sex type differences do exist, the extent of these differences are far less than that caused by slaughter weight

The effect of slaughter weight on the carcass characteristics of pigs

Table 3.5 Means and standard errors of Intrascop® fat thickness measurements (cm) taken on pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights

Variable	2 nd and 3 rd last rib	5 th and 6 th lumbar vertebrae	3 rd and 4 th lumbar vertebrae
Sex type			
Boar	14.36 ^a ±0.696	13.69 ^a ±0.774	15.77 ^a ±0.819
Gilt	15.46 ^a ±0.665	15.29 ^a ±0.739	17.47 ^a ±0.783
Castrate	17.92 ^b ±0.630	18.25 ^b ±0.700	19.87 ^b ±0.741
Genotype			
1	16.28±0.809	16.69 ^{bc} ±0.900	18.79 ^{bc} ±0.952
2	16.20±0.862	14.48 ^{ab} ±0.958	16.17 ^{ab} ±1.014
3	16.36±0.916	16.62 ^{bc} ±1.018	18.70 ^{bc} ±1.077
4	17.43±0.837	17.88 ^c ±0.930	20.13 ^c ±0.984
5	13.87±0.858	13.72 ^a ±0.954	15.26 ^a ±1.010
Slaughter weight (kg)			
62	11.26 ^a ±0.802	10.80 ^a ±0.945	11.69 ^a ±0.899
78	12.88 ^{ab} ±0.802	12.21 ^a ±0.974	14.36 ^b ±0.927
86	-	-	-
102	14.79 ^{bc} ±0.804	14.91 ^b ±0.947	15.77 ^{bc} ±0.901
113	16.13 ^c ±0.781	15.75 ^b ±0.921	17.69 ^{cd} ±0.876
128	16.38 ^c ±0.735	16.50 ^b ±0.867	18.55 ^d ±0.824
133	20.30 ^d ±0.801	20.38 ^c ±0.944	23.04 ^e ±0.898
146	21.28 ^d ±0.997	22.13 ^c ±1.175	24.49 ^e ±1.118

Values in columns within groups with different superscripts differ significantly (P≤0.05)

The effect of slaughter weight on the carcass characteristics of pigs

Table 3.6 Means and standard errors of Hennessy Grading Probe® (HGP) fat depth measurements (cm) taken on pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights

Variable	2 nd and 3 rd last rib	5 th and 6 th lumbar vertebrae	3 rd and 4 th lumbar vertebrae
Sex type			
Boar	14.00 ^a ±0.666	13.66 ^a ±0.653	15.20 ^a ±0.749
Gilt	14.81 ^a ±0.642	14.67 ^a ±0.630	16.63 ^a ±0.722
Castrate	17.46 ^b ±0.612	17.22 ^b ±0.600	19.52 ^b ±0.688
Genotype			
1	16.21 ^a ±0.804	16.56 ^b ±0.789	18.96 ^c ±0.905
2	15.37 ^a ±0.818	13.96 ^a ±0.802	15.76 ^{ab} ±0.920
3	16.34 ^a ±0.887	15.81 ^{ab} ±0.870	18.01 ^{bc} ±0.998
4	16.69 ^a ±0.807	16.53 ^b ±0.791	18.72 ^c ±0.907
5	13.13 ^b ±0.815	13.64 ^a ±0.800	14.82 ^a ±0.917
Slaughter weight (kg)			
62	10.91 ^a ±0.832	11.06 ^a ±0.802	12.70 ^a ±0.978
78	12.71 ^{ab} ±0.833	12.66 ^{ab} ±0.803	14.79 ^{ab} ±0.979
86	12.88 ^{bc} ±0.847	12.37 ^{ab} ±0.816	14.20 ^{ab} ±0.995
102	15.09 ^{cd} ±0.834	13.93 ^{bc} ±0.804	15.17 ^a ±0.980
113	15.99 ^d ±0.811	15.82 ^{cd} ±0.781	17.33 ^{bc} ±0.952
128	16.89 ^d ±0.765	16.63 ^d ±0.738	18.63 ^c ±0.899
133	19.95 ^e ±0.836	19.74 ^e ±0.806	22.80 ^d ±0.983
146	20.81 ^e ±1.026	21.70 ^e ±0.989	23.90 ^d ±1.206

Values in columns within groups with different superscripts differ significantly (P≤0.05)

Table 3.7 Means and standard errors of Hennessy Grading Probe® (HGP) muscle depth measurements (cm) taken on pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights

Variable	2 nd and 3 rd last rib	5 th and 6 th lumbar vertebrae	3 rd and 4 th lumbar vertebrae
Sex type			
Boar	55.18±1.22	53.86 ^a ±1.20	52.19±1.58
Gilt	55.65±1.18	57.42 ^b ±1.15	56.01±1.52
Castrate	54.92±1.12	57.40 ^b ±1.10	56.18±1.45
Genotype			
1	56.41±1.47	56.69±1.45	54.50±1.91
2	51.40±1.50	53.35±1.47	52.70±1.94
3	56.60±1.63	58.55±1.59	55.63±2.10
4	55.78±1.48	57.35±1.45	55.87±1.91
5	56.08±1.50	55.87±1.47	55.88±1.93
Slaughter weight (kg)			
62	43.62 ^a ±1.31	46.87 ^a ±1.40	47.99 ^a ±2.22
78	47.53 ^b ±1.31	50.20 ^b ±1.40	51.37 ^{ab} ±2.22
86	50.98 ^b ±1.33	52.32 ^b ±1.43	52.19 ^{abc} ±2.26
102	55.54 ^c ±1.31	54.08 ^b ±1.40	53.10 ^{abc} ±2.22
113	58.72 ^{cd} ±1.27	59.32 ^c ±1.37	58.17 ^{cd} ±2.16
128	62.10 ^{de} ±1.20	62.87 ^{cd} ±1.29	63.78 ^d ±2.04
133	59.66 ^{de} ±1.31	58.98 ^c ±1.41	57.40 ^{bc} ±2.23
146	63.45 ^e ±1.61	64.82 ^d ±1.73	51.63 ^{abc} ±2.74
Values in columns within groups with different superscripts differ significantly (P≤0.05)			

Table 3.8 Regression analysis ($y = a + bx$) describing changes in carcass characteristics of pork carcasses with increased slaughter weight (x)

Y	a	b	Adjusted R ²	F prob
Dressing percentage (%)	73.877	0.036*	0.667	0.008
Eye muscle area (mm ²)	1808.844	29.210**	0.830	0.001
Subcutaneous fat area (mm ²)	-795.543	20.916**	0.936	≤0.001
Intra muscular fat area (mm ²)	31.682	-0.157	0.203	0.147
Percentage marbling (%)	0.419	0.269**	0.839	≤0.001
Subcutaneous fat:eye muscle area	0.850	-0.005	0.406	0.053
IS fat 2 nd and 3 rd last rib (mm)	2.971	0.122**	0.912	≤0.001
IS fat 5 th and 6 th lumbar vertebrae (mm)	1.363	0.136**	0.920	≤0.001
IS fat 3 rd and 4 th lumbar vertebrae (mm)	1.466	0.152**	0.906	≤0.001
HGP fat 2 nd and 3 rd last rib (mm)	2.456	0.124**	0.949	≤0.001
HGP fat 5 th and 6 th lumbar vertebrae (mm)	1.666	0.130**	0.908	≤0.001
HGP fat 3 rd and 4 th lumbar vertebrae (mm)	2.634	0.140**	0.864	≤0.001
HGP muscle depth 2 nd and 3 rd last rib (mm)	28.349	0.253**	0.939	≤0.001
HGP muscle depth 5 th and 6 th lumbar vertebrae (mm)	32.745	0.221**	0.917	≤0.001
HGP muscle depth 3 rd and 4 th lumbar vertebrae (mm)	43.174	0.106	0.232	0.128

* Significant coefficients (P≤0.05), ** Highly significant coefficients (P≤0.01)
 IS – Intrascop® measurement, HGP – Hennessy Grading Probe® measurement

Muscle depth was measured using the HGP. Measurements were taken between the 2nd and 3rd last rib, between the 3rd and 4th lumbar vertebrae and between the 5th and 6th lumbar vertebrae (Table 3.7). No significant ($P>0.05$) genotype differences were observed, while a significant ($P\leq 0.05$) was observed with boars having a thinner muscle between the 5th and 6th lumbar vertebrae, highly significant ($P\leq 0.01$) slaughter weight differences were observed for the muscle measurements taken at all sites. Changes in these parameters with increased slaughter weight (kg) are depicted in Table 3.8. These regressions show HGP muscle depth measurements to increase at 0.253 mm ($P\leq 0.001$; $R^2=0.94$) and 0.221 mm ($P\leq 0.001$; $R^2=0.92$) respectively between the 2nd and 3rd last rib, the 5th and 6th lumbar vertebrae. However, measurements taken between the 3rd and 4th lumbar vertebrae did not have a good predictive value ($R^2=0.232$).

The means and standard errors of the various linear carcass measurements are shown in Table 3.10. No significant ($P>0.05$) sex type or genotype differences were observed. Latorre *et al.* (2004) also reported no differences for ham and carcass length but greater ham circumference for castrates. Highly significant ($P\leq 0.01$) slaughter weight differences were observed for all carcass measurements and a significant ($P=0.021$) sex type X slaughter weight interaction was also observed for chest depth. However, this interaction only accounted for 4.76% of the variance. Changes in these parameters with increased slaughter weight are shown in Table 3.9. Since these regressions show carcass length, ham length, ham circumference and chest depth to increase as the pigs became heavier, the order of these increases are similar to that reported by Latorre *et al.* (2004). The differences in changes of these measurements are shown in Table 3.9, indicating that ham circumference increased the fastest followed by carcass length, ham length and lastly chest depth.

Table 3.9 Regression analysis ($y = a + bx$) describing changes in carcass measurements of pork carcasses with increased slaughter weight (x)

Y	a	b	Adjusted R ²	F prob
Carcass length (cm)	58.24	0.248**	0.978	≤0.001
Ham length (cm)	34.69	0.162**	0.966	≤0.001
Ham circumference (cm)	36.89	0.338**	0.947	≤0.001
Chest depth (cm)	12.24	0.067**	0.974	≤0.001

* Significant coefficients ($P \leq 0.05$),

** Highly significant coefficients ($P \leq 0.01$)

Conclusion

Sex type differences observed were mainly associated with fat measurements showing gilts and boars to be leaner than castrates. Other significant ($P \leq 0.05$) sex type differences included dressing percentage and muscle depth measured between the 5th and 6th lumbar vertebrae. These differences, however, accounted for less than 10% of the variance and the effects were overshadowed by the slaughter weight effects accounting respectively for 20% and 40% of the variance.

Genotypic differences observed were observed for eye muscle, subcutaneous and intramuscular fat areas as well as certain fat depth measurements. These differences showed Genotype 5 to be mostly superior and Genotype 1 to be mostly inferior to other genotypes.

Table 3.10 Means and standard errors of carcass measurements (cm) of carcasses obtained from group housed pigs of three sex types, five genotypes and eight slaughter weights

Variable	Carcass length (mm)	Ham length (mm)	Ham circumference (mm)	Chest depth (mm)
Sex type				
Boar	86.89±0.938	52.49±0.621	72.87±1.27	19.37±0.274
Gilt	85.18±0.910	51.23±0.599	72.53±1.22	19.01±0.265
Castrate	84.97±0.854	51.88±0.571	72.88±1.17	19.50±0.254
Genotype				
1	84.84±1.14	50.83±0.750	72.16±1.53	18.88±0.331
2	85.74±1.16	52.16±0.762	73.37±1.56	19.27±0.337
3	86.44±1.23	52.74±0.827	74.10±1.69	19.91±0.365
4	86.41±1.12	52.44±0.752	74.02±1.54	19.61±0.336
5	84.74±1.16	51.21±0.760	70.28±1.55	18.89±0.336
Slaughter weight (kg)				
62	75.39 ^a ±3.872	45.39 ^a ±0.430	57.34 ^a ±0.671	16.56 ^a ±0.245
78	75.79 ^a ±0.721	48.54 ^b ±0.431	61.23 ^b ±0.672	17.44 ^b ±0.246
86	80.80 ^b ±0.733	47.96 ^b ±0.438	69.32 ^c ±0.683	18.54 ^c ±0.250
102	84.14 ^c ±0.721	50.35 ^c ±0.431	73.43 ^d ±0.672	18.61 ^c ±0.246
113	86.13 ^d ±0.701	53.13 ^d ±0.419	76.57 ^e ±0.654	20.08 ^d ±0.239
128	89.68 ^e ±0.662	55.41 ^e ±0.396	78.59 ^f ±0.617	20.57 ^{de} ±0.226
133	90.61 ^e ±0.722	56.30 ^e ±0.433	82.85 ^g ±0.674	20.81 ^e ±0.251
146	-	58.16 ^f ±0.537	82.90 ^g ±0.827	22.09 ^f ±0.303
Values in columns within groups with different superscripts differ significantly (P≤0.05)				

Significant ($P \leq 0.05$) and highly significant ($P \leq 0.01$) slaughter weight differences were observed for all characteristics measured, describing in all instances, more than 10% of the variance. These differences observed, showed a decrease ($P \leq 0.05$) in the ratio of subcutaneous fat to eye muscle area and increases ($P \leq 0.001$) for all other characteristics. The increase in eye muscle area per kilogram slaughter weight change was larger than the increase in subcutaneous fat area. This was confirmed by the significant ($P \leq 0.05$) decrease observed for subcutaneous fat to eye muscle area ratio. It can therefore be concluded that, in the South African scenario, with all production and slaughter factors being equal, the effect of sex type and genotype is small while the effect of slaughter weight is substantial. Although some negative effects were observed in terms of backfat thickness the advantages observed in terms of dressing percentage and eye muscle area probably outweigh these negative effects. Therefore, increasing the slaughter weight of pigs in South Africa could have a beneficial effect on carcass characteristics or, at least, should not have any detrimental effects.

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Chapter 4

The effect of slaughter weight on the meat quality characteristics of pork

Abstract

The South African pork industry is characterised by low slaughter weights compared to the rest of the world. This inadvertently leads to a smaller number of kilograms produced per unit fixed cost and consequently the efficiency of production is reduced. A study with slaughter weight (62 to 146kg) as main effect was conducted with 189 pigs of three sex (boar, gilt and castrate) types and five genotypes. Differences observed were for the main effect of slaughter weight with significant differences ($P \leq 0.05$) describing more than 10% of variance observed for initial pH (pH_1), ultimate pH (pH_u), water holding capacity (WHC), Drip loss, Cielab colour and HGP colour measurements measured except for tenderness measurements and Hennessy Grading Probe® (HGP) colour measurements between the 5th & 6th and 3rd & 4th lumbar vertebrae. Significant ($P \leq 0.05$) genotype differences were observed for pH_1 , drip loss and CIELab measurements a^* and b^* , however, percentage variance accounted for was low ($\leq 10\%$) for all characteristics except Cielab measurement a^* (11.18%). Significant sex type differences were observed for tenderness (6.21% variance accounted for) and CIELab factor L^* (4.44% variance accounted for). Although significant sex and genotype differences ($P \leq 0.05$) were noted, slaughter weight had the largest effect on meat quality in the given circumstances. It can therefore be accepted that heavier slaughter weights will not have a negative effect on meat quality characteristics in the South African scenario.

Key words

Pork, slaughter weight, sex, genotype, meat quality, pH, drip loss, water holding capacity, colour, tenderness.

Introduction

Meat quality is becoming increasingly important to both meat processors and consumers (Beattie, Weatherup, Moss & Walker, 1999). Meat quality has many different definitions. In some instances these definitions refer to factors exclusively associated with biochemical processes (Bruwer, 1992; Van der Wal, Engel & Hulsegge, 1997) while others define meat quality as a combination of physical and biochemical factors such as eye muscle area, ham shape, muscle quality and fat quality (Whittemore, 1993), the latter characteristics are all closely related to carcass weight.

A longstanding problem in the pig industry is pale soft and exudative (PSE) meat. This meat appears pale because of a high degree of light scattering caused by a low pH, it is soft because of free fluid between the muscle fibres and other factors and it is exudative, resulting in weight loss by drip and evaporation (Lundström, Essén-Gustavsson, Rundgren Edfors-Lilja & Malmfors, 1989). PSE meat is defined as meat with a drip loss in excess of 5% and a L* value above 50 (Warner, Kauffman & Greaser, 1977). Dark firm and dry meat (DFD) is the opposite condition to PSE. This condition results when animals are exposed to long-term stress and depletion of nutrients, primarily glycogen (Seideman, Cross, Smith & Durland, 1984).

The South African pork market consists mainly of two sections i.e. the fresh meat market and the processed (value added products) market. Pork usage in these markets is approximately equal. Until recently the average carcass weight of pigs slaughtered was below 70kg. There is however, a trend in South Africa for increased carcass weights.

Results suggested that pork quality may be improved when the slaughter weight of pigs is increased from 95 to 125kg (Moon, Mullen, Troy, Yang, Joo & Park, 2003). As slaughter weight increases from 95 to 115kg it was found that ultimate pH (pH_u) decreased but no differences were observed for carcasses slaughtered at 105kg or more. A decrease in cooking losses and an increase in shear force was also noted. The lightness (L^*) and redness (a^*) of pork loin were increased with increasing slaughter weight (Moon *et al.*, 2003). Kocwin-Podsiadla *et al.* (2002) similarly found that an increase in hot carcass weight above 90kg had a positive effect on the rate and extent of *longissimus dorsi* muscle acidity measured 45 min (pH_1) and 24 h post-mortem, resulting in higher water holding capacity, lower drip loss and lower losses of cured meat during cooking.

Differences in meat quality due to genotypic differences, other than the presence of the halothane or RN genes, have been reported by various authors. Findings to date have however, not been conclusive with authors reporting contradicting results. Lack of genotypic differences have been reported for water binding capacity, colour (Sencic, Speranda, Antunovic & Spreanda, 2003; Channon, Kerr & Walker, 2004) and pH_1 (Channon *et al.*, 2004) while genotypic differences for meat tenderness, colour (Latorre, Lázaro, Gracia, Nieto & Mateos, 2003) and pH_u (Channon *et al.*, 2004) were reported.

Genotype and sex type did not influence pH at 1, 3 and 6 hours *post mortem*, however, pH_u was lower for Duroc and entire male carcasses with entire male carcasses showing a pH_u 0.07 units higher than that of female carcasses (5.64 vs. 5.57) (Channon *et al.*, 2004). Latorre, Lázaro, Valencia, Medel & Mateos (2004) further reported pH_1 and pH_u to be lower for gilts than for castrates while Bañon, Andreu, Laencna & Garrido (2004) reported no differences between males and castrates.

Although tenderness is influenced by a number of factors, Latorre *et al.* (2004) in contrast with Moon *et al.* (2003) found no effect of increased slaughter weight (age) on shear force values. Influence of sex type on shear force value is also not conclusive, in a study by Latorre *et al.* (2004) it was found that castrates were more tender than gilts while Blanchard, Warkup, Ellis, Willis & Avery, (1999) reported that intact males and females had the same shear force values and Channon *et al.* (2004) reported lower shear force values for females than entire males.

Genetic (Bañon *et al.*, 2004), sex type (Channon *et al.*, 2004; Nold, Romans, Costello & Libal, 1999) and slaughter weight (Latorre *et al.*, 2004) differences have been reported for CIELab colour measurements by various authors and results are also not always conclusive. Entire male carcasses were found to have lower L* values (thus darker meat) than that of females (Channon *et al.*, 2004) while Nold *et al.* (1999) reported higher L* values for castrates and boars in comparison with females. Nold *et al.* (1999) reported lower CIELab a* and b* values for boars than for gilts and castrates. However, no differences in colour measurements were reported between gilts and castrates by Latorre *et al.* (2004) and between boars and castrates (Bañon *et al.*, 2004). Observed slaughter weight differences showed decreased L* and increased a* values, indicating darker meat with increased red hue (Latorre *et al.*, 2004).

Increasing the slaughter weight of pigs in the South African scenario did not result in the expected decrease in growth rate and productivity (Chapter 2) nor was it detrimental for carcass characteristics (Chapter 3). The effect of this carcass weight increase on the meat quality characteristics of pigs representing three sex types and five genotypes, deemed to be representative of pigs currently slaughtered in South Africa, are investigated in this Chapter.

Materials and methods

The experiment was conducted at the Agricultural Research Council – Animal Nutrition and Animal Products Institute at Irene (Gauteng Province) and RTV abattoir in Benoni (Gauteng Province). The experimental outlay, housing and growth performance of the pigs have been described in detail in Chapter 2 and the carcass characteristics in Chapter 3.

Treatments were according to slaughter weight. Each sex type had eight slaughter groups of eight pigs. The first group of pigs was slaughtered when the average live weight of all the pigs was 62kg and the subsequent groups at two-week intervals thereafter. By using this design average live slaughter weights ranging from 62 to 146kg were obtained. Slaughter weights are shown in Table 4.1.

Care was taken to eliminate all unnecessary *ante mortem* stress that could influence meat quality. Pigs were transported 100 km to the abattoir where they were maintained in lairage for two hours prior to slaughter. Pigs were herded into a stunning cage, where they were stunned using an electrical stunner set at 220 Volts, with a current flow of 1.4 Amps for four seconds. The electrodes were positioned at the base of each ear. Exsanguinations followed stunning within ten seconds after cessation of stunning. After 50 seconds the pig was shackled and hoisted, and bath scalding commenced five minutes after stunning. The same commercial abattoir practises were used for all the slaughter groups. Thereafter the normal commercial dressing procedures were followed.

Table 4.1 Age at slaughter (days) and live weight at slaughter (kg) of group housed animals of three sex types representing five South African genotypes

Slaughter group	Age at slaughter (days)	Average live slaughter weight (kg)
1	112	61.93 ^a
2	126	77.99 ^b
3	140	86.04 ^c
4	154	102.37 ^d
5	168	112.70 ^e
6	182	128.39 ^f
7	196	133.10 ^f
8	210	145.45 ^g

Values in columns with different superscripts differ significantly ($P \leq 0.05$)

Initial muscle pH was determined 60 minutes *post mortem* (pH_1), prior to Intrascop® (IS) and HGP measurements. Muscle pH_1 was measured with the use of a calibrated (standard buffers pH 4.0 and 7.0 at 25°C) portable Crison 506 pH-meter by inserting the pH electrode into the *longissimus lumborum* muscle from the inside of the carcass between the 2nd and 3rd lumbar vertebrae counting from the caudal end. Ultimate muscle pH was determined 24 hours (pH_u) *post mortem* in the same manner and position as described for pH_1 . Following the initial pH measurement, the carcasses were hung in cold storage at 4°C for a minimum of 12 hours (average cold carcass temperature 8.12°C) whereafter the remaining measurements were taken.

The left loin muscle (*longissimus lumborum*) was removed by cutting through the back between the last thoracic and first lumbar vertebrae. The top section of the lumbar region (approximately 15 cm) was then removed and the muscle

portion of this section used for measuring the following meat quality characteristics: meat colour, drip loss, water binding capacity and toughness. Meat colour was (L^* , a^* , b^* measurements) measured with a Minolta® chroma meter (Model CR200, Japan) where L^* represents brightness, a^* represents the red-green range and b^* represents the blue-yellow range (Swatland, 1984). Measurements were taken at three different positions on the loin-cut and an average was then determined from the combination of the results obtained. The remainder was frozen at -20°C for sensory analysis and tenderness measurements.

Drip loss was estimated on duplicate slices of the eye muscle 1-1.5 cm thick, cut across the long axis of the muscle and hung individually inside polythene bottles for 48 hours at 5°C . Drip loss was expressed as a percentage of the initial muscle mass (Honikel, 1998).

Water binding capacity was calculated by using the method described by Hamm (1972) to determine water loss. A muscle sample of 0.3g was pressed on a filter paper at $35\text{kg}/\text{cm}^2$ between two plates for five minutes. The areas covered by the flattened meat sample and the stain from the meat sample were marked and measured using video image analysis (Irie, Izumo, & Mohri, 1996). The meat-covered area was subtracted from the total stained area to obtain the wetted area, the water content was calculated as:

$$\text{mg H}_2\text{O} = \frac{\text{Wetted area (cm}^2\text{)}}{0.0948} - 8.0$$

For the determination of toughness, the frozen loin samples were processed into 20mm thick chops by means of a band saw before being thawed at 4°C for 24 hours and prepared according to an oven-broiling method using direct radiant heat (AMSA, 1987). The chops were broiled at 260°C (pre-set) to 70°C internal temperature. Chops were left to cool at room temperature (18°C),

processed into 12.5mm diameter cores along the muscle fibres and sheared perpendicular to the fibres with a Warner Bratzler shear force device attached to an Instron Universal Testing machine (Instron, 1990). Shear force was measured as the peak force (Newton) required to shear the cores. The values given are a minimum of four cores per sample.

Data obtained in this trial were subjected to analysis of variance for unbalanced design using GenStat (GenStat 5 release 4.2, 2000), testing for slaughter group effects alternating with genotype and sextype effects, as well as the interaction of slaughter weight by genotype and sextype. All requirements concerning homogeneity of treatment variances and normality were met. The trial was designed in such a manner as to have three sex types and five genotypes per slaughter group. Since each repetition was represented by a pen, and floor space had to be similar to that of commercial production systems the pens were filled to capacity by randomly allocating pigs of different genotypes within sextype to pens. This resulted in the trial being unbalanced for genotype. Further mortalities and removals resulted in the trial becoming unbalanced. Mortalities (3) were due to pneumonia and one to Hemorrhagic Enteritis while two animals were removed from the trial because of leg problems. A result was considered as highly significant at $P \leq 0.01$ and significant at $P \leq 0.05$. Percentage variance accounted for were calculated as the percentage ratio of the sum of squares of the individual parameter and the total.

Results and discussion

Results obtained for muscle pH measurements are shown in Table 4.2. Muscle pH showed normal pork ($pH_1 > 5.9$, $pH_u \leq 6.2$) (Fisher & Mellet, 1997) for all sex types and genotypes but with PSE characteristics ($pH_1 \leq 5.9$) (Fisher & Mellet, 1997) for the 62 and 128kg slaughter groups with $pH_1 = 5.86$ and 5.85, respectively. No incidence of DFD ($pH_{24} > 6.2$) (Fisher & Mellet, 1997) was recorded. Values obtained for pH_1 are, however, much lower than that reported by Channon *et al.* (2004). Muscle pH_1 showed no significant differences

($P > 0.05$) for sex type or any interactions confirming results obtained by Channon *et al.* (2004). Significant differences ($P \leq 0.05$) and highly significant pH_1 differences ($P \leq 0.01$) were however, observed for genotype and slaughter weight. This genotypic difference showed Genotype 2 and 3 to have the highest pH_1 and Genotype 4 and 5 to have the lowest pH_1 with Genotype 1 being intermediate. This decreased pH_1 observed for genotype 5 is reflected in the increased drip loss although the same does not hold true for Genotype 4. If the lower back fat thickness of genotype 5 is further considered (Chapter 3) an increased rate of cooling would be expected which should lead to decreased drip loss while Genotype 4 having the thickest subcutaneous back fat showed no apparent effect of low pH_1 on drip loss. These findings are in contrast with the work of Channon *et al.* (2004) who reported no genetic effect on pH_1 . Genotypic differences accounted for 6.47% of variance while slaughter weight differences accounted for 10.96% of variance. Muscle pH_u showed no significant sex type or genotype differences ($P > 0.05$), these findings are in contrast with the literature where sex type (Channon *et al.*, 2004; Latorre *et al.*, 2004) and genotype differences (Channon *et al.*, 2004) were reported. Highly significant ($P \leq 0.001$) and significant ($P \leq 0.05$) differences for slaughter weight describing more than 10% of the variance were observed for pH_1 , pH_u , water holding capacity and drip loss.

The significant slaughter weight differences observed for pH_1 and pH_u could, not be directly associated with changes in slaughter weight as the differences appeared to be random. It is well known that *ante mortem* stress influences muscle pH values and, although care was taken in this investigation to ensure that this was kept to a minimum, the pigs may have been exposed to different levels of stress on the various slaughter dates.

Table 4.2 Initial pH (pH_1) and ultimate (pH_u) of the eye muscle measured in pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights (mean \pm se)

Variable	pH_1	pH_u
Sex type		
Boar	6.04 \pm 0.047	5.53 \pm 0.032
Gilt	5.95 \pm 0.045	5.46 \pm 0.031
Castrate	5.99 \pm 0.043	5.42 \pm 0.029
Genotype		
1	5.99 ^{ab} \pm 0.057	5.53 \pm 0.038
2	6.12 ^b \pm 0.058	5.47 \pm 0.039
3	6.07 ^b \pm 0.063	5.50 \pm 0.041
4	5.90 ^a \pm 0.057	5.53 \pm 0.038
5	5.89 ^a \pm 0.058	5.51 \pm 0.039
Slaughter weight (kg)		
62	5.86 ^{ab} \pm 0.071	5.39 ^a \pm 0.231
78	6.22 ^d \pm 0.071	5.63 ^b \pm 0.043
86	6.05 ^{bcd} \pm 0.072	5.50 ^a \pm 0.044
102	6.06 ^{bcd} \pm 0.071	5.44 ^a \pm 0.043
113	5.93 ^{ab} \pm 0.069	5.46 ^a \pm 0.042
128	5.85 ^a \pm 0.065	5.41 ^a \pm 0.039
133	5.94 ^{abc} \pm 0.071	5.59 ^b \pm 0.043
146	6.16 ^{cd} \pm 0.087	-

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)

Results obtained for water holding capacity and drip loss are shown in

Table 4.3. There were highly significant ($P \leq 0.001$) differences in water binding capacity for the main effect of slaughter weight describing 28% of observed variance. No significant ($P > 0.05$) interaction between the main effects was found for water binding capacity. While sex type and genotype had no significant effect on water holding capacity ($P > 0.05$) Genotype 5 differed

significantly ($P \leq 0.05$) from the other genotypes in terms of drip loss. This difference does not reflect results obtained for pH_1 as pH_1 was the same for Genotypes 1, 4 and 5. The values obtained for pH_1 were, however, not near the isoelectric point of meat ($pH 5.0$) (Swatland 1984). In a study by Wood, Jones, Francombe & Whelehan (1986) it was shown that backfat thickness had no effect on pH_u , but leaner carcasses showed increased moisture on the cut surface of the loin, probably indicating increased drip loss. This was attributed to the increased moisture content of these carcasses observed in that study. However, the significant effect of genotype on drip loss and sex type X genotype interaction in this investigation, accounted for less than 10% of variance.

Genotypic differences are well documented and are mostly related to the occurrence of genetic factors like the RN^- or MH gene. Experimental animals were NN or Nn in all instances but the status of the animals with relation to the RN^- was not known. Highly significant ($P \leq 0.001$) differences in drip loss were observed for slaughter weight, describing 15.78% of the variance. It is therefore accepted that the main factors affecting drip loss and water binding capacity in this trial could be linked to slaughter weight and that other effects, although in some instances significant, are not as important when compared to the effect of slaughter weight. Changes in drip loss and water binding capacity showed increased water binding capacity and decreased drip loss with increasing slaughter weight. This is a beneficial effect and is in accordance with the results observed by Moon *et al.* (2003) and Kocwin-Podsiadla *et al.* (2002). Changes in these parameters with increased slaughter weight were determined using regression analysis (Table 4.4). Regression analysis showed water binding capacity to increase ($P=0.019$; $R^2=0.56$) at 0.001mg H_2O per kg increase in live weight and drip loss to decrease ($P=0.102$; $R^2=0.28$) at 0.016 percentage units per kg increase in live weight, a 2nd order polynomial fit did not improve the fit. The non significance observed for drip loss could probably be attributed to the stabilising of drip loss after slaughter group 7, with the removal

of the data of slaughter group 8 the change in drip loss in relation to increased slaughter weight showed a change of 0.025 percentage points per kilogram increase in live weight changes to 0.025 ($P=0.021$; $R^2=0.63$ reflected in Table 4.4 as drip loss₂).

Table 4.3 Water holding capacity (WHC) (mg H₂O) and percentage drip loss (%) of the eye muscle measured in pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights (mean \pm se)

Variable	WHC (mg H ₂ O)	Drip loss (%)
Sex type		
Boar	0.372 \pm 0.008	4.6 \pm 0.206
Gilt	0.368 \pm 0.008	4.9 \pm 0.195
Castrate	0.386 \pm 0.007	4.7 \pm 0.186
Genotype		
1	0.382 \pm 0.009	4.5 ^a \pm 0.244
2	0.372 \pm 0.009	4.6 ^a \pm 0.251
3	0.386 \pm 0.010	4.6 ^a \pm 0.270
4	0.367 \pm 0.009	4.5 ^a \pm 0.248
5	0.373 \pm 0.009	5.5 ^b \pm 0.247
Slaughter weight (kg)		
62	0.316 ^a \pm 0.010	6.2 ^c \pm 0.299
78	0.347 ^b \pm 0.010	5.3 ^b \pm 0.307
86	0.393 ^e \pm 0.010	4.4 ^a \pm 0.309
102	0.396 ^e \pm 0.010	4.3 ^a \pm 0.300
113	0.362 ^{bc} \pm 0.010	4.5 ^a \pm 0.292
128	0.390 ^{de} \pm 0.010	4.1 ^a \pm 0.275
133	0.381 ^{cd} \pm 0.010	4.3 ^a \pm 0.301
146	0.439 ^f \pm 0.012	4.9 ^{ab} \pm 0.370
Values in columns within groups with different superscripts differ significantly ($P\leq 0.05$)		

Table 4.4 Regression analysis ($y = a + bx$) describing rates of change (b) in drip loss and water binding capacity of pork muscle with increased slaughter weight (x)

y	a	b	Adjusted R²	F prob
Water binding capacity	0.2668	0.001*	0.56	0.019
Drip loss	6.382	-0.0161	0.28	0.102
Drip loss ₂	7.227	-0.025*	0.63	0.021

*Significant coefficients ($P \leq 0.05$)

Means and standard errors obtained for CIELab colour measurements are shown in Table 4.5. Significant sex type differences ($P \leq 0.05$) were observed for CIELab L* with boars having lower L* values than gilts and castrates being statistically equal to both males and females. The results are comparable to that reported by Latorre *et al.* (2004). Genotypic differences were observed for CIELab a* and b* values. In all instances except for CIELab a* values, these differences accounted for less than 10% of the variance. Although genotypic differences were also reported by Latorre *et al.* (2003) that study did not investigate the effect of slaughter weight and the extent of this difference can not be compared to the current study. Sex type differences observed for CIELab L* values indicates that the meat obtained from boars and castrates had a lower luminance and probably a better appearance than that obtained from gilt carcasses. This is however, not reflected in the results obtained for drip loss. Since no sex type differences were observed for intramuscular fat area and intramuscular fat area:eye muscle area (Chapter 3) this difference can not be attributed to the higher L* readings expected for fat and, as no sex type differences were observed for a* and b* readings, this difference can also not be attributed to increased pigmentation (Goerl *et al.*, 1995). Similar results pertaining to CIELab L* measurements and drip loss were reported by Channon *et al.* (2004). Genotypic differences for CIELab a* and b* values showed Genotype 4 to be different from the other genotypes showing more red and yellow hue but not increase L* values as would be expected due to the observed higher drip loss shown in Table 4.3.

The effect of slaughter weight on the meat quality characteristics of pork

Table 4.5 CIELab colour measurements of the eye muscle measured in pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights (mean \pm se)

Variable	CieLab L*	CieLab a*	CieLab b*
Sex type			
Boar	52.07 ^a \pm 0.432	5.05 \pm 0.197	5.56 \pm 0.175
Gilt	53.73 ^b \pm 0.408	4.85 \pm 0.186	5.95 \pm 0.165
Castrate	53.18 ^{ab} \pm 0.389	5.05 \pm 0.178	5.97 \pm 0.158
Genotype			
1	52.43 \pm 0.511	4.92 ^a \pm 0.233	5.71 ^a \pm 0.207
2	52.56 \pm 0.527	4.55 ^a \pm 0.241	5.56 ^a \pm 0.213
3	53.00 \pm 0.565	4.66 ^a \pm 0.258	5.76 ^a \pm 0.229
4	53.80 \pm 0.520	5.96 ^b \pm 0.237	6.51 ^b \pm 0.211
5	53.45 \pm 0.518	4.79 ^a \pm 0.236	5.66 ^a \pm 0.210
Slaughter weight (kg)			
62	52.85 ^{ab} \pm 0.640	4.22 ^{ab} \pm 0.254	5.58 ^{ab} \pm 0.241
78	52.68 ^{ab} \pm 0.657	4.29 ^{ab} \pm 0.260	5.24 ^a \pm 0.247
86	52.93 ^{ab} \pm 0.661	4.15 ^a \pm 0.262	5.48 ^a \pm 0.249
102	51.92 ^a \pm 0.642	4.15 ^{ab} \pm 0.254	5.24 ^a \pm 0.242
113	52.31 ^a \pm 0.624	4.77 ^{ab} \pm 0.248	5.38 ^a \pm 0.235
128	54.74 ^c \pm 0.589	5.98 ^c \pm 0.234	6.73 ^c \pm 0.222
133	54.05 ^{bc} \pm 0.645	6.27 ^c \pm 0.256	6.49 ^c \pm 0.243
146	52.88 ^{ab} \pm 0.792	5.68 ^c \pm 0.314	6.28 ^{bc} \pm 0.298

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)

Table 4.6 Hennessy Grading Probe® (HGP) colour measurements of the eye muscle measured at three sites in pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights (mean \pm se)

Variable	Position of measurement		
	HGP colour between 2 nd and 3 rd last rib	HGP colour between 5 th and 6 th lumbar vertebrae	HGP colour between 3 rd and 4 th lumbar vertebrae
Sex type			
Boar	46.04 \pm 1.56	50.08 \pm 2.21	51.07 \pm 2.20
Gilt	50.09 \pm 1.50	56.46 \pm 2.11	57.04 \pm 2.14
Castrate	47.42 \pm 1.43	51.15 \pm 2.04	56.44 \pm 2.02
Genotype			
1	47.64 \pm 1.89	54.14 \pm 2.64	56.94 \pm 2.63
2	46.93 \pm 1.89	50.10 \pm 2.69	52.32 \pm 2.68
3	44.93 \pm 2.06	47.19 \pm 3.00	55.41 \pm 2.91
4	48.44 \pm 1.90	56.61 \pm 2.70	54.65 \pm 2.75
5	51.20 \pm 1.92	54.11 \pm 2.68	55.59 \pm 2.71
Slaughter weight (kg)			
62	55.97 ^a \pm 2.32	58.09 \pm 3.39	60.51 ^b \pm 3.39
78	49.30 ^b \pm 2.33	54.41 \pm 3.40	54.57 ^a \pm 3.35
86	48.60 ^b \pm 2.36	48.95 \pm 3.46	51.01 ^a \pm 3.34
102	44.54 ^b \pm 2.33	49.62 \pm 3.40	49.81 ^a \pm 3.29
113	48.48 ^b \pm 2.26	49.75 \pm 3.31	56.23 ^a \pm 3.19
128	48.10 ^b \pm 2.24	57.86 \pm 3.29	61.89 ^b \pm 3.12
133	44.40 ^b \pm 2.33	53.56 \pm 3.42	54.78 ^a \pm 3.29
146	42.23 ^b \pm 2.86	45.38 \pm 4.20	47.01 ^a \pm 4.05
Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)			

Highly significant ($P \leq 0.01$) slaughter weight differences were observed for all colour parameters measured. Changes in CIELab L^* measurements could not be directly associated with changes in slaughter weight as the differences appeared to be random. These findings are in contrast with that of Moon *et al.* (2003) who found an increase in lightness (L^*) with increased slaughter weight. Changes in CIELab a^* and b^* measurements showed increased red and blue hues with increased slaughter weight, the results obtained for a^* values confirm the results of Moon *et al.* (2003) and Latorre *et al.* (2004) who found that the muscle appeared darker as slaughter weights increased.

Means and standard errors obtained for HGP colour measurements are shown in Table 4.6. No significant sex type or genotype differences ($P > 0.05$) were observed for HGP colour measurements. However, significant ($P \leq 0.05$) and highly significant ($P \leq 0.01$) slaughter weight differences were observed for measurements taken between the 3rd and 4th lumbar vertebrae and the 2nd and 3rd last rib, respectively.

Table 4.7 Regression analysis ($y = a + bx$) describing rates of change in colour measurements with increased slaughter weight (x)

y	A	b	Adjusted R²	F prob
CieLab L^*	51.578	0.014**	0.034	0.307
CieLab a^*	2.011	0.028*	0.673	0.008
CieLab b^*	4.112	0.016*	0.451	0.012
HGP 2 nd and 3 rd last rib	60.982	-0.125*	0.620	0.012
HGP 3 rd and 4 th lumbar vertebrae	60.314	-0.055**	-0.065	0.477

*Significant coefficients ($P \leq 0.05$)

These data show that the 62kg slaughter group had the highest luminance ($P \leq 0.05$) and that the remainder of the slaughter groups had statistically the same lower luminance. As the 62kg live animal is usually slaughtered for the fresh meat market it might be beneficial to consider increasing the preferred

carcass weight for the fresh meat market as colour acceptability would improve (Risvik, 1996) Table 4.7.

Table 4.8 Results of instron® measurements obtained from pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights (mean \pm se)

Variable	Load at maximum load (N)
<i>Sex type</i>	
Boar	3.134 ^a \pm 0.092
Gilt	2.827 ^b \pm 0.092
Castrate	3.130 ^a \pm 0.091
<i>Genotype</i>	
1	3.120 \pm 0.118
2	3.076 \pm 0.116
3	2.884 \pm 0.122
4	3.109 \pm 0.118
5	2.967 \pm 0.118
<i>Slaughter weight (kg)</i>	
62	2.990 \pm 0.160
78	3.245 \pm 0.144
86	3.153 \pm 0.140
102	2.841 \pm 0.144
113	3.240 \pm 0.144
128	2.903 \pm 0.132
133	2.950 \pm 0.154
146	2.970 \pm 0.192

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)

Results on tenderness of the loin muscle are presented in Table 4.8. Significant sex type differences ($P \leq 0.05$) were observed showing gilts to be more tender than boars or castrates. These results confirm that of Channon *et al.* (2004) who reported lower shear force values for females than for entire males. These gender differences however, account for less than 10% of the variance. No

further significant differences were observed for the main effects. These results are in contrast with that reported on by Moon *et al.* (2003) who reported an increase in toughness with increased slaughter weight and Latorre *et al.* (2003) who reported genotypic differences for tenderness. It has been noted that tenderness is one of the major meat quality attributes that influences consumer preference (Risvik, 1996). The results of this investigation clearly indicate that increasing the slaughter weight/age of the pigs did not result in an increase in this important quality trait.

Conclusion

Sex type differences were only observed for factors affecting luminance (CIELab L*) and tenderness with boars being superior in terms of luminance and gilts being more tender. Genotypic differences observed were mainly for factors affecting, or directly related to drip loss with significant differences ($P \leq 0.05$) observed for pH₁, CIELab a* and b* values and drip loss. The difference in pH₁ is however, not reflected in the differences observed for drip loss with Genotype 5 being statistically equal to Genotype 1 and 4 but showing a significantly higher drip loss than all the other genotypes. In terms of genetic differences observed for colour measurements, Genotype 4 showed more red and blue hue than all other genotypes, making this a more visually acceptable fresh product. Differences observed for slaughter weight were observed for all parameters measured except for HGP colour measurements between the 5th and 6th lumbar vertebrae and toughness measurements. These differences observed showed a significant ($P \leq 0.05$) slaughter weight effect that tends to improve with increased slaughter weight.

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Chapter 5

The effect of slaughter weight on the retail carcass yield of pork

Abstract

A study was conducted with 189 pigs of three sex types and five genotypes, to ascertain their effect on the retail yield of pig carcasses. Treatments were according to slaughter weight ranging between 62 and 146kg. The main statistical differences observed were for the main effect of slaughter weight with significant ($P \leq 0.05$) and highly significant ($P \leq 0.01$) differences describing more than 10% of variance observed for absolute and percentage yield of all cuts. Significant sex type differences ($P \leq 0.05$) were also observed for absolute yield (castrates > boars = gilts) and percentage yield (castrates > gilts > boars) of abdominal adipose tissues. Significant genotypic differences ($P \leq 0.05$) for percentage yield of legs with the genotype with Pietrain as terminal sire having the largest leg yield (15.46%) followed by a synthetic line (14.78%) with all other genotypes being equal. Changes in cut yield with increased slaughter weight are described showing an increase in yield of absolute weights with $R^2 > 0.80$ whereas changes in percentage yield, indicating the shift in cut weight relative to carcass weight, showed poor descriptive value $R^2 \leq 0.24$. From these results it is concluded that although the absolute weight of individual cuts increase as slaughter weight increases, the percentage change in cut yield showed a shift in the composition of the carcass with increased percentage head, neck, belly and fillet and decreased percentage shoulder, leg and loin.

Key words

Pig, slaughter weight, sex type, genotype, carcass yield, cut yield.

Introduction

As pig carcass weights increase, profitability of production also increases (Ellis & Horsfield, 1988; Ellis, Webb, Avery, & Brown, 1996; Latorre, Lázaro, Valencia, Medel & Mateos, 2004). This could however be to the disadvantage of the processor as fat thickness increases with a subsequent reduction in percentage lean in the carcass (Ellis & Horsfield, 1988; Ellis *et al.*, 1996). However, not only the percentage lean in the carcass is of value to the processor, but also the yield of individual retail cuts as this represents the main raw material in the further value adding processes.

A number of factors influence cut yield of pork. These factors include dietary lysine level (Unruh *et al.*, 1996), use of growth promoters (Crome, McKeith, Carr, Jones, Mowrey & Cannon, 1996), sex type (Cisneros, Ellis, McKeith, McCaw, & Fernanco, 1996; Latorre, *et al.*, 2004), genotype (Unruh *et al.*, 1996; Fabrega *et al.*, 2002; Grzeskowiak, 2002) as well as slaughter weight (Cisneros *et al.*, 1996; Unruh *et al.*, 1996; Kawano, Tajima, Andou & Suzuki, 1997).

Documented sex type differences showed gilt carcasses to have higher yields of ham and shoulder than castrates (Latorre *et al.*, 2004). These differences were also reported by Cisneros *et al.* (1996) but were found to be small and probably of little commercial value. Genotypic differences are somewhat controversial with some authors reporting no genotypic differences in cut yield (Cisneros *et al.*, 1996) and others noting differences with lean type pigs yielding more processable lean meat, percentage wise, than fatter genotypes (Unruh *et al.*, 1997). Purebreds were also found to yield less in terms of ham, shoulder, loin and neck than commercial crossbreds (Grzeskowiak, 2002) while Pietrain sired animals yielded more in terms of leg and loin (Fabrega *et al.*, 2002). Observed increases in yields were mainly restricted to absolute yields (Kawano *et al.*, 1997). Cisneros *et al.* (1996) however reported that percentage loin increased with increased slaughter weight but that percentage ham, shoulder

and spare rib decreased with increased slaughter weight. Optimum cut ability of gilt carcasses was estimated at 127kg in a study by Unruh *et al.* (1996).

An earlier investigation in South Africa has shown that increasing the slaughter weight of pigs from 62 to 146kg did not result in a decrease in production efficiency (Chapter 2) nor in physical carcass characteristics (Chapter 3) or meat quality characteristics (Chapter 4). However, whether this increase in slaughter weight will influence the cut and processing yields under South African conditions, still needs to be elucidated. The aim of this study was therefore to determine the effect of increased slaughter weight on the yield of different commercial cuts of carcasses obtained from typical South African genotypes representing three sex types.

Materials and methods

For the purpose of this study, carcass yield refers to the absolute weight and percentage of total carcass weight contributed by individual retail cuts i.e the head, right neck, right shoulder, left leg, right leg, right belly and right loin.

The experiment was conducted at the Agricultural Research Council – Animal Nutrition and Animal Products Institute at Irene (Gauteng Province) and RTV abattoir in Benoni (Gauteng Province). The experimental outlay, housing and growth performance of the pigs have been described in detail in Chapter 2, carcass characteristics in Chapter 3 and meat quality characteristics in Chapter 4. Slaughter information of pigs is shown in Table 5.1.

Warm carcass weight was determined using a commercial abattoir scale. The weight was determined approximately 90 minutes *post mortem*. Carcasses were hung in cold storage overnight and were cut up the following day into standard South African retail cuts as described.

Table 5.1 Age at slaughter (days) and live weight at slaughter (kg) of group housed animals of three sex types representing five South African genotypes

Slaughter group	Age at slaughter (days)	Average live slaughter weight (kg)
1	112	61.93 ^a
2	126	77.99 ^b
3	140	86.04 ^c
4	154	102.37 ^d
5	168	112.70 ^e
6	182	128.39 ^f
7	196	133.10 ^f
8	210	145.45 ^g

Values in columns with different superscripts differ significantly ($P \leq 0.05$)

The fillet was removed by cutting it away on the inside of the carcass directly below the hipbone by cutting along the hip bone and the lumbar vertebrae. The abdominal adipose tissue was loosened along the edges of the inside of the carcass and pulled out. The head was removed from the carcass by cutting at a 90° angle to the ventral line between the atlas and axis. The neck was removed by cutting at a 90° angle to the ventral line between the last cervical and first thoracic vertebrae. The front leg was removed by cutting along the inside of the front leg, around the scapula up to the spinal cord and along the thoracic vertebrae. Trotters were removed by cutting through the metacarpal region and the hock by cutting through the leg just behind the elbow. The remainder of the front leg represented the shoulder. The hind leg was removed between the 2nd and 3rd sacral vertebrae perpendicular to the stretched leg. The trotter was removed from the ham at the distal end of the tibia and fibula parallel to the cut made to remove the leg from the carcass.

Thereafter the middle part of the remaining carcass was split with a stationary band saw along the middle of the spinal cord. The belly was removed from the back by cutting parallel to the spinal cord, next to the eye muscle, i.e. a straight line from the posterior ventral point of the *psoas major* muscle to the cranio-ventral edge of the 4th thoracic vertebra at the anterior end. The right loin (*longissimus thoracis et lumborum* muscle) was removed by cutting through the back adjacent to the vertebrae. Absolute yields shown represent absolute weights of individual cuts obtained from the one side of the carcass while percentage yield represents these cuts expressed as a percentage of the total carcass weight.

Data obtained in this trial were subjected to analysis of variance for unbalanced design using GenStat (GenStat 5 release 4.2, 2000), testing for slaughter group effects alternating with genotype and sextype effects, as well as the interaction of slaughter weight by genotype and sextype. All requirements concerning homogeneity of treatment variances and normality were met. The trial was designed in such a manner as to have three sex types and five genotypes per slaughter group. Since each repetition was represented by a pen, and floor space had to be similar to that of commercial production systems the pens were filled to capacity by randomly allocating pigs of different genotypes within sextype to pens. This resulted in the trial being unbalanced for genotype. Further mortalities and removals resulted in the trial becoming unbalanced. Mortalities (3) were due to pneumonia and one to Hemorrhagic Enteritis while two animals were removed from the trial because of leg problems. A result was considered as highly significant at $P \leq 0.01$ and significant at $P \leq 0.05$. Percentage variance accounted for was calculated as the percentage ratio of the sum of squares of the individual parameter and the total.

Results and discussion

Means and standard errors obtained for absolute yields are shown in Table 5.2 and percentage yields in Table 5.3. Significant sex type differences ($P \leq 0.05$)

were only observed for absolute yield and percentage yield of abdominal adipose tissues with boars and gilts yielding the same amount but less than castrates. As a percentage, boars yielded less than gilts and gilts less than castrates. Abdominal adipose tissues represented the smallest yield of all cuts observed both in absolute and percentage terms. These gender differences accounted for 7.18% of variance in absolute yields but 12.80% in percentage yields. The lack of observed sex type differences are in contrast with the observations of Cisneros *et al.* (1996) and Latorre *et al.* (2004) and probably confirms the observation of Cisneros *et al.* (1996) that sex type differences are small.

Significant genotypic differences ($P \leq 0.05$) describing 5.91% of the variance observed were calculated for percentage yield of legs with Genotype 1 (Pietrain sire) showing a proportionally higher leg weight than all other genotypes and Genotype 5 (synthetic line) having a proportionally higher leg weight than the remaining genotypes, the latter being statistically equal ($P > 0.05$). Since genotypes in the current study were all commercial cross breeds, the observations in this study only confirms that genotypic differences do exist, the extent, as seen in this study, being small and not of practical importance in the South African industry.

Highly significant differences ($P \leq 0.01$) were observed with slaughter weight as main effect for all carcass cuts measured in both absolute and percentage yields except for percentage of leg where a significant slaughter weight difference ($P = 0.025$) was observed. For absolute yields these differences accounted for more than 50% of the observed variance while percentage yields accounted for more than 10% of the observed variance in all instances except for the leg (7.27%). Similar differences as seen for increased slaughter weight in the current study were reported by Kawano *et al.* (1997) and Cisneros *et al.* (1996).

Table 5.2 Mean (\pm se) yield (kg) of retail cuts obtained from the left side of pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights

Variable	Head	Neck	Shoulder	Belly	Back (loin)	Leg	Fillet	Abdominal adipose tissues
Sex type								
Boar	7.42 \pm 0.234	4.53 \pm 0.214	6.27 \pm 0.204	7.53 \pm 0.350	6.08 \pm 0.252	11.97 \pm 0.450	1.40 \pm 0.076	0.68 ^a \pm 0.080
Gilt	6.94 \pm 0.226	4.24 \pm 0.206	5.83 \pm 0.197	7.51 \pm 0.337	6.10 \pm 0.243	11.55 \pm 0.434	1.32 \pm 0.073	0.85 ^a \pm 0.076
Castrate	7.09 \pm 0.215	4.51 \pm 0.197	6.03 \pm 0.188	7.72 \pm 0.321	6.24 \pm 0.231	11.93 \pm 0.414	1.35 \pm 0.069	1.09 ^b \pm 0.073
Genotype								
1	6.79 \pm 0.283	4.14 \pm 0.256	5.71 \pm 0.247	7.30 \pm 0.422	6.02 \pm 0.304	11.47 \pm 0.544	1.28 \pm 0.091	0.90 \pm 0.095
2	7.38 \pm 0.288	4.50 \pm 0.268	6.27 \pm 0.251	7.98 \pm 0.429	6.10 \pm 0.309	11.74 \pm 0.553	1.41 \pm 0.094	0.99 \pm 0.099
3	7.51 \pm 0.312	4.76 \pm 0.285	6.40 \pm 0.272	8.03 \pm 0.466	6.45 \pm 0.335	12.68 \pm 0.600	1.46 \pm 0.100	0.94 \pm 0.105
4	7.32 \pm 0.284	4.66 \pm 0.260	6.26 \pm 0.247	7.82 \pm 0.424	6.45 \pm 0.305	12.15 \pm 0.545	1.37 \pm 0.091	0.91 \pm 0.096
5	6.75 \pm 0.287	4.15 \pm 0.260	5.58 \pm 0.250	6.89 \pm 0.428	5.74 \pm 0.308	11.14 \pm 0.551	1.27 \pm 0.092	0.72 \pm 0.097
Slaughter weight (kg)								
62	4.62 ^a \pm 0.141	2.63 ^a \pm 0.135	3.52 ^a \pm 0.143	3.38 ^a \pm 0.197	3.84 ^a \pm 0.148	6.76 ^a \pm 0.229	0.45 ^a \pm 0.039	0.42 ^a \pm 0.085
78	5.42 ^b \pm 0.141	3.18 ^b \pm 0.135	4.68 ^b \pm 0.144	5.03 ^b \pm 0.198	4.65 ^b \pm 0.148	8.61 ^b \pm 0.230	1.00 ^b \pm 0.039	0.40 ^a \pm 0.085
86	6.32 ^c \pm 0.143	3.20 ^b \pm 0.138	5.17 ^c \pm 0.146	6.19 ^c \pm 0.201	4.53 ^b \pm 0.151	9.44 ^c \pm 0.234	1.02 ^b \pm 0.040	0.53 ^a \pm 0.087
102	6.55 ^c \pm 0.141	3.74 ^c \pm 0.135	6.11 ^d \pm 0.145	7.36 ^d \pm 0.198	5.47 ^c \pm 0.148	11.56 ^d \pm 0.230	0.96 ^b \pm 0.041	0.58 ^a \pm 0.094
113	7.29 ^d \pm 0.137	4.31 ^d \pm 0.132	6.67 ^e \pm 0.140	8.73 ^e \pm 0.192	6.28 ^d \pm 0.144	12.22 ^e \pm 0.224	1.64 ^c \pm 0.038	0.93 ^b \pm 0.083
128	8.48 ^d \pm 0.130	5.92 ^e \pm 0.139	7.11 ^f \pm 0.132	9.56 ^f \pm 0.182	7.81 ^e \pm 0.136	14.57 ^f \pm 0.211	1.85 ^d \pm 0.036	1.17 ^c \pm 0.078
133	9.14 ^e \pm 0.142	5.99 ^e \pm 0.136	7.11 ^f \pm 0.144	9.80 ^f \pm 0.198	7.90 ^e \pm 0.149	15.01 ^f \pm 0.231	1.86 ^d \pm 0.039	1.39 ^c \pm 0.086
146	9.44 ^e \pm 0.174	6.94 ^f \pm 0.168	7.99 ^g \pm 0.177	10.90 ^g \pm 0.244	8.82 ^f \pm 0.182	16.58 ^g \pm 0.283	2.06 ^e \pm 0.048	1.82 ^d \pm 0.105

Means within columns with different superscripts differ significantly ($P \leq 0.05$)

Table 5.3 Percentage yield (%) obtained from the left side of the carcass expressed as a percentage of total warm carcass weight of group housed pigs of three sex types, five genotypes and eight slaughter weights (mean \pm se)

Variable	Head (%)	Neck (%)	Shoulder (%)	Belly (%)	Loin (%)	Leg (%)	Fillet (%)	Abdominal adipose tissues (%)
Sex type								
Boar	8.97 \pm 0.113	5.50 \pm 0.083	7.31 \pm 0.077	8.95 \pm 0.143	7.26 \pm 0.103	14.41 \pm 0.122	1.61 \pm 0.051	0.77 ^a \pm 0.060
Gilt	9.80 \pm 0.109	5.27 \pm 0.080	7.14 \pm 0.074	9.17 \pm 0.138	7.61 \pm 0.099	14.51 \pm 0.118	1.60 \pm 0.049	0.99 ^b \pm 0.058
Castrat	9.63 \pm 0.104	5.43 \pm 0.077	7.10 \pm 0.071	9.20 \pm 0.131	7.47 \pm 0.094	14.32 \pm 0.112	1.56 \pm 0.047	1.20 ^c \pm 0.055
Genotype								
1	8.65 \pm 0.137	5.37 \pm 0.101	7.06 \pm 0.093	8.91 \pm 0.173	7.56 \pm 0.124	15.46 ^a \pm 0.147	1.55 \pm 0.062	1.06 \pm 0.073
2	8.88 \pm 0.139	5.45 \pm 0.100	7.21 \pm 0.094	9.18 \pm 0.176	7.20 \pm 0.126	14.18 ^b \pm 0.150	1.60 \pm 0.064	1.06 \pm 0.074
3	8.65 \pm 0.151	5.37 \pm 0.111	7.14 \pm 0.102	9.11 \pm 0.190	7.29 \pm 0.137	14.30 ^b \pm 0.162	1.60 \pm 0.068	0.97 \pm 0.080
4	8.74 \pm 0.137	5.31 \pm 0.101	7.09 \pm 0.093	9.28 \pm 0.173	7.62 \pm 0.124	14.31 ^b \pm 0.148	1.57 \pm 0.062	1.02 \pm 0.073
5	9.01 \pm 0.138	5.49 \pm 0.102	7.39 \pm 0.094	9.08 \pm 0.175	7.55 \pm 0.126	14.78 ^c \pm 0.149	1.64 \pm 0.063	0.87 \pm 0.074
Slaughter weight (kg)								
62	9.89 ^a \pm 0.133	5.34 ^{ab} \pm 0.126	7.54 ^a \pm 0.106	7.26 ^a \pm 0.155	8.17 ^a \pm 0.126	14.42 ^{bc} \pm 0.182	0.96 ^a \pm 0.048	0.864 ^{ab} \pm 0.075
78	8.98 ^b \pm 0.130	5.02 ^a \pm 0.123	7.48 ^a \pm 0.103	8.60 ^b \pm 0.151	7.68 ^{be} \pm 0.123	14.21 ^{ac} \pm 0.178	1.68 ^d \pm 0.047	0.662 ^a \pm 0.073
86	9.49 ^c \pm 0.137	5.33 ^{ab} \pm 0.129	7.38 ^{ab} \pm 0.109	9.38 ^{cd} \pm 0.160	6.74 ^c \pm 0.129	14.15 ^{ab} \pm 0.187	1.54 ^c \pm 0.050	0.771 ^a \pm 0.075
102	8.30 ^d \pm 0.134	5.61 ^{bc} \pm 0.126	6.95 ^c \pm 0.106	9.64 ^d \pm 0.155	6.92 ^{cd} \pm 0.126	14.68 ^c \pm 0.183	1.23 ^b \pm 0.050	0.726 ^a \pm 0.075
113	8.27 ^d \pm 0.130	5.60 ^{bc} \pm 0.122	7.13 ^{bc} \pm 0.103	9.76 ^d \pm 0.151	7.12 ^d \pm 0.122	13.85 ^a \pm 0.177	1.86 ^e \pm 0.047	1.067 ^{bc} \pm 0.073
128	8.55 ^{de} \pm 0.133	5.70 ^c \pm 0.126	7.07 ^c \pm 0.106	9.60 ^d \pm 0.155	7.86 ^{ab} \pm 0.126	14.69 ^c \pm 0.182	1.87 ^e \pm 0.048	1.128 ^c \pm 0.075
133	8.73 ^{be} \pm 0.134	5.30 ^{ab} \pm 0.126	6.91 ^c \pm 0.106	9.09 ^c \pm 0.156	7.48 ^e \pm 0.126	14.26 ^{abc} \pm 0.183	1.77 ^{de} \pm 0.049	1.270 ^c \pm 0.074
146	8.26 ^d \pm 0.139	5.34 ^{ab} \pm 0.131	6.99 ^c \pm 0.110	9.64 ^d \pm 0.162	7.77 ^{be} \pm 0.131	14.53 ^{bc} \pm 0.190	1.80 ^{de} \pm 0.050	1.491 ^d \pm 0.078

Means within columns with different superscripts differ significantly ($P \leq 0.05$)

Table 5.4 Regression analysis ($y = a + bx$ and $y = a + bx + cx^2$) describing rates of change in percentage and absolute yields (g) of different pork cuts with increased slaughter weight (x)

Parameter	y=a+bx with x = slaughter weight				Y=a+bx+cx2 with x = slaughter weight				
	a	b	R 2	FProb	a	b	c	R 2	FProb
Carcass yield % head	10.57	-0.022**	0.336	≤0.001	12.105	-0.0616**	0.0002415	0.361	≤0.001
Carcass yield % left neck	5.28	0.001**	-	NS	7.754	-0.0683**	0.0004434	0.125	≤0.001
Carcass yield % left shoulder	8.13	-0.011**	0.203	≤0.001	7.438	0.0177**	-0.0001986	0.279	≤0.001
Carcass yield % left leg	14.95	-0.006**	0.020	0.026	13.758	0.0195**	-0.000139	-	NS
Carcass yield % left belly	7.29	0.022**	0.225	≤0.001	2.283	0.1515**	-7.757E-05	0.427	≤0.001
Carcass yield % left back	7.94	-0.008**	0.066	≤0.001	9.596	-0.0543**	0.0003181	0.050	0.003
Carcass yield % fillets	0.93	0.008**	0.232	≤0.001	0.026	0.03159**	-0.0001421	0.277	≤0.001
Carcass yield head (kg)	1238	71.52**	0.889	≤0.001	774	83.6**	-0.073	0.889	≤0.001
Carcass yield left neck (kg)	36.00	53.640**	0.843	≤0.001	1115	15.3**	0.2825	0.837	≤0.001
Carcass yield left shoulder (kg)	725.00	62.280**	0.905	≤0.001	-1376	122.8**	-0.3702	0.864	≤0.001
Carcass yield left leg (kg)	540.00	137.220**	0.928	≤0.001	-1330	182.3**	-0.258	0.933	≤0.001
Carcass yield left belly (kg)	-953.00	104.150**	0.901	≤0.001	-4616	195.5**	-0.5345	0.914	≤0.001
Carcass yield left back (kg)	598.00	64.900**	0.867	≤0.001	1026	46.5**	0.174	0.880	≤0.001
Carcass yield fillet (kg)	-430.20	21.611**	0.804	≤0.001	-772	30.54**	-0.0537	0.806	≤0.001

* Significant coefficients ($P \leq 0.05$); ** Highly significant coefficients ($P \leq 0.01$); NS – Not significant

Changes in the absolute and percentage yields of the different cuts in relation to changes in slaughter weight is shown in Table 5.4. Changes in absolute weights of the different cuts in relation to slaughter weight showed a constant increase with increasing slaughter weight ($P \leq 0.001$) with adjusted $R^2 \geq 0.80$ for all cuts. Adjusted R^2 values obtained for rates of change in percentage yield is generally small ($R^2 \leq 0.3$) describing a shift in carcass composition with the percentage head, neck, belly and fillets increasing while the percentage shoulder, leg and loin decreased.

Changes in absolute values showed the heavier cuts like the absolute leg yield to increase at the fastest rate followed by the lighter cuts like the belly and then the loin, neck and shoulder. Changes in percentage values in relation to increased slaughter weight showed a shift in carcass composition in terms of retail cuts with a redistribution within the carcass. Similar results were also observed by Unruh *et al.* (1996), these results are however not completely comparable because of differences in cutting techniques.

Conclusion

Since very little information pertaining to the subject could be found in literature, as pertaining to South African cuts, comparisons are restricted. Sex type and genotype differences were small and probably negligible for practical purposes. Slaughter weight differences showed a steady increase in absolute yields while changes in percentage yields showed a shift in weight toward the head, neck, shoulder, belly and fillet, these were however poorly described with $R^2 \leq 0.30$. It is concluded that, in the South African scenario, given the commercial genotypes, increased slaughter weight would have little or no effect on the relative cut yield of carcasses in the processing plant although the absolute size of the cuts would be affected and carcasses should therefore be selected with this in mind if specific cut sizes are required.

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Chapter 6

The effect of slaughter weight on the deboning and processing yield as well as chemical composition of bacon and ham cuts from pork carcasses

Abstract

A study was conducted with 189 pigs of three sex types and five genotypes, wherein the main treatment was according to slaughter weight (ranging between 62 and 146kg). Sex type differences showed castrates to have more processable lean meat (PLM) from the belly and less from the gammon than boars and gilts. Regression analysis describing changes in PLM with increased slaughter weight showed good predictive value for absolute yields but relatively poor predictive value for percentage PLM yields. Processing characteristics showed gilts to have a higher percentage brine uptake for belly bacon and castrates to have a higher percentage brine uptake of whole gammon ham as well as increased topside gammon ham fresh to smoke losses. Slaughter weight differences generally showed decreased brine uptake and fresh to smoke losses indicating that the total yield could be increased with heavier slaughter weights. Chemical analysis showed castrates to be generally inferior because of increased fat levels while genotypic differences showed two genotypes to have higher fat content than the other genotypes. Differences attributed to the main effect of slaughter weight generally showed decreased brine uptake and smoke losses indicating that the total yield could be increased with heavier slaughter weights. Chemical analysis showed castrates to be generally inferior because of increased fat levels while genotypic differences showed two genotypes to have higher fat content than the other genotypes. Chemical differences attributed to the main effect of slaughter weight generally showed increased fat content and decreases in moisture content with little or no differences observed for ash and protein content. In conclusion, the production

of intact boars and gilts appear to be beneficial in terms of PLM yields as well as chemical composition. Genotypic differences were small and of little practical importance while increased slaughter weight showed increases in absolute yields but changes in percentage PLM yield could not be described accurately. Processing yields increased with increased slaughter weight and this is of benefit to the processor.

Key words

Pork, slaughter weight, sex type, genotype, deboning, processing yield.

Introduction

Processing characteristics are largely dependant on meat quality characteristics and particularly water holding capacity and drip loss as these two factors are the main determinants in processing yields/losses. The effects of genotype (as pertaining to stress susceptibility) and *ante mortem* stress on these two muscle characteristics have been well documented. Other factors associated with processing characteristics are specific to certain cuts. For example Persson *et al.* (2005) reported optimum belly thickness for production of belly bacon. Bellies thinner than 2 cm led to excessive losses during processing, especially slicing losses while bellies 3 cm and thicker, although superior in terms of processing yields, did not appeal to consumers because of colour attributes and lean to fat ratio. The optimum belly thickness was deemed to be 2.5 cm. Similarly Brewer, Stites, McKeith, Bechtel, Movakosfski & Bruggen (1995) reported that, as belly thickness increased, sensory assessment of lean to fat ratio decreased. Genotype differences have also been reported to influence processing yield, for example, Candek-Potokar, Monin & Zlender (2002) found that Duroc crosses exhibited higher intramuscular fat content, marbling and intermuscular fat. Crossing with Duroc resulted in lower weight losses during ham processing. Observed sex type differences also demonstrated that castrates were fatter and had more intra- and intermuscular fat and lower ham processing weight losses than females (Candek-Potokar *et al.*, 2002). Dry

hams from female pigs also had higher total and non-protein nitrogen, but a drier, firmer texture and higher resistance to cutting force compared to dry hams produced from castrated pigs (Candek-Potokar *et al.*, 2002). However, Cisneros, Ellis, McKeith, McCaw & Fernando (1996) reported slaughter weight differences, small sex type differences but no genotypic differences.

Cisneros *et al.* (1996) and Latorre, Lázaro, Valencia, Medel & Mateos (2004) reported that absolute yield of trimmed boneless cuts increased with an increase in slaughter weight. In the study of Cisneros *et al.* (1996) it was, however, found that the percentage yields decreased with increased slaughter weight while Latorre *et al.* (2004) found that percentage yields were not affected by slaughter weight. Cisneros *et al.* (1996) also reported increased curing yields for belly bacon obtained from carcasses up to 160kg live weight.

The chemical composition of carcasses is influenced by a number of factors. Differences exist for sex types (Wagner, Schinckel, Chen, Forrest & Coe, 1999; Gonzales, Soler, Gispert, Puigvert & Tibau, 2001; Tibau, Gonzalez. Soler, Gisper, Lizardo & Mourot, 2003) with gilts proving to have more protein and water and less lipid than castrates (Gonzalez *et al.*, 2001; Tibau, *et al.*, 2003) but having higher lipid and lower protein contents than boars (Zullo, Barone, Colatruglio, Girolami & Matassino, 2003). Wagner *et al.* (1999) further reported significantly different changes in the ratio and composition of the tissues of barrows and gilts during growth.

Genotypic differences exist in terms of moisture, protein, lipid and ash contents, but these differences depended largely on sex and live weight at slaughter. However, a recent study by Park, Kim, Jung, Park, Lee & Moon (2005) showed that no genotypic differences exist for chemical composition. Then again the study of Zullo *et al.* (2003) showed that the genotypic differences observed were carried through to bacon in terms of dry matter content - they attributed this to differences observed in lipid and protein content of the initial product.

Genotypic differences were summarized by Fabian, Chiba, Kuhlert, Grobisch, Nadarajah & McElhenney (2002) who concluded that “overall it can be said that pigs with distinct genotypes exhibit differences in growth rate, metabolite and hormonal profiles and ultimately body composition”.

Ellis & Avery (1994) found that dissection of carcasses with increased slaughter weight led to the proportion of skin decreasing while the proportion of lean, fat and bone remained relatively constant. Increased slaughter weight leads to decreased ash levels (Zullo *et al.*, 2003) increased protein levels (Candek-Potokar, Zlender & Bonneay, 1997; Wagner *et al.*, 1999; Gonzalez *et al.*, 2001; Zullo *et al.*, 2003), increased lipid levels (Candek-Potokar *et al.*, 1997; Wagner *et al.*, 1999; Gonzalez *et al.*, 2001; Zullo *et al.*, 2003) and decreased moisture content (Candek-Potokar *et al.*, 1997; Wagner *et al.*, 1999). A study by Tibau, *et al.* (2003) showed that protein deposition followed a quadratic function, reaching a maximum at 70kg BW while lipid deposition increased linearly from 25 up to 140kg. The increase in intramuscular lipids and the decreased water to protein ratio, resulting from an elevation of both age and weight at slaughter, should be beneficial for meat quality (Candek-Potokar *et al.*, 1997).

For the purpose of this study processable lean meat (PLM) refers to the portion of the cut that remains after deboning, de-rinding and trimming and represents the meat that is processed further into whole smoked neck, belly bacon, back bacon, gammon ham, topside ham and cooked shoulder ham. The aim of this study was to determine what the influence of increased live weight at slaughter would have on PLM, value added processing yield and chemical composition of the fresh and processed products.

Materials and methods

The experiment was conducted at the Agricultural Research Council – Animal Nutrition and Animal Products Institute at Irene (Gauteng Province) and RTV abattoir in Benoni (Gauteng Province). The experimental outlay, housing and

growth performance of the pigs have been described in detail in Chapter 2, carcass characteristics in Chapter 3 and meat quality characteristics Chapter 4. Slaughter information of pigs is shown in Table 6.1.

Table 6.1 Age at slaughter (days) and live weight at slaughter (kg) of group housed animals of three sex types representing five South African genotypes

Slaughter group	Age at slaughter (days)	Average live slaughter weight (kg)
1	112	61.93 ^a
2	126	77.99 ^b
3	140	86.04 ^c
4	154	102.37 ^d
5	168	112.70 ^e
6	182	128.39 ^f
7	196	133.10 ^f
8	210	145.45 ^g

Values in columns with different superscripts differ significantly ($P \leq 0.05$)

Warm carcass weight was determined using a commercial abattoir scale. The weight was determined approximately 90 minutes *post mortem*. Carcasses were hung in cold storage over night and were cut up the following day into standard South African retail cuts.

The fillet was removed by cutting it away on the inside of the carcass directly below the hipbone by cutting along the hip bone and the lumbar vertebrae. Membranes and connective tissue were removed - the fillet was not used for further processing. The abdominal adipose tissues was loosened along the edges of the inside of the carcass and pulled out. The head was removed from the carcass by cutting at a 90° angle to the ventral line between the atlas and

axis. Cheeks were removed by cutting along the edges with a knife and ears were cut off at the base along the skull. No further processing was done with any section of the head. The neck was removed by cutting at a 90° angle to the ventral line between the last cervical and first thoracic vertebrae, the rind and bones were removed as well as membranes, connective tissue and all visible fat and the remaining lean meat processed as whole smoked neck.

The front leg was removed by cutting along the inside of the front leg, around the scapula up to the spinal cord and along the thoracic vertebrae. Trotters were removed by cutting through the metacarpal region and the hock by cutting through the leg just behind the elbow. The remainder of the front leg represented the shoulder. Membranes, connective tissue and all visible fat were removed. The remaining lean meat was used for the production of cooked shoulder ham. The hind leg was removed between the 2nd and 3rd sacral vertebrae perpendicular to the stretched leg. The trotter was removed from the ham at the distal end of the tibia and fibula parallel to the cut made to remove the leg from the carcass. The remainder of the leg represented the ham. Membranes, connective tissue and all visible fat were removed from the left leg and the remaining lean meat was used for the production of whole gammon ham. The right leg was further processed into the topside, silverside and rump with the topside being further processed into topside gammon ham.

Thereafter the middle section of the remaining carcass was split with a stationary band saw along the middle of the spinal cord. The belly was removed from the back by cutting parallel to the spinal cord, next to the eye muscle, i.e. a straight line from the posterior ventral point of the *psaos major* muscle to the cranio-ventral edge of the 4th thoracic vertebra at the anterior end. The rind, bones and all but 5mm of subcutaneous fat were removed from the belly. This represented the belly and was further used for the production of belly bacon. The right loin (*longissimus thoracis et lumborum* muscle) was removed by cutting through the back adjacent to the vertebrae. The rind, bones

and all but 5 mm of subcutaneous fat was removed from the right loin. This represented the loin and was further used for the production of back bacon. The left loin was removed in the same manner but was vacuum packed and frozen at -20°C and served as representative of a fresh sample. All cuts were individually marked for identification during later weighing.

Processing of all cuts commenced by immersing the fresh cuts in a commercial brine mixture supplied by Crown National (Crown National, Shorthorn street, City Deep X 1) in a cooled facility at 10°C for a maximum of 72 hours or until an average brine uptake of 10% was achieved. The brine mixture contained carbohydrate, sodium chloride, sodium nitrite, sodium nitrate, colourant and sodium carbonate. A random sample of cuts was weighed every morning to determine brine uptake.

After brining, bacon and leg cuts were weighed and smoked. Bacons (neck, back and belly) were smoked for a period of 2.5 hours at 65°C whilst the whole and topside gammon hams were smoked in a commercial cooker/smoker at 82°C until an internal temperature of 72°C was reached as determined using a temperature probe inserted into the cut. The topside gammon hams were then cooled, vacuum packed and sampled whole for chemical and sensory analysis (Chapter 7). Bacons were cooled, vacuum packed and frozen overnight prior to slicing. After brining, the shoulders were placed in moulds and cooked in a 225l cooking pot for one hour per kilogram at 76°C until a core temperature of 69 °C was reached. The cooked shoulder hams were allowed to cool in the moulds prior to removal and smoking. Cooked shoulder hams were smoked for 30 minutes at 65°C and refrigerated overnight (4°C) before slicing. All cuts were sliced from the anterior end, the first 5 cm of the product being discarded and the following 10 cm sampled and vacuum packed for chemical and descriptive sensory analysis. Chemical composition of the samples was determined according to the Association of Official Analytical Chemist's Standard Techniques (AOAC, 1997). Yields and losses are shown as a percentage ratio

of weights of the fresh cuts and the same cut after emmersion (% brine uptake), smoking (% smoking losses) or cooking (% cooking losses).

Data obtained in this trial were subjected to analysis of variance for unbalanced design using GenStat (GenStat 5 release 4.2, 2000), testing for slaughter group effects alternating with genotype and sextype effects, as well as the interaction of slaughter weight by genotype and sextype. All requirements concerning homogeneity of treatment variances and normality were met. The trial was designed in such a manner as to have three sex types and five genotypes per slaughter group. Since each repetition was represented by a pen, and floor space had to be similar to that of commercial production systems the pens were filled to capacity by randomly allocating pigs of different genotypes within sextype to pens. This resulted in the trial being unbalanced for genotype. Further mortalities and removals resulted in the trial becoming unbalanced. Mortalities (3) were due to pneumonia and one to Hemorrhagic Enteritis while two animals were removed from the trial because of leg problems. A result was considered as highly significant at $P \leq 0.01$ and significant at $P \leq 0.05$. Percentage variance accounted for were calculated as the percentage ratio of the sum of squares of the individual parameter and the total.

Results and discussion

Means and standard errors obtained for the absolute and percentage processable lean meat (PLM) (Table 6.2) as well as the processing yields for the bacon cuts (neck, belly and back) (Table 6.4) show a highly significant difference ($P < 0.001$) for percentage belly and loin yields for sex type with castrates yielding more belly than boars and gilts and more loin than boars. Significant genotype differences were observed for percentage neck and absolute loin yield with Genotype 3 having a higher neck yield, in percentage terms, than the other genotypes and Genotype 3 and 1 having less loin, in absolute terms, than the other genotypes. No significant ($P > 0.05$) interactions

between the main effects were observed. These results correspond to that reported by Cisneros *et al.* (1996).

Highly significant slaughter weight differences ($P \leq 0.01$) were observed for all characteristics measured in both the absolute and the percentage PLM obtained from the neck, belly and back bacon. For absolute PLM yields, the percentage variance accounted for was, in all instances $>72\%$, while differences observed in percentage PLM yields accounted for $>20\%$ of observed variance. These results confirm those reported by Cisneros *et al.* (1996) and Latorre *et al.* (2004).

Means and standard errors for the absolute and percentage PLM yields of the ham cuts are shown in Table 6.3 and processing yields in Table 6.5. No significant sex type differences ($P > 0.05$) were observed for any of the absolute cut PLM weights while significant ($P \leq 0.05$) sex type differences were observed for percentage topside as well as percentage whole gammon PLM yields with boars and gilts yielding more than castrates. The only significant genotypic difference ($P \leq 0.05$) observed was for percentage PLM yield of whole gammon with Genotype 2 yielding the same as Genotype 1 but less than all other genotypes. No significant ($P > 0.05$) interactions were observed. These results correspond with that obtained by Cisneros *et al.* (1996).

Highly significant ($P \leq 0.01$) and significant ($P \leq 0.05$) slaughter weight differences were observed for shoulder, whole gammon and topside gammon ham absolute and percentage PLM yields. For absolute PLM yields the percentage variance accounted for was, in all instances $>60\%$ while differences observed in percentage PLM yields accounted for $>12\%$ of observed variance except for the percentage PLM obtained from the shoulder where only 7.6% of the variance is accounted for.

Table 6.2 Absolute (kg) and percentage processable lean meat (PLM) obtained from bacon cuts of pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights (mean \pm se)

Variable	Neck (kg)	Neck (%)	Belly (kg)	Belly (%)	Loin (kg)	Loin (%)
Sex type						
Boar	1.982 \pm 0.093	42.45 \pm 0.753	2.082 \pm 0.119	26.62 ^a \pm 0.578	3.438 ^{ab} \pm 0.835	56.57 \pm 0.815
Gilt	1.841 \pm 0.090	43.32 \pm 0.726	2.030 \pm 0.115	26.43 ^a \pm 0.558	3.355 ^b \pm 0.762	57.81 \pm 0.743
Castrate	1.899 \pm 0.086	41.37 \pm 0.692	2.279 \pm 0.110	28.53 ^b \pm 0.531	3.609 ^a \pm 0.808	56.08 \pm 0.788
Genotype						
1	1.789 \pm 0.112	41.82 ^{ab} \pm 0.909	2.075 \pm 0.144	27.81 \pm 0.698	2.893 ^{ab} \pm 0.213	53.56 \pm 1.46
2	1.867 \pm 0.114	40.07 ^a \pm 0.924	2.226 \pm 0.147	27.61 \pm 0.710	3.823 ^b \pm 0.209	57.21 \pm 1.43
3	2.174 \pm 0.124	45.38 ^c 1.1003	2.275 \pm 0.159	27.22 \pm 0.770	3.342 ^a \pm 0.221	57.51 \pm 1.51
4	1.974 \pm 0.113	43.44 ^{bc} \pm 0.912	2.234 \pm 0.145	27.59 \pm .700	3.535 ^b \pm 0.206	57.82 \pm 1.41
5	1.752 \pm 0.114	41.28 ^{ab} \pm 0.922	1.889 \pm 0.146	26.05 \pm 0.708	3.777 ^b \pm 0.209	58.35 \pm 1.43
Slaughter weight (kg)						
62	1.029 ^a \pm 0.059	41.11 ^{bc} \pm 0.890	0.865 ^a \pm 0.939	25.09 ^{ab} \pm 0.848	1.829 ^a \pm 0.131	49.79 ^a \pm 1.27
78	1.307 ^b \pm 0.059	43.09 ^c \pm 0.870	1.241 ^b \pm 0.941	23.68 ^a \pm 0.828	2.058 ^{ab} \pm 0.128	47.62 ^a \pm 1.25
86	1.372 ^b \pm 0.060	39.42 ^b \pm 0.916	1.686 ^c \pm 0.956	26.65 ^{bc} \pm 0.873	2.364 ^b \pm 0.131	49.12 ^a \pm 1.28
102	1.580 ^c \pm 0.059	36.20 ^a \pm 0.892	2.169 ^d \pm 0.941	28.22 ^{cd} \pm 0.850	3.465 ^c \pm 0.131	58.17 ^b \pm 1.27
113	2.039 ^d \pm 0.058	41.52 ^{bc} \pm 0.867	2.389 ^d \pm 0.915	27.70 ^{cd} \pm 0.826	3.979 ^d \pm 0.128	61.02 ^{bc} \pm 1.25
128	2.615 ^e \pm 0.054	45.64 ^d \pm 0.891	2.640 ^e \pm 0.864	27.40 ^{bcd} \pm 0.849	4.453 ^e \pm 0.131	62.58 ^c \pm 1.28
133	2.415 ^f \pm 0.059	43.21 ^{cd} \pm 0.895	2.866 ^e \pm 0.944	29.71 ^{de} \pm 0.852	4.915 ^f \pm 0.129	64.31 ^c \pm 1.26
146	2.951 ^g \pm 0.073	49.08 ^e \pm 0.928	3.411 ^f \pm 0.116	30.30 ^e \pm 0.884	4.819 ^{ef} \pm 0.137	62.71 ^c \pm 1.26

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)

Latorre *et al.* (2004) also found an increase in trimmed shoulder and ham weights but no difference in percentage yield of these cuts. The cutting method in this study was, however, different and could possibly account for this difference in observations.

Changes in these characteristics in relation to slaughter weight are shown in Table 6.6. In absolute terms, lean meat for processing increased as slaughter weight increased. In percentage terms, however, loin, shoulder, whole gammon and topside gammon decreased in percentage PLM while the neck and belly increased in percentage PLM, this could possibly be attributed to a redistribution of tissues within the cuts. These results correspond closely with the growth of different carcass portions as described by Siebrits (1984) and Whittemore (1993).

Results obtained for processing yields (Table 6.4 & Table 6.5) regarding sex type were inconclusive with castrates having a higher percentage brine uptake ($P \leq 0.05$) for whole gammon hams but also a higher ($P \leq 0.05$) fresh to smoke loss for topside gammon ham. Gilts showed a higher percentage brine uptake ($P \leq 0.05$) for belly bacon. Genotypic differences ($P \leq 0.05$) were observed for smoke losses (percentage difference between the fresh and final smoked cuts) in back bacon and whole gammons with Genotype 5 being inferior to the other genotypes for back bacon production and Genotype 1 and 4 being inferior for gammon production. Changes in processing characteristics in relation to slaughter weight (Table 6.7) showed constant decreases in percentage brine uptake with increased carcass weight; this could probably be attributed to the inability of the brine mixture to effectively reach all parts of a larger cut. As brining took place in a brining vat and not with an injector the ability of the cut to absorb brine would be related to the ratio of the surface relative to the weight ($W^{0.66}$). The proportional surface available for brine uptake decreases as cut weight increases thus brine uptake in larger cuts would be compromised should immersion rather than injection be used. Fresh to smoke losses also decreased

with increased slaughter weight, which is positive as pertaining to processing yield, however, the R^2 values were low in most instances and these differences are probably of little practical significance.

Chemical composition (Table 6.8, Table 6.9, Table 6.10, Table 6.11 & Table 6.12) showed significant sex type differences ($P \leq 0.05$) for belly and back bacon with castrates having less moisture and ash and more fat than gilts and boars. No significant sex type differences ($P > 0.05$) were observed for the fresh loin cut or for topside gammon ham. Cooked shoulder ham of the gilts had more protein than that of the castrates with the boars being intermediate and equal to both. Fat content of the shoulder ham obtained from castrates contained more fat than boars and gilts. Sex type differences were also observed by Wagner *et al.* (1999), Gonzales, *et al.* (2001), Tibau *et al.* (2003) and Zullo *et al.* (2003) although their results showed differences between gilts and boars that were not observed in the current study. Differences observed between gilts and castrates in the previous studies and the current study are similar.

Genotypic differences (Table 6.8, Table 6.9, Table 6.10, Table 6.11 & Table 6.12) were observed for fat content of the fresh cut with Genotype 2 and 3 having a higher fat content than the other genotypes. Back bacon of Genotype 3 and 5 had higher ash content ($P \leq 0.05$) than Genotype 2 and 4 with Genotype 1 being intermediate and statistically equal ($P > 0.05$) to all other genotypes. Further more, Genotype 5 had higher moisture and less fat than the other genotypes. Genotypic differences ($P \leq 0.05$) observed in the chemical composition of belly bacon were restricted to moisture content with Genotype 5 having the highest moisture content. Genotypic differences ($P \leq 0.05$) observed for cooked shoulder ham and topside gammon ham showed Genotype 5 and 4 to have the least fat and Genotypes 2 and 3 to have the most with Genotype 1 being intermediate and statistically equal ($P > 0.05$) to all. These observed genotypic differences confirm the summary of Fabian *et al.* (2002) who reported that pigs with distinct genotypes exhibit differences in body composition.

The effect of slaughter weight on the deboning and processing yield as well as chemical composition of bacon and ham cuts from pork carcasses

Table 6.3 Absolute (kg) and percentage processable lean meat obtained from shoulder and ham cuts of pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights (mean \pm se)

Variable	Shoulder (kg)	Shoulder (%)	Whole gammon (kg)	Whole gammon (%)	Topside (kg)	Topside (%)
Sex type						
Boar	2.83 \pm 0.092	46.64 \pm 0.502	6.415 \pm 0.228	53.92 ^a \pm 0.514	1.46 \pm 0.056	12.24 ^a \pm 0.270
Gilt	2.67 \pm 0.089	47.58 \pm 0.484	6.152 \pm 0.220	53.58 ^a \pm 0.496	1.41 \pm 0.054	12.34 ^a \pm 0.261
Castrate	2.69 \pm 0.085	46.13 \pm 0.462	6.171 \pm 0.210	52.13 ^b \pm 0.472	1.36 \pm 0.052	11.49 ^b \pm 0.248
Genotype						
1	2.56 \pm 0.111	46.32 \pm 0.607	6.05 \pm 0.276	52.96 ^{ab} \pm 0.621	1.38 \pm 0.068	11.53 \pm 0.533
2	2.76 \pm 0.113	46.11 \pm 0.617	5.99 \pm 0.280	51.67 ^b \pm 0.631	1.38 \pm 0.059	11.12 \pm 0.516
3	2.87 \pm 0.122	45.92 \pm 0.669	6.75 \pm 0.304	53.55 ^a \pm 0.685	1.51 \pm 0.075	12.22 \pm 0.688
4	2.81 \pm 0.111	47.16 \pm 0.608	6.51 \pm 0.276	59.96 ^a \pm 0.623	1.47 \pm 0.068	11.39 \pm 0.516
5	2.64 \pm 0.113	48.18 \pm 0.615	5.95 \pm 0.279	53.95 ^a \pm 0.629	1.31 \pm 0.069	11.26 \pm 0.533
Slaughter weight (kg)						
62	1.70 ^a \pm 0.070	48.28 ^c \pm 0.795	3.69 ^a \pm 0.150	54.80 ^{cd} \pm 0.776	0.91 ^a \pm 0.055	13.47 ^d \pm 0.400
78	2.14 ^b \pm 0.070	47.63 ^{bc} \pm 0.776	4.77 ^b \pm 0.150	55.33 ^d \pm 0.758	1.14 ^b \pm 0.055	13.12 ^{cd} \pm 0.391
86	2.35 ^c \pm 0.071	47.70 ^{bc} \pm 0.818	5.04 ^b \pm 0.152	53.44 ^{bcd} \pm 0.799	1.14 ^b \pm 0.056	11.77 ^b \pm 0.412
102	2.56 ^d \pm 0.070	46.68 ^{abc} \pm 0.797	6.04 ^c \pm 0.150	52.26 ^{ab} \pm 0.778	1.21 ^b \pm 0.056	10.62 ^a \pm 0.401
113	2.87 ^e \pm 0.068	45.55 ^{ab} \pm 0.774	6.44 ^c \pm 0.146	52.71 ^{abc} \pm 0.756	1.49 ^c \pm 0.054	11.69 ^{ab} \pm 0.390
128	3.28 ^f \pm 0.064	46.88 ^{abc} \pm 0.796	7.72 ^d \pm 0.138	53.74 ^{bcd} \pm 0.777	1.70 ^d \pm 0.051	11.76 ^b \pm 0.401
133	3.36 ^{fg} \pm 0.070	46.19 ^{abc} \pm 0.799	7.81 ^d \pm 0.150	52.03 ^{ab} \pm 0.780	1.79 ^d \pm 0.056	12.25 ^{bc} \pm 0.402
146	3.54 ^g \pm 0.086	44.80 ^a \pm 0.829	8.40 ^e \pm 0.184	50.65 ^a \pm 0.809	1.85 ^d \pm 0.068	11.19 ^{ab} \pm 0.417

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)

Table 6.4 Percentage brine uptake and fresh to smoke loss of whole smoked necks, belly bacon and back bacon obtained from pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights (mean + se)

Variable	Whole smoked necks % Brine uptake	Whole smoked necks %Smoke loss*	Belly bacon % Brine uptake	Belly bacon %Smoke loss*	Back bacon % Brine uptake	Back bacon %Smoke loss*
Sex type						
Boar	7.26±0.354	6.24±0.367	7.73 ^a ±0.562	12.34±0.676	5.640±0.361	6.486±0.318
Gilt	7.76±0.339	5.90±0.351	9.33 ^b ±0.539	11.24±0.652	5.682±0.347	6.215±0.307
Castrate	7.40±0.323	6.34±0.335	7.22 ^a ±0.512	10.45±0.621	4.958±0.330	5.767±0.295
Genotype						
1	8.18±0.424	5.73±0.440	8.21±0.674	10.03±0.816	4.803±0.432	5.937 ^a ±0.385
2	7.30±0.431	6.25±0.447	7.80±0.685	11.21±0.830	5.772±0.446	5.777 ^a ±0.391
3	6.66±0.468	6.10±0.486	7.71±0.751	10.51±0.901	5.193±0.482	5.509 ^a ±0.423
4	7.12±0.425	6.11±0.441	7.66±0.676	11.33±0.819	5.105±0.433	6.159 ^a ±0.386
5	8.04±0.436	6.66±0.452	8.92±0.683	13.30±0.828	6.165±0.443	7.260 ^b ±0.395
Slaughter weight (kg)						
62	9.32 ^a ±0.451	8.67 ^a ±0.474	10.72 ^c ±0.667	16.80 ^f ±0.843	7.82 ^a ±0.417	6.99 ^{cd} ±0.486
78	9.17 ^a ±0.441	5.36 ^b ±0.464	12.40 ^c ±0.667	11.69 ^d ±0.844	7.63 ^{ab} ±0.416	5.72 ^{abc} ±0.487
86	6.38 ^b ±0.449	7.30 ^c ±0.472	8.74 ^b ±0.678	15.12 ^e ±0.858	6.66 ^{ab} ±0.438	6.87 ^{bcd} ±0.495
102	9.30 ^a ±0.442	4.38 ^b ±0.464	10.62 ^c ±0.667	10.28 ^{cd} ±0.844	6.54 ^b ±0.417	5.98 ^{abcd} ±0.487
113	8.38 ^a ±0.429	7.23 ^c ±0.451	5.91 ^a ±0.662	12.61 ^d ±0.821	4.20 ^c ±0.416	7.23 ^d ±0.473
128	6.05 ^b ±0.405	4.21 ^b ±0.426	6.07 ^a ±0.612	9.01 ^{bc} ±0.775	4.33 ^c ±0.382	5.11 ^a ±0.447
133	6.03 ^b ±0.441	5.35 ^b ±0.464	4.55 ^a ±0.670	7.42 ^{ab} ±0.847	2.95 ^d ±0.449	5.30 ^a ±0.523
146	4.95 ^b ±0.543	8.39 ^{ac} ±0.571	4.27 ^a ±0.823	6.18 ^a ±1.039	2.55 ^d ±0.515	5.45 ^{ab} ±0.599

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)

* Smoke loss is the percentage difference between the fresh and final smoked cuts

Table 6.5 Percentage brine uptake and smoke loss of cooked shoulder hams, whole gammon hams and topside gammon hams obtained from pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights (mean + se)

Variable	Cooked shoulder ham % Cooking loss**	Cooked shoulder ham %Smoke loss*	Whole gammon % Brine uptake	Whole gammon %Smoke loss*	Topside gammon % Brine uptake	Topside gammon %Smoke loss*
Sex type						
Boar	22.01±0.885	25.66±0.910	4.46 ^a ±0.317	4.59±0.322	7.21±0.543	11.26 ^a ±0.667
Gilt	23.10±0.853	26.67±0.874	4.44 ^a ±0.311	4.76±0.312	7.54±0.520	10.44 ^a ±0.640
Castrate	22.12±0.830	25.73±0.844	5.34 ^b ±0.283	3.88±0.290	7.58±0.494	8.27 ^b ±0.608
Genotype						
1	22.91±1.11	25.74±1.12	4.46±0.387	5.24 ^b ±0.387	7.45±0.651	9.22±0.801
2	21.68±1.08	25.81±1.11	5.11±0.389	3.79 ^a ±0.395	7.13±0.662	9.73±0.813
3	22.24±1.18	25.74±1.21	5.02±0.407	3.86 ^a ±0.413	7.38±0.726	9.52±0.893
4	22.20±1.07	25.82±1.09	4.37±0.382	4.83 ^{ab} ±0.396	6.84±0.653	9.19±0.802
5	23.05±1.08	26.98±1.13	5.03±0.387	4.13 ^a ±0.393	8.47±0.660	11.75±0.812
Slaughter weight (kg)						
62					10.72 ^a ±0.602	16.81 ^a ±0.756
78	22.12 ^b ±0.962	27.01 ^b ±0.983	5.53 ^{ab} ±1.870	2.66 ^b ±1.840	12.40 ^a ±0.602	11.69 ^b ±0.757
86	23.22 ^b ±0.943	26.51 ^b ±0.943	3.69 ^a ±0.382	3.84 ^b ±0.376	5.95 ^b ±0.612	12.17 ^b ±0.769
102	22.38 ^b ±0.962	26.77 ^b ±0.962	6.23 ^b ±0.382	4.48 ^a ±0.376	8.28 ^c ±0.602	9.39 ^c ±0.757
113	14.90 ^a ±0.962	17.65 ^a ±0.943	5.96 ^b ±0.418	3.11 ^b ±0.422	5.56 ^b ±0.598	10.90 ^{bc} ±0.751
128	23.30 ^b ±1.005	26.63 ^b ±1.005	4.07 ^a ±0.353	6.45 ^c ±0.342	5.57 ^b ±0.552	6.15 ^d ±0.694
133	28.59 ^c ±0.943	31.71 ^c ±0.943	4.54 ^a ±0.374	3.81 ^b ±0.368	5.74 ^b ±0.605	6.23 ^d ±0.760
146	21.11 ^b ±1.260	25.59 ^b ±1.217	4.53 ^a ±0.454	3.76 ^b ±0.446	5.75 ^b ±0.743	4.24 ^d ±0.934

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$); * Smoke loss is the percentage difference between the fresh and final smoked cuts

** Cooking loss is the percentage difference between the fresh and cooked cuts

Table 6.6 Regression analysis ($y = a + bx$ and $y = a + bx + cx^2$) describing rates of change in absolute and percentage yields of bacon and ham cuts with increased pig slaughter weight (x)

Parameter (y)	y=a+bx with x = slaughter weight				y=a+bx+cx2 with x = slaughter weight				
	a	b	R ²	F Prob	a	b	c	R ²	F Prob
Neck PLM (kg)	-337.30	27.157*	0.808	≤.001	- 33	19.21*	0.0478	0.809	≤0.001
Neck PLM (%)	35.82	0.0790*	0.091	≤.001	51.11	-0.32	0.002404	0.145	≤0.001
Belly PLM (kg)	-742.00	34.920*	0.823	≤.001	-1280	48.98*	-0.0846	0.825	≤0.001
Belly PLM (%)	19.71	0.092*	0.230	≤.001	16.75	0.1694*	-0.000465	0.230	≤0.001
Loin PLM (kg)	-356.90	25.441*	0.794	≤.001	-1556	72.9*	-0.1325	0.797	
Loin PLM (%)	6.61	-0.015*	0.284	≤.001	24.85	0.549*	-0.001804	0.429	≤0.001
Shoulder PLM (kg)	560.40	26.230*	0.780	≤.001	-127	44.2*	-0.1081	0.788	≤0.001
Shoulder PLM (%)	50.87	-0.050*	0.085	≤.001	50.22	-0.033*	-0.000102	0.081	≤0.001
Leg PLM (kg)	688.00	67.270*	0.829	≤.001					
Leg PLM (%)	57.98	-0.058*	0.107	≤.001					
Topside PLM (kg)	148.20	5.814*	0.790	≤.001	116	17.27*	-0.0185	0.604	≤0.001
Topside PLM (%)	6.61	-0.015*	0.284	≤0.001	17.14	-0.1081*	0.00051	0.083	≤0.001

*Highly significant coefficients ($P \leq 0.01$); NS – Not significant

The effect of slaughter weight on the deboning and processing yield as well as chemical composition of bacon and ham cuts from pork carcasses

Table 6.7 Regression analysis ($y = a + bx$ and $y = a + bx + cx^2$) describing rates of change in percentage processing yields of bacon and ham cuts with increased pig slaughter weight (x)

Parameter (y)	y=a+bx with x = slaughter weight				y=a+bx+cx2 with x = slaughter weight				
	a	b	R ²	F prob	a	B	c	R ²	F-prob
Belly bacon brine uptake (%)	16.79	-0.106*	0.329	≤.001	19.64	-0.1806*	0.000448	0.329	≤0.001
Belly bacon smoke losses (%)	21.98	-0.129*	0.329	≤.001	27.01	-0.2608*	0.000791	0.334	≤0.001
Loin bacon brine uptake (%)	11.34	-0.072*	0.374	≤.001	12.93	-0.1136*	0.00025	0.374	≤0.001
Loin bacon smoke losses (%)	8.42	-0.028*	0.065	≤.001	10.18	-0.074*	0.000277	0.640	≤0.001
Neck brine uptake (%)	11.80	-0.053*	0.200	≤.001	9.42	0.0098*	-0.000372	0.203	≤0.001
Neck smoke losses (%)	8.07	-0.023*	0.034	0.006	16.77	-0.2497*	0.001361	0.120	≤0.001
Topside gammon ham brine uptake (%)	14.92	-0.091*	0.273	≤.001	24.62	-0.3442*	0.001525	0.321	≤0.001
Topside gammon ham smoke losses (%)	22.81	-0.157*	0.495	≤.001	30.5	-0.3579*	0.001209	0.512	≤0.001

*Highly significant coefficients ($P \leq 0.01$); NS – Not significant

Slaughter weight differences ($P \leq 0.05$) (Table 6.8, Table 6.9, Table 6.10, Table 6.11 & Table 6.12) were observed for moisture, fat and ash contents of the fresh cuts. The moisture content of the 132.2kg group was below that of all other groups whilst the animals above 132.2kg had more fat than the other groups. The animals above 128kg also had more ash than other groups. Similar results were reported by various authors (Candek-Potokar *et al.*, 1997; Wagner *et al.*, 1999; Gonzalez *et al.*, 2001; Zullo *et al.*, 2003). Back bacon samples showed increased ($P \leq 0.05$) fat and decreased ($P \leq 0.05$) moisture with increased slaughter weight.

Table 6.8 Chemical composition (mean \pm s.e.) of fresh pork loin samples obtained from pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights (mean \pm se)

Variable	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Sex type				
Boar	63.28 \pm 0.322	30.61 \pm 0.356	3.62 \pm 0.212	2.86 \pm 0.149
Gilt	63.51 \pm 0.294	30.54 \pm 0.329	3.69 \pm 0.192	2.81 \pm 0.135
Castrate	63.15 \pm 0.342	29.98 \pm 0.390	4.12 \pm 0.229	3.27 \pm 0.160
Genotype				
1	63.20 \pm 0.411	31.14 \pm 0.466	3.52 ^a \pm 0.272	2.77 \pm 0.190
2	63.64 \pm 0.384	29.82 \pm 0.435	4.33 ^b \pm 0.254	2.83 \pm 0.178
3	63.42 \pm 0.491	29.75 \pm 0.537	4.49 ^b \pm 0.316	3.21 \pm 0.221
4	63.43 \pm 0.383	30.30 \pm 0.424	3.38 ^a \pm 0.254	3.01 \pm 0.174
5	62.93 \pm 0.401	31.00 \pm 0.454	3.33 ^a \pm 0.266	3.04 \pm 0.191
Slaughter weight (kg)				
62				
78	63.78 ^a \pm 0.422	30.62 \pm 0.531	3.51 ^a \pm 0.306	2.64 ^a \pm 0.199
86	63.72 ^a \pm 0.393	29.96 \pm 0.495	3.72 ^a \pm 0.285	2.86 ^a \pm 0.185
102	63.46 ^a \pm 0.422	30.50 \pm 0.512	3.62 ^a \pm 0.306	2.66 ^a \pm 0.199
113	63.91 ^a \pm 0.439	30.56 \pm 0.553	3.05 ^a \pm 0.319	2.57 ^a \pm 0.207
128	62.77 ^a \pm 0.380	30.78 \pm 0.479	3.78 ^a \pm 0.276	3.08 ^{ab} \pm 0.179
133	61.98 ^b \pm 0.507	30.64 \pm 0.606	5.11 ^b \pm 0.349	3.49 ^b \pm 0.226
146	63.35 ^a \pm 0.538	29.64 \pm 0.677	4.08 ^{ab} \pm 0.390	3.60 ^b \pm 0.253

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)

Changes in protein and ash contents did not follow the same pattern as slaughter weight. Belly bacon showed decreases ($P \leq 0.05$) in moisture, protein

and ash and increases in fat contents as slaughter weight increased. Cooked shoulder ham showed an increase ($P \leq 0.05$) in ash content in the heaviest slaughter group, decreased ($P \leq 0.05$) moisture and protein and increased fat with increased slaughter weight. Topside gammon ham showed increased ($P \leq 0.05$) fat content with increased slaughter weight, whilst no differences ($P > 0.05$) in protein content were observed.

Table 6.9 Chemical composition (mean \pm s.e.) of back bacon samples obtained from pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights (mean \pm se)

Variable	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Sex type				
Boar	55.00 ^a \pm 1.17	20.82 \pm 0.597	20.30 ^a \pm 1.24	2.57 ^a \pm 0.099
Gilt	52.60 ^a \pm 1.15	21.04 \pm 0.585	22.57 ^a \pm 1.22	2.54 ^a \pm 0.097
Castrate	46.67 ^b \pm 1.09	20.20 \pm 0.559	29.20 ^b \pm 1.16	2.21 ^b \pm 0.093
Genotype				
1	50.18 ^a \pm 1.44	21.22 \pm 0.734	24.58 ^b \pm 1.53	2.43 ^{ab} \pm 0.122
2	49.66 ^a \pm 1.44	20.47 \pm 0.733	26.08 ^b \pm 1.52	2.22 ^a \pm 0.122
3	50.24 ^a \pm 1.59	20.53 \pm 0.810	25.29 ^b \pm 1.68	2.62 ^b \pm 0.135
4	49.98 ^a \pm 1.45	20.18 \pm 0.738	25.76 ^b \pm 1.53	2.23 ^a \pm 0.123
5	55.72 ^b \pm 1.43	20.91 \pm 0.732	19.82 ^a \pm 1.52	2.67 ^b \pm 0.122
Slaughter weight (kg)				
62	54.65 ^{ab} \pm 1.76	18.56 ^a \pm 0.918	24.17 ^{bc} \pm 1.85	3.26 ^a \pm 0.148
78	58.57 ^a \pm 1.83	24.10 ^c \pm 0.952	13.82 ^a \pm 1.92	2.36 ^b \pm 0.154
86	54.93 ^a \pm 1.76	20.05 ^a \pm 0.915	21.84 ^b \pm 1.84	2.39 ^b \pm 0.148
102	56.70 ^a \pm 1.69	19.98 ^{ab} \pm 0.882	19.94 ^b \pm 1.78	2.20 ^{bc} \pm 0.142
113	49.93 ^{bc} \pm 1.65	21.32 ^b \pm 0.857	24.68 ^{cd} \pm 1.73	2.48 ^b \pm 0.138
128	47.15 ^{cd} \pm 1.59	19.90 ^{ab} \pm 0.826	28.43 ^{cd} \pm 1.66	1.90 ^c \pm 0.133
133	44.75 ^d \pm 1.70	20.02 ^a \pm 0.887	30.77 ^d \pm 1.78	2.36 ^b \pm 0.143
146	43.45 ^d \pm 2.08	20.16 ^a \pm 1.083	31.38 ^d \pm 2.18	2.35 ^b \pm 0.175
Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)				

Table 6.10 Chemical composition (mean \pm s.e.) of belly bacon samples obtained from pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights (mean \pm se)

Variable	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Sex type				
Boar	48.57 ^a \pm 1.18	20.08 \pm 0.641	27.94 ^a \pm 1.51	2.64 ^a \pm 0.151
Gilt	46.00 ^a \pm 1.16	19.74 \pm 0.622	29.99 ^a \pm 1.48	2.61 ^a \pm 0.148
Castrate	51.56 ^b \pm 1.12	18.65 \pm 0.599	36.42 ^b \pm 1.42	2.13 ^b \pm 0.142
Genotype				
1	42.82 ^a \pm 1.46	19.88 \pm 0.783	34.02 \pm 1.86	2.15 \pm 0.186
2	44.59 ^b \pm 1.47	20.10 \pm 0.790	31.12 \pm 1.88	2.66 \pm 0.188
3	43.37 ^{ab} \pm 1.59	19.59 \pm 0.854	33.11 \pm 2.02	2.37 \pm 0.203
4	45.99 ^b \pm 1.44	18.56 \pm 0.774	31.78 \pm 1.84	2.37 \pm 0.184
5	49.13 ^b \pm 1.48	19.13 \pm 0.807	28.40 \pm 1.89	2.67 \pm 0.189
Slaughter weight (kg)				
62	55.33 ^d \pm 1.74	22.51 ^c \pm 1.029	17.39 ^a \pm 2.22	4.92 ^a \pm 0.165
78	51.32 ^d \pm 1.83	21.36 ^{bc} \pm 1.083	24.22 ^b \pm 2.34	2.81 ^b \pm 0.174
86	45.84 ^{bc} \pm 1.72	19.93 ^{abc} \pm 1.034	31.51 ^c \pm 2.20	2.21 ^c \pm 0.164
102	46.13 ^c \pm 1.60	20.39 ^{bc} \pm 0.950	30.24 ^{bc} \pm 2.05	1.94 ^c \pm 0.153
113	42.73 ^{bc} \pm 1.57	17.58 ^a \pm 0.932	35.81 ^c \pm 2.01	1.99 ^c \pm 0.150
128	41.55 ^b \pm 1.45	18.99 ^{ab} \pm 0.860	35.37 ^c \pm 1.86	2.19 ^c \pm 0.138
133	41.38 ^b \pm 1.58	19.23 ^{ab} \pm 0.931	35.42 ^c \pm 2.02	2.09 ^c \pm 0.150
146	36.05 ^a \pm 1.93	16.94 ^a \pm 1.144	42.78 ^d \pm 2.47	1.84 ^c \pm 0.184
Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)				

Table 6.11 Chemical composition of cooked shoulder ham samples obtained from pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights (mean \pm se)

Variable	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Sex type				
Boar	64.24 \pm 0.457	23.36 ^{ab} \pm 0.306	8.41 ^a \pm 0.395	2.76 \pm 0.127
Gilt	62.84 \pm 0.439	23.61 ^a \pm 0.295	9.67 ^b \pm 0.380	2.69 \pm 0.122
Castrate	61.17 \pm 0.428	22.66 ^b \pm 0.290	10.45 ^b \pm 0.368	2.71 \pm 0.117
Genotype				
1	63.54 \pm 0.552	22.78 \pm 0.376	9.38 ^{ab} \pm 0.485	2.78 \pm 0.153
2	62.48 \pm 0.545	22.61 \pm 0.366	11.13 ^c \pm 0.473	2.69 \pm 0.152
3	63.15 \pm 0.641	23.19 \pm 0.429	10.23 ^{bc} \pm 0.535	2.82 \pm 0.172
4	64.09 \pm 0.561	23.50 \pm 0.377	8.65 ^a \pm 0.486	2.60 \pm 0.156
5	63.71 \pm 0.560	23.93 \pm 0.376	8.41 ^a \pm 0.485	2.72 \pm 0.156
Slaughter weight (kg)				
62				
78	64.81 ^c \pm 0.598	23.15 ^{abc} \pm 0.449	8.25 ^a \pm 0.591	2.66 ^b \pm 0.154
86	64.27 ^c \pm 0.612	22.76 ^{ab} \pm 0.459	9.20 ^{ab} \pm 0.591	2.31 ^{ab} \pm 0.154
102	63.80 ^{bc} \pm 0.626	24.01 ^{bc} \pm 0.470	8.56 ^{ab} \pm 0.618	2.20 ^a \pm 0.163
113	64.73 ^c \pm 0.586	22.27 ^a \pm 0.440	9.40 ^{ab} \pm 0.578	2.59 ^{ab} \pm 0.151
128	63.41 ^{bc} \pm 0.533	23.08 ^{abc} \pm 0.400	9.18 ^{ab} \pm 0.526	3.46 ^c \pm 0.137
133	60.54 ^a \pm 0.598	24.12 ^c \pm 0.449	11.86 ^c \pm 0.591	2.33 ^{ab} \pm 0.154
146	62.19 ^{ab} \pm 0.717	22.83 ^{abc} \pm 0.556	10.39 ^{bc} \pm 0.731	3.39 ^c \pm 0.185
Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)				

Table 6.12 Chemical composition (mean \pm s.e.) of topside gammon ham samples obtained from pig carcasses of group housed animals of three sex types, five genotypes and eight slaughter weights (mean \pm se)

Variable	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Sex type				
Boar	63.40 \pm 0.346	30.42 \pm 0.340	3.63 \pm 0.202	3.02 \pm 0.160
Gilt	63.18 \pm 0.337	30.56 \pm 0.338	3.74 \pm 0.197	2.81 \pm 0.156
Castrate	63.13 \pm 0.384	30.00 \pm 0.379	4.16 \pm 0.224	3.23 \pm 0.178
Genotype				
1	63.16 \pm 0.445	31.02 \pm 0.437	3.68 ^{ab} \pm 0.259	2.68 \pm 0.206
2	63.53 \pm 0.432	29.80 \pm 0.439	4.35 ^b \pm 0.252	2.89 \pm 0.200
3	62.89 \pm 0.543	29.75 \pm 0.535	4.46 ^b \pm 0.316	3.24 \pm 0.251
4	63.60 \pm 0.432	30.07 \pm 0.424	3.41 ^a \pm 0.252	3.06 \pm 0.200
5	62.90 \pm 0.453	31.02 \pm 0.445	3.34 ^a \pm 0.264	3.24 \pm 0.210
Slaughter weight (kg)				
62				
78	63.83 ^a \pm 0.483	30.39 \pm 0.550	3.62 ^{ab} \pm 0.315	2.65 ^a \pm 0.238
86	63.59 ^a \pm 0.447	30.01 \pm 0.509	3.75 ^{ab} \pm 0.292	2.85 ^{ab} \pm 0.220
102	63.64 ^a \pm 0.447	30.50 \pm 0.509	3.53 ^{ab} \pm 0.292	2.93 ^{ab} \pm 0.220
113	63.91 ^a \pm 0.483	30.56 \pm 0.550	3.05 ^a \pm 0.315	2.57 ^a \pm 0.238
128	62.73 ^a \pm 0.405	30.70 \pm 0.477	3.93 ^b \pm 0.265	2.95 ^{ab} \pm 0.200
133	61.29 ^b \pm 0.529	30.64 \pm 0.603	5.11 ^c \pm 0.346	3.49 ^b \pm 0.261
146	63.41 ^a \pm 0.557	29.59 \pm 0.635	4.05 ^b \pm 0.364	3.65 ^b \pm 0.275

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)

Conclusion

Sex type differences showed castrates to have more PLM from the belly and less from the gammon than boars and gilts. Genotypic differences showed Genotype 2 to be yielding less and Genotype 4 yielding more in terms of percentage PLM for whole gammon while Genotype 2 yielded less and Genotype 3 more in percentage PLM for the neck cut. Regression analysis describing changes in PLM with increased slaughter weight showed good predictive values for absolute yields but relatively poor predictive values for percentage PLM yields.

Processing characteristics did not show any sex type to constantly have higher processing yields than other. Slaughter weight differences generally showed decreased brine uptake and smoke losses indicating that the total yield could be increased with heavier slaughter weights.

Chemical analysis of fresh and processed cuts generally showed castrates to be inferior because of increased fat levels while genotypic differences showed 2 genotypes to have higher fat content than the other genotypes. Slaughter weight differences generally showed increased fat content and decreases in moisture content with little or no differences observed for ash and protein content - where differences were observed these could not be associated with increased slaughter weight.

In conclusion the production of intact boars and gilts appear to be beneficial in terms of PLM yields as well as chemical composition. Genotypic differences were small and of little practical importance while increased slaughter weight showed increases in absolute yields. Changes in percentage PLM showed a redistribution of tissues within different cuts with percentage PLM decreasing in the loin, shoulder, leg and topside while increasing in the neck and belly. Overall the net effect of increased slaughter weight on PLM and processing yields appear to be positive and should be to the benefit of the processor.

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Chapter 7

The effect of slaughter weight on the descriptive sensory characteristics of pork

Abstract

This study was conducted with 189 pigs of three sex types and five genotypes. Treatments were according to slaughter weight ranging between 62 and 146kg. A total of 72 carcasses representing three per sex type and slaughter weight group were selected for sensory analysis. Aroma intensity of the fresh pork showed no significant genotype or slaughter weight differences ($P>0.05$) but significant ($P\leq 0.02$) difference for sex type while off flavour intensity showed highly significant genotype and sex type differences. Changes observed for characteristics with increased slaughter weight did not have the same pattern as slaughter weight. Once the meat was processed, most differences in flavour and aroma attributes were no longer observed. Juiciness attributes showed no significant ($P>0.05$) sex type and genotype differences. However, highly significant ($P\leq 0.01$) differences were observed for slaughter weight. Generally there was an increased juiciness with increased slaughter weight. Tenderness differences were observed in the fresh loin showing highly significant ($P\leq 0.01$) genotype, sex type and slaughter weight differences for first bite as well as muscle fibre and overall tenderness attributes. No significant genotypic difference ($P>0.05$) were observed for the amount of connective tissue attribute. Slaughter weight differences observed showed an increase in toughness of fresh pork with increased slaughter weight. As most of the heavier carcasses are processed in South Africa, the effect of increased slaughter weight on the fresh pork is of less importance as pertaining to the consumer. The negative characteristic of increased toughness with an increase in carcass weight found in the fresh product was not found in the processed products and since these

differences were small they would probably not be detectable by the average consumer.

Key words

Pork, sensory attributes, sex type, slaughter weight, flavour, aroma, tenderness, juiciness, genotype

Introduction

In the highly competitive world of pork production, increased efficiency of production is often the only survival tool available to the producer. Increased efficiency can be achieved in a number of ways amongst which are increased slaughter weights and the production of intact males instead of females or castrates. These methods for increasing efficiency can often be in direct competition with processor and consumer preferences as an increase in age and live weight of, especially male animals, can correspond with an increase in the occurrence and intensity of taints (Bañon, Andreu, Laencina & Garrido, 2004). Ellis & Horsfield (1988) however found that pork eating quality could be increased by increasing the age and weight of the pig at slaughter. Sensory attributes of pork is closely related to the consumer's willingness to purchase the product again in future. A number of factors are associated and the most important factors according to Channon, Kerr & Walker (2004) are flavour and juiciness. A number of factors influence the sensory attributes of pork. Level of intramuscular fat is associated with tenderness and levels of between 2 and 3% were shown to be detectable and to have a positive influence (Bejerholm & Barton-Gade, 1986). Genotypic differences also exist with, for example, Durocs being juicier than other breeds while genotypic differences for tenderness, odour, flavour and overall liking were not influenced by genotype (Channon *et al.*, 2004). Sex type differences observed showed males to have higher shear force values than females (Channon *et al.*, 2004). Tenderness is however influenced by a number of factors, although often believed otherwise; fatness level does not have an influence on tenderness (Wood, Mottran & Brown,

1981). Differences that do exist include sex type differences with bacon from boars being more tender than that from castrates, this effect was found to be an inherent difference between boars and castrates and not an age effect (Mottran, Wood & Patterson, 1982). Tenderness is further influenced by diet with an increase in tenderness being noted with an increase in the percentage maize included in the diet - this also had a positive effect on flavour (Castaing, Cazette, Coudure & Peyhorgu, 1995).

Comparisons of sensory results over studies are, however, difficult due to variations in sample preparation, ageing time of meat, cut used and the statistical method used (Rødbotten, Kubberød, Lea & Ueland, 2004). It was therefore deemed necessary to evaluate the effect of increased slaughter weight on the sensory properties of fresh pork as well as processed products produced from pig genotypes typically found in the South African pork industry.

Materials and methods

The experiment was conducted at the Agricultural Research Council – Animal Nutrition and Animal Products Institute at Irene (Gauteng Province) and RTV abattoir in Benoni (Gauteng Province). The experimental outlay, housing and growth performance of the pigs have been described in detail in Chapter 2, carcass characteristics in Chapter 3 and meat quality characteristics Chapter 4, carcass yields in Chapter 5 and processing procedures and characteristics in Chapter 6. Slaughter information of pigs is shown in Table 7.1 .

Samples were taken from three carcasses per sex type and slaughter weight, in such a way as to ensure that all the genotypes are equally represented. Belly bacon, topside gammon ham and fresh loin samples (muscle and fat) were submitted to sensory analysis.

Table 7.1 Age at slaughter (days) and live weight at slaughter (kg) of group housed animals of three sex types representing five South African genotypes

Slaughter group	Age at slaughter (days)	Average live slaughter weight (kg)
1	112	61.93 ^a
2	126	77.99 ^b
3	140	86.04 ^c
4	154	102.37 ^d
5	168	112.70 ^e
6	182	128.39 ^f
7	196	133.10 ^f
8	210	145.45 ^g

Values in columns with different superscripts differ significantly ($P \leq 0.05$)

All samples were stored at -20°C until analysis. Loins were cooked using a dry cooking method. Loins were roasted whole at 180°C , on a rack in an open oven pan, until an internal temperature of 75°C was reached, muscle and fat were separated and the cooked pork fat analysed on aroma attributes. Bacons (2.5mm thick) were fried in an electric frying pan at medium heat for one minute and turned over and cooked on the other side for one minute. The meat cubes and bacon were wrapped in three digit coded foil squares (90mm X 90mm) and presented on pre-warmed (53°C) plates to the panel. The pieces of fat were each placed into a pre-heated glass beaker (60°C) and covered with similar pre coded aluminium foil and placed in a pre-heated sand bath at 120°C and presented simultaneously with the meat sample to the panel. Water at room temperature and carrot rings were served as pallet cleansers in between samples.

Gammon hams were boiled until an internal temperature of 73°C was reached, cooled overnight, sliced and served at room temperature (20°C) (AMSA, 1987).

Descriptive sensory attributes were evaluated by using a trained ten member descriptive attribute panel. The initial panel was selected on basis of their participation in previous descriptive sensory panels, taste and smell acuity, interest, ability to discriminate between the four basic tastes and availability throughout the study. The panel was trained in accordance with the AMSA Guidelines for Cooking and Sensory Evaluation (AMSA, 1987) from the trained panel the final panel was selected on members' sensitivity towards androstenone and skatole.

Fresh loin samples were evaluated for Aroma intensity, initial impression of juiciness, first bite, and sustained impression of juiciness, muscle fibre and overall tenderness, amount of connective tissue (residue), overall flavour intensity and off flavour intensity. Pork fat was evaluated for aroma intensity and off-aroma intensity. Belly bacon samples were evaluated for aroma intensity, sustained impression of juiciness, overall tenderness, amount of connective tissue (residue) and overall flavour intensity. Gammon ham samples were evaluated for aroma intensity, first bite, impression of juiciness, overall tenderness, and amount of connective tissue (residue), overall flavour intensity and off flavour intensity.

Analysis of variance was done with the General Linear Model (GLM) (Statistical Analysis Systems, 1994) to determine the significance between differences for genotype, sex type and slaughter weight effects for an unbalanced design. Least square means and standard errors were calculated. Significant differences (5%) were separated by multiple comparisons using Fischer t-test (Sameuls, 1989).

Results and discussion

Flavour and aroma attributes are described by aroma intensity, overall flavour intensity and off flavour/aroma intensity. The factors were judged as being extremely intense (score 8) to being extremely bland (score 1) for aroma intensity and overall flavour intensity while off flavour and aroma intensity were scored from extremely bland (score 8) to extremely intense (score 1). For the fresh loin cut, overall flavour intensity showed no significant differences ($P>0.05$) for sex type, genotype or slaughter weight (Table 7.2).

Although aroma intensity showed no significant genotype or slaughter weight differences ($P>0.05$), significant ($P\leq 0.02$) differences for sex type were found for this attribute. However, this observed difference represents a small practical difference as all averages obtained were within the category “slightly intense” with boars rating at the top of this category (5.9) and gilts and castrates slightly lower (5.7).

Off flavour intensity of the fresh cut showed highly significant ($P\leq 0.01$) differences for genotype and sex type and significant ($P\leq 0.05$) differences for slaughter weight (Table 7.2), these findings are in accordance with that of Nold, Romans, Costello, Henson & Libal, (1997). Genotypic differences observed showed Genotype 4 to have a slightly more intense off flavour score of 6.8 vs. the other four genotypes (all scoring statistically the same either 7.0 or 7.1). Off flavour intensity was also more intense for boars (6.8) than for either castrates (7.2) or gilts (7.1). However, slaughter weight differences were inconsistent; off flavour intensity does not appear to change with an increase in slaughter weight.

Once the meat was processed, differences in aroma intensity were no longer detected with the only significant difference ($P\leq 0.05$) observed being for the main effect of slaughter weight in the belly bacon. However, this difference was inconsistent and could not be related to increased slaughter weight with weight groups 3, 4 and 5 being atypical (Table 7.2, Table 7.3, Table 7.4).

Table 7.2 Average score (\pm se) of sensory attributes associated with flavour and aroma in fresh pork loins, belly bacon, gammon hams and cooked pork fat for five genotypes, three sex types and eight different slaughter weights

Variable	Aroma intensity				Overall flavour intensity			Off flavour intensity			Off aroma intensity
	Fresh loin	Belly bacon	Gammon ham	Cooked pork fat	Fresh loin	Belly bacon	Gammon ham	Fresh loin	Belly bacon	Gammon ham	Cooked pork fat
Sex type											
Boar	5.9 ^a \pm 0.053	6.3 \pm 0.046	6.0 \pm 0.061	6.3 \pm 0.045	6.0 \pm 0.046	6.3 \pm 0.039	6.3 \pm 0.043	6.8 ^a \pm 0.054	6.8 ^a \pm 0.054	7.4 \pm 0.049	6.0 ^a \pm 0.069
Gilt	5.7 ^b \pm 0.055	6.3 \pm 0.047	6.0 \pm 0.680	6.2 \pm 0.046	5.9 \pm 0.048	6.4 \pm 0.039	6.4 \pm 0.048	7.2 ^b \pm 0.056	7.2 ^b \pm 0.055	7.4 \pm 0.055	6.7 ^b \pm 0.071
Castrate	5.7 ^b \pm 0.052	6.3 \pm 0.046	6.0 \pm 0.067	6.3 \pm 0.043	6.0 \pm 0.045	6.4 \pm 0.039	6.3 \pm 0.047	7.1 ^b \pm 0.053	7.3 ^b \pm 0.054	7.5 \pm 0.054	6.9 ^b \pm 0.067
Genotype											
1	5.8 \pm 0.073	6.4 \pm 0.062	5.9 \pm 0.090	6.3 \pm 0.062	6.0 \pm 0.062	6.3 \pm 0.053	6.3 \pm 0.063	7.1 ^a \pm 0.074	7.2 \pm 0.073	7.4 \pm 0.073	6.5 \pm 0.095
2	5.8 \pm 0.065	6.3 \pm 0.058	6.1 \pm 0.079	6.3 \pm 0.055	6.0 \pm 0.055	6.4 \pm 0.049	6.3 \pm 0.055	7.1 ^a \pm 0.066	7.0 \pm 0.068	7.3 \pm 0.064	6.6 \pm 0.084
3	5.9 \pm 0.069	6.3 \pm 0.061	5.9 \pm 0.097	6.3 \pm 0.058	5.9 \pm 0.058	6.4 \pm 0.052	6.4 \pm 0.068	7.0 ^a \pm 0.070	7.1 \pm 0.072	7.5 \pm 0.078	6.5 \pm 0.089
4	5.7 \pm 0.071	6.2 \pm 0.054	6.0 \pm 0.076	6.2 \pm 0.060	6.0 \pm 0.060	6.3 \pm 0.045	6.2 \pm 0.053	6.8 ^b \pm 0.072	7.1 \pm 0.063	7.4 \pm 0.061	6.4 \pm 0.093
5	5.8 \pm 0.073	6.3 \pm 0.064	5.9 \pm 0.089	6.2 \pm 0.062	5.9 \pm 0.062	6.4 \pm 0.054	6.3 \pm 0.063	7.1 ^a \pm 0.075	7.2 \pm 0.075	7.4 \pm 0.072	6.7 \pm 0.095
Slaughter weight (kg)											
62	5.8 \pm 0.100	6.2 ^a \pm 0.091	-	6.4 ^c \pm 0.084	6.0 \pm 0.087	6.6 ^c \pm 0.076	-	6.9 ^a \pm 0.101	7.0 ^{ab} \pm 0.106	-	6.7 ^{cd} \pm 0.130
78	5.9 \pm 0.074	6.2 ^a \pm 0.069	5.9 \pm 0.081	6.3 ^{bc} \pm 0.062	5.7 \pm 0.064	6.4 ^b \pm 0.058	6.3 \pm 0.057	7.1 ^{bc} \pm 0.075	7.3 ^d \pm 0.080	7.5 ^{bc} \pm 0.065	6.5 ^{bc} \pm 0.096
86	5.7 \pm 0.078	6.4 ^{bc} \pm 0.073	6.0 \pm 0.089	6.4 ^c \pm 0.065	6.0 \pm 0.068	6.3 ^{ab} \pm 0.062	6.3 \pm 0.063	7.1 ^{bc} \pm 0.079	7.2 ^{cd} \pm 0.086	7.4 ^{ab} \pm 0.072	6.2 ^a \pm 0.101
102	5.9 \pm 0.086	6.5 ^c \pm 0.076	6.0 \pm 0.092	6.4 ^c \pm 0.072	6.0 \pm 0.076	6.3 ^{ab} \pm 0.064	6.3 \pm 0.065	7.1 ^{bc} \pm 0.088	6.9 ^a \pm 0.088	7.3 ^a \pm 0.075	6.5 ^{bc} \pm 0.112
113	5.8 \pm 0.079	6.4 ^{bc} \pm 0.072	6.1 \pm 0.110	6.1 ^a \pm 0.067	6.0 \pm 0.069	6.4 ^b \pm 0.061	6.4 \pm 0.077	7.1 ^{bc} \pm 0.081	7.1 ^{bc} \pm 0.084	7.6 ^c \pm 0.089	6.4 ^{ab} \pm 0.103
128	5.8 \pm 0.081	6.3 ^{ab} \pm 0.067	6.0 \pm 0.086	6.1 ^a \pm 0.068	6.0 \pm 0.071	6.3 ^{ab} \pm 0.057	6.3 \pm 0.060	7.2 ^c \pm 0.082	7.2 ^{cd} \pm 0.079	7.3 ^a \pm 0.069	6.8 ^d \pm 0.105
133	5.7 \pm 0.101	6.2 ^a \pm 0.075	6.0 \pm 0.131	6.2 ^{ab} \pm 0.085	6.0 \pm 0.088	6.3 ^{ab} \pm 0.063	6.2 \pm 0.092	6.9 ^{ab} \pm 0.103	7.1 ^{bc} \pm 0.088	7.4 ^{ab} \pm 0.106	6.7 ^{cd} \pm 0.131
146	5.7 \pm 0.108	6.2 ^a \pm 0.082	5.8 \pm 0.117	6.3 ^{bc} \pm 0.091	6.0 \pm 0.095	6.2 ^a \pm 0.069	6.3 \pm 0.082	6.8 ^a \pm 0.111	7.2 ^{cd} \pm 0.096	7.5 ^{bc} \pm 0.094	6.5 ^{bc} \pm 0.140

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)

As pertaining to the sensory attribute of overall flavour intensity; this attribute showed no significant differences ($P>0.05$) for genotype, sex type or slaughter weight in the gammon ham. Belly bacon also showed no significant ($P>0.05$) genotype and sex type differences, while a highly significant difference ($P\leq 0.01$) for the main effect of slaughter weight was observed with overall flavour intensity decreasing as slaughter weight increased. Off flavour intensity of belly bacon showed no significant genotype differences ($P>0.05$) but highly significant differences ($P\leq 0.01$) for sex type and significant differences ($P\leq 0.05$) for slaughter weight. Sex type differences observed in belly bacon samples showed a more intense off flavour in samples obtained from boar carcasses than for samples obtained from carcasses of either gilts or castrates. Observed differences were inconsistent and do not appear to change with slaughter weight.

Cooked pork fat showed no significant aroma intensity differences ($P>0.05$) for genotype and sex type but highly significant differences ($P\leq 0.01$) for slaughter weight (Table 7.2). These differences were however, small and inconsistent showing no tendency to change with increasing slaughter weight. Off aroma intensity for cooked pork fat showed no significant differences ($P>0.05$) for genotype but highly significant differences ($P\leq 0.01$) for sex type and slaughter group. Boars had stronger off flavour intensity (6.0) with gilts (6.9) and castrates (6.7) having weaker off flavour intensities. Slaughter group differences, although significant, were small with only slaughter group three scoring atypically to have a more intense off aroma than the other groups. Similar results were reported by Blanchard, Warkup, Ellis, Willis & Avery, (1999) and Jeremiah, Squires & Sather (1999) however, Jonsall, Johansson, Lundström, Andersson, Nilsen & Risvik, (2002) found significant differences in off flavour intensity between castrates and gilts

Table 7.3 Average score, (\pm se) of juiciness attributes in fresh and processed pork products for five genotypes, three sex types and eight different slaughter weights

	Initial impression of juiciness		Sustained impression of juiciness	
	Fresh loin	Fresh loin	Belly bacon	Gammon ham
Sex type				
Boar	5.2 \pm 0.052	4.6 \pm 0.057	5.4 ^a \pm 0.043	4.7 \pm 0.054
Castrate	5.2 \pm 0.054	4.6 \pm 0.059	5.7 ^b \pm 0.044	4.7 \pm 0.061
Gilt	5.1 \pm 0.051	4.6 \pm 0.055	5.6 ^b \pm 0.044	4.5 \pm 0.060
Genotype				
1	5.2 \pm 0.072	4.5 \pm 0.078	5.6 ^{bc} \pm 0.059	4.5 \pm 0.080
2	5.2 \pm 0.064	4.7 \pm 0.069	5.7 ^c \pm 0.055	4.7 \pm 0.070
3	5.2 \pm 0.068	4.7 \pm 0.074	5.7 ^c \pm 0.058	4.7 \pm 0.086
4	5.2 \pm 0.070	4.7 \pm 0.076	5.5 ^b \pm 0.051	4.6 \pm 0.068
5	5.1 \pm 0.072	4.5 \pm 0.079	5.3 ^a \pm 0.061	4.7 \pm 0.080
Slaughter group (kg)				
62	5.4 ^e \pm 0.098	4.9 ^c \pm 0.107	5.2 ^a \pm 0.085	-
78	5.3 ^{de} \pm 0.073	4.7 ^{bc} \pm 0.079	5.5 ^b \pm 0.065	4.8 ^c \pm 0.073
86	5.3 ^{de} \pm 0.077	4.6 ^b \pm 0.083	5.7 ^c \pm 0.069	4.6 ^b \pm 0.080
102	5.4 ^e \pm 0.085	4.6 ^b \pm 0.093	5.5 ^b \pm 0.071	5.0 ^d \pm 0.083
113	5.0 ^{bc} \pm 0.078	4.3 ^a \pm 0.085	5.6 ^{bc} \pm 0.068	4.4 ^a \pm 0.098
128	4.9 ^{ab} \pm 0.080	4.6 ^b \pm 0.087	5.7 ^c \pm 0.064	4.3 ^a \pm 0.077
133	4.8 ^a \pm 0.100	4.4 ^a \pm 0.109	5.6 ^{bc} \pm 0.071	4.7 ^{bc} \pm 0.117
146	5.2 ^{cd} \pm 0.107	4.7 ^{bc} \pm 0.116	5.7 ^c \pm 0.077	4.7 ^{bc} \pm 0.105

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)

Juiciness attributes (Table 7.3) are described by initial impression of juiciness and sustained impression of juiciness. The factors were judged as being extremely dry (score 1) to being extremely juicy (score 8). Initial impression of juiciness and sustained impression of juiciness were determined on fresh loin samples and showed no significant ($P>0.05$) sex type and genotype differences. However, a highly significant ($P\leq 0.01$) difference was observed for slaughter weight showing increased initial impression of juiciness with increased slaughter weight while differences observed for sustained impression of juiciness were not consistent with slaughter group.

Once the pork was processed, the belly bacon showed highly significant differences ($P\leq 0.01$) for sex type, genotype and slaughter weight as pertaining to juiciness attributes (Table 7.3). Genotypic differences showed Genotype 5 to be juicier than the other genotypes and sex type differences showed gilts and castrates as being juicier than boars. Gammon hams showed no significant ($P>0.05$) sex type or genotype differences but highly significant slaughter weight differences ($P\leq 0.01$). Differences observed for slaughter weight were, however, not consistent with changes in slaughter weight. Genotypic differences for juiciness were noted by Ellis, Webb, Avery & Brown (1996) while Channon *et al.* (2004) found that genotype did not have an influence on overall eating quality of pork. Jonsall *et al.* (2002) also reported sex type differences for juiciness. The positive effect of processing on the acceptability of tainted meat have been noted previously (Bonneau, Desmoulin & Dumont, 1979) and can be attributed to a decrease in the level of odorous components during processing (Bonneau, Desmoulin & Frouin, 1980) and higher threshold for detection of off flavours in processed meat, especially those served at room temperature (Desmoulin, Bonneau, Frouin & Bidard, 1982).

Table 7.4 Average score (\pm se) of sensory attributes associated with tenderness attributes fresh pork loins, belly bacon and gammon hams fat for five genotypes, three sex types and eight different slaughter weights

Variable	First bite		Muscle fibre and overall tenderness			Amount of connective tissue		
	Fresh loin	Gammon ham	Fresh loin	Belly bacon	Gammon ham	Fresh loin	Belly bacon	Gammon ham
Sex type								
Boar	5.8 ^a \pm 0.052	5.8 \pm 0.046	5.8 ^a \pm 0.051	5.6 \pm 0.047	5.7 \pm 0.046	6.2 ^a \pm 0.047	5.7 \pm 0.059	5.9 \pm 0.053
Gilt	5.8 ^a \pm 0.054	5.8 \pm 0.052	5.8 ^a \pm 0.053	5.6 \pm 0.048	5.7 \pm 0.052	6.3 ^a \pm 0.048	5.7 \pm 0.060	5.9 \pm 0.060
Castrate	6.2 ^b \pm 0.051	5.8 \pm 0.051	6.2 ^b \pm 0.050	5.6 \pm 0.048	5.7 \pm 0.051	6.5 ^b \pm 0.046	5.7 \pm 0.060	5.9 \pm 0.059
Genotype								
1	6.1 ^a \pm 0.072	5.9 ^a \pm 0.068	6.0 ^a \pm 0.070	5.6 \pm 0.065	5.8 \pm 0.069	6.4 \pm 0.065	5.6 \pm 0.080	6.0 \pm 0.078
2	5.8 ^b \pm 0.064	5.8 ^a \pm 0.060	5.9 ^b \pm 0.063	5.6 \pm 0.060	5.8 \pm 0.060	6.2 \pm 0.057	5.7 \pm 0.075	6.0 \pm 0.069
3	5.8 ^b \pm 0.068	5.7 ^{ab} \pm 0.073	5.8 ^b \pm 0.066	5.7 \pm 0.064	5.8 \pm 0.074	6.3 \pm 0.061	5.7 \pm 0.079	5.9 \pm 0.084
4	6.1 ^a \pm 0.071	5.9 ^a \pm 0.058	6.0 ^a \pm 0.069	5.6 \pm 0.055	5.7 \pm 0.058	6.4 \pm 0.063	5.6 \pm 0.069	6.0 \pm 0.066
5	6.0 ^a \pm 0.072	5.6 ^b \pm 0.068	6.0 ^a \pm 0.071	5.5 \pm 0.066	5.6 \pm 0.068	6.4 \pm 0.065	5.7 \pm 0.082	5.8 \pm 0.078
Slaughter weight (kg)								
62	6.4 ^f \pm 0.099	-	6.3 ^e \pm 0.096	5.5 \pm 0.094	-	6.4 ^{cd} \pm 0.088	5.7 \pm 0.116	-
78	6.0 ^{de} \pm 0.073	5.8 \pm 0.062	6.0 ^b \pm 0.071	5.5 \pm 0.071	5.8 \pm 0.062	6.5 ^d \pm 0.065	5.6 \pm 0.088	6.2 ^c \pm 0.071
86	6.1 ^e \pm 0.077	5.9 \pm 0.068	6.0 ^b \pm 0.075	5.7 \pm 0.076	5.8 \pm 0.068	6.3 ^{bc} \pm 0.069	5.8 \pm 0.094	6.0 ^b \pm 0.078
102	6.0 ^{de} \pm 0.086	5.8 \pm 0.070	6.0 ^b \pm 0.083	5.6 \pm 0.078	5.7 \pm 0.071	6.5 ^d \pm 0.077	5.7 \pm 0.097	5.9 ^{ab} \pm 0.081
113	5.8 ^{bc} \pm 0.078	5.6 \pm 0.084	5.8 ^a \pm 0.076	5.6 \pm 0.074	5.5 \pm 0.084	6.2 ^{ab} \pm 0.070	5.6 \pm 0.093	5.8 ^{ab} \pm 0.096
128	5.9 ^{cd} \pm 0.080	5.8 \pm 0.065	6.0 ^b \pm 0.078	5.7 \pm 0.070	5.7 \pm 0.066	6.4 ^{cd} \pm 0.072	5.7 \pm 0.087	6.0 ^b \pm 0.075
133	5.6 ^a \pm 0.100	5.8 \pm 0.100	5.8 ^{ab} \pm 0.098	5.7 \pm 0.078	5.7 \pm 0.100	6.2 ^{ab} \pm 0.090	5.7 \pm 0.097	5.7 ^a \pm 0.114
146	5.7 ^{ab} \pm 0.107	5.7 \pm 0.089	5.8 ^{ab} \pm 0.104	5.6 \pm 0.085	5.7 \pm 0.090	6.1 ^a \pm 0.096	5.5 \pm 0.105	5.8 ^{ab} \pm 0.102

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)

Tenderness attributes (Table 7.4) are described by the attributes first bite, muscle fibre and overall tenderness and amount of connective tissue. These factors are judged as being extremely tough/abundant (score 1) to being extremely tender/none (score 8). Fresh loin samples showed highly significant ($P \leq 0.01$) genotype, sex type and slaughter weight differences for first bite as well as muscle fibre and overall tenderness. Differences observed in first bite showed Genotype 2 and 3 to be tougher than the other genotypes (5.8 vs. 6.0). These observed differences were however, reversed for muscle fibre and overall tenderness with Genotype 2 and 3 judged to be more tender than the other genotypes (6.0 vs. 5.8 and 5.9). No significant genotypic difference ($P > 0.05$) (Table 7.4) were observed for amount of connective tissue. In contrast, Channon *et al.* (2004) reported no genotypic differences for hardness, chewiness and cohesiveness of pork. Gilts were further judged to be more tender than boars and castrates in terms of first bite (6.2 vs. 5.8), muscle fibre and overall tenderness (6.2 vs. 5.8) as well as amount of connective tissue (6.5 vs. 6.2 and 6.3), these results confirm that of Channon *et al.* (2004).

Blanchard *et al.* (1999) found no differences in eating quality between boars and gilts up to a live weight of 90kg while Ellis *et al.* (1996) found no differences in eating quality between that of gilts and castrates up to a live weight of 120kg. The differences observed in this study could possibly be attributed to the increased slaughter weight. Slaughter weight differences (Table 7.4) observed showed an increase in toughness with increased slaughter weight with first bite being scored as being fairly tender in the first four groups and slightly tender in the remaining groups. These differences were also observed in muscle fibre and overall tenderness showing a decrease in tenderness with increased slaughter weight. However, the significant slaughter weight difference ($P \leq 0.05$) observed for amount of connective tissue was not consistent with increased slaughter weight.

These differences in tenderness attributes observed for fresh pork were not totally mirrored in instron® measurements where no significant ($P > 0.05$)

genotype or slaughter weight differences were observed but significant ($P \leq 0.05$) sex type differences showed gilts to be more tender than boars and castrates (Chapter 4).

Once the pork was processed, slaughter weight and sex type differences disappeared in terms of the attribute first bite. However, a highly significant genotypic difference ($P \leq 0.01$) for first bite were observed for gammon hams with Genotype 3 and 5 being judged as being tougher than the other genotypes. This difference observed for Genotype 3 is also reflected in the fresh sample while difference observed for Genotype 2 in the fresh sample disappeared after processing and Genotype 5 apparently became tougher during processing than the other genotypes, which could be attributed to the increased drip loss reported for this genotype (Chapter 4). Amount of connective tissue showed no significant ($P > 0.05$) differences for sex type or genotype in any of the processed products. Observed slaughter weight differences ($P \leq 0.01$) for this attribute were restricted to gammon ham samples. These differences were however, inconsistent and did not show any trend with changes in slaughter weight. Muscle fibre and overall tenderness showed no significant ($P > 0.05$) sex type, genotype or slaughter weight difference in the processed samples.

Conclusion

In conclusion it can be said that sex type only influenced flavour and aroma attributes and specifically off aroma intensity of cooked pork fat and off flavour intensity of fresh loin and belly samples as well as aroma intensity of fresh loin samples. Boars were less desirable in all instances. Genotypic differences observed for flavour and aroma were small and probably not of practical importance. Sex type and genotypic differences observed for juiciness attributes were restricted to belly bacon with boars and Genotype 5 being less juicy than the other sex types and genotypes.

Tenderness attributes showed castrates to be more tender than other sex types and Genotypes 2 and 3 tending to be less tender than other genotypes. Tenderness also showed a decrease with increased slaughter weight. These differences generally fell within one or two categories showing differences to be small and probably not detectable by the average consumer.

Slaughter weight differences for flavour and aroma attributes as well as juiciness attributes did not appear to change in relation to slaughter weight except for sustained impression of juiciness where an increase with increased slaughter weight was observed. Overall observed differences were small and would probably not be detectable by the average consumer.

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Chapter 8

The prevalence of boar taint in relation to slaughter weight, sex type and South African genotype

Abstract

Results on three trials are presented. The first trial was run with castrates and gilts. 192 animals were used and animals were grown to slaughter weights ranging between 90 and 120kg live weight. Although unacceptable levels of androstenone were not expected, an increased incidence of skatole could have been prevalent. However, levels of skatole were low for all slaughter groups and could probably be attributed to the management practices used including slatted floors (25% slats), *ad libitum* fresh water and diets fed and formulated in accordance with heavy pig production standards. The second trial consisted of 189 animals of which 64 were boars representing five commercial South African genotypes. These animals were slaughtered at weights ranging between 62 and 146kg live weight. No differences were observed in average level of androstenone for genotype or slaughter weight while unacceptable levels of Androstenone were detected in seven samples of which five were above 100 kg carcass weight. Skatole showed an increase with increased slaughter weight, this increase becoming more prominent in the last two slaughter groups (133 en 146kg), indicating that a cut-off point is probably reached at 130kg live weight. The third trial was conducted on farm. Boars were selected to produce carcasses of approximately 80kg at ages of 128, 140 and 158 days. Levels of androstenone were too low in the first two age groups for detection using HPLC while levels observed in the 158 days group showed measurable but below minimum acceptable levels of androstenone. It is concluded that given the modern genotypes, fast growth rate, proper nutrition and modern production systems utilising slatted floors, boar taint should not be a problem in South Africa in carcasses of up to 100kg.

Key words

Pork, sex type, slaughter weight, androstenone, skatole, boar taint, genotype

Introduction

Boar taint refers to the presence of urine and faeces like off-odours and off-flavours found mostly, but not exclusively, in meat from entire males. Boar taint is caused mainly by α -androstenone and 3-methylindole (skatole) (Jeremiah, Squires, & Sather, 1999).

Androstenone acts as a pheromone and is released from the salivary gland (Booth & Signoret, 1992) after synthesis in the boar testes (Brooks & Pearson, 1989). Androstenone causes urine like off odour, is hydrophobic and therefore accumulates in adipose tissue (Bonneau, 1982). Levels of androstenone in fat from entire males range between 0 and 5 ppm and depend amongst others, on pig weight (Bonneau, 1982), stage of sexual maturity and genotype (Jonsson, 1985). Zamaratskaia, Babol, Andersson, Andersson & Lundström (2005a), however, reported that intact males slaughtered between 90 and 115kg did not differ in terms of androstenone levels in fat.

Sinclair & Squires (2005) reported that levels of the sulfoconjugated form of androstenone present in peripheral plasma influences the accumulation of androstenone in fat. The level of the sulfoconjugated form of androstenone is governed by an enzyme, hydroxysteroid sulfotransferase. Animals with a decreased ability to sulfoconjugate 5α -androstenone will have increased circulating unconjugated 5α -androstenone available for accumulation in fat, potentially leading to the development of boar taint.

Androst-16-ene steroids are not generally affected by the environment and the control thereof has therefore not been very successful. Methods of control

include immunization (Brooks, Pearson, Hogberg, Pestka & Gray, 1986; Hazas, Horn, Feher & Sandor, 1993; Turkstra *et al.*, 2002) inhibition of synthesis, blocking of metabolic pathways (Squires, 1989) and genetic selection (Jonsson, 1985; Sellier, Bonneau & Gruand, 1993).

Skatole is a product of bacterial degradation of tryptophan in the hind gut (Claus, Lösel, Lacorn, Mentschel & Schenkel, 2003). This tryptophan is, at least partially, produced by apoptosis of colon crypt cells (Claus *et al.*, 2003). The skatole is absorbed from the gut, metabolised in the liver, partially excreted with the urine and partially deposited in fatty tissue (Agergaard & Laue, 1993). It produces a faecal-like odour and a bitter taste (Hansson, Lundström, Fjelkner Modig & Persson, 1980). Although similar skatole concentration in the gut and faeces of males and females have been reported (Agergaard & Jensen, 1993), skatole levels in back fat were reported to be positively correlated with testosterone levels given certain dietary conditions (Zamaratskaia *et al.*, 2005a) as well as with free oestrone levels (Zamaratskaia, Madej, Babol, Squires & Lundström, 2005b).

Cytochrome P450 2A6 (CYP2A6) has further been shown to be a key enzyme in the liver metabolism of skatole with the activity of CYP2A6 negatively correlated to accumulated skatole levels in fat. A single base deletion in CYP2A6 results in a frame shift in the coding region resulting in a non-functional enzyme and thus increased skatole levels in fat (Lin, Lou & Squires, 2004).

Skatole levels can be reduced by slaughtering at a lower weight (Zamaratskaia *et al.*, 2005a,b), supplementation with linseed (Matthews, Homer, Thies & Calder, 2000; Kouba, Enser, Whittington, Nute, & Wood, 2003) as well as supplementation with raw potato starch (Zamaratskaia *et al.*, 2005a). The decrease in skatole levels with the use of raw potato starch was shown to be dose dependant (Lösel & Claus, 2005). It is further hypothesised that the raw

potato starch leads to increased butyrate formation in the colon, thereby contributing to reduced epithelial cell apoptosis, thus leading to reduced skatole formation and absorption (Claus *et al.*, 2003).

As skatole levels in fat are strongly related to the environment it can be reduced through wet feeding, *ad libitum* access to water, cleanliness and ventilation, low fibre diet, addition of feed additives like bicarbonate, antibiotics (Lundström *et al.*, 1988; Kjeldsen, 1993; Hansen, Larsen, Jensen, Hansen-Møller & Barton-Gade, 1993; Claus, Weiler & Herzog, 1994) and fructo-oligosaccharide (Xu, Hu & Wang, 2002).

Other compounds which can also have an effect on boar taint but which are considered of less importance are 5α -androst-16-en-3 α -ol (androstenol) (Brennan, Shand, Fenton, Nichols & Aherne, 1986; Brooks & Pearson, 1989) and another tryptophan derivative, indole (Garcia-Regueiro & Diaz, 1989).

In previous chapters it was reported that increased slaughter weight did not have a detrimental effect on production parameters, carcass characteristics, meat quality characteristics, dressing and deboning yield or processing yields. A slight effect was however, reported in chapter 7 on sensory characteristics. Whether or not the presence of skatole and androstenone were causative factors needed to be determined; this led to the current study.

Materials and methods

Three trials were conducted:

Trial 1:

This trial was done during 1995 and 1996 and served as a pilot study for the trial reported in the thesis.

Gilts and castrates (96 per sex type) of a commercial crossbreed were used in the trial. Animals entered into the trial at an age of 11 weeks and approximately 18kg live weight. Animals were housed in a commercial type grower facility consisting of 12 pens, each equipped with a feeder and two drinking nipples. Floors of pens were 25% slatted while the remainder of the floors were solid concrete. Bedding in the form of pine shavings was supplied on the concrete section until an average live weight of 62kg was reached. Soiled bedding was replaced daily. The experiment was done in two independent phases, starting with the gilts followed by castrates. The trials were run separately in the same facility both starting at more or less the same time of year in order to compensate for seasonal differences. Each phase consisted of twelve slaughter groups of eight pigs each. The twelve groups were randomly allocated to six different slaughter periods. When the average live weight of all the pigs reached 90kg, the first group was slaughtered. Then, with weekly intervals, the remaining five groups were slaughtered. By using this design, a slaughter weight range of ± 90 to ± 120 kg over a period of six weeks was obtained. A commercial grower diet containing 18% crude protein (CP), 1.1% lysine and 14 MJ/kg digestible energy was used for all the groups. This diet was supplied until an average live weight of respectively 60kg for the castrates and 90kg for the gilts was reached. Thereafter a diet containing 16% crude protein, 0.9% lysine and 13.5 MJ/kg digestible energy was used until slaughter. This feeding regime is in accordance with European heavy pig production systems (Whittemore, 1993; Ellis & Avery, 1994). The diets were balanced according to the ideal protein concept as described by Kemm, Siebrits & Barnes (1990).

Data was analysed using Genstat 5 release 4.2 (2000). All requirements concerning homogeneity and normality were met. ANOVA analysis was done for all parameters measured. All analyses showing significant sex X treatment interaction were further analysed using the Bonferonni pairwise comparison.

Trial 2:

The experiment was conducted at the Agricultural Research Council – Animal Nutrition and Animal Products Institute at Irene (Gauteng Province) and RTV abattoir in Benoni (Gauteng Province) during 2003. The experimental outlay, housing and growth performance of the pigs have been described in detail in Chapter 2, carcass characteristics in Chapter 3, and meat quality parameters and sampling methodology in Chapter 4. After the VIA measurements were completed, a subcutaneous fat sample measuring 20x20 mm was cut from all the boar samples, vacuum packed and frozen at -20°C until analysis.

Data obtained in this trial were subjected to analysis of variance for unbalanced design using GenStat (GenStat 5 release 4.2, 2000), testing for slaughter group effects alternating with genotype and sextype effects, as well as the interaction of slaughter weight by genotype and sextype. All requirements concerning homogeneity of treatment variances and normality were met. The trial was designed in such a manner as to have three sex types and five genotypes per slaughter group. Since each repetition was represented by a pen, and floor space had to be similar to that of commercial production systems the pens were filled to capacity by randomly allocating pigs of different genotypes within sextype to pens. This resulted in the trial being unbalanced for genotype. Further mortalities and removals resulted in the trial becoming unbalanced. Mortalities (3) were due to pneumonia and one to Hemorrhagic Enteritis while two animals were removed from the trial because of leg problems. A result was considered as highly significant at $P \leq 0.01$ and significant at $P \leq 0.05$. Percentage variance accounted for was calculated as the percentage ratio of the sum of squares of the individual parameter and the total.

Trial 3:

This trial was conducted in 2005. For the purpose of boar taint analysis a group of 60 boars were selected and grown on the farm Blouwbank of Mr. Kosie Snyman. Boars were selected according to growth rate in such a manner as to have a fast growing group, a medium growing group and a slow growing group.

The boars were slaughtered in three groups over a period of four weeks. On the day of slaughter a 400 mm² subcutaneous fat sample was taken on the midline next to the classification site (Chapter 3). These samples were individually packed in plastic bags, sealed and subsequently frozen at -20°C until analysis.

Data obtained in this trial were subjected to analysis of variance for unbalanced design using GenStat (GenStat 5 release 4.2, 2000), testing for slaughter group. All requirements concerning homogeneity of treatment variances and normality were met. Rates of change in parameters measured were determined using linear regression ($Y = a + bx$) with age at slaughter as independent variable (x) and the slope (b) representing rate of change. A result was considered as highly significant at $P \leq 0.01$ and significant at $P \leq 0.05$. Percentage variance accounted for were calculated as the percentage ratio of the sum of squares of the individual parameter and the total.

Chemical analysis of androstenone and skatole

Samples from all three trials were analysed for androstenone and skatole concentrations using High Performance reversed-phase Liquid Chromatography (HPLC) (Hansen-Møller, 1994).

Boar taint components were extracted from the test portion by homogenising with 95% isopropyl alcohol using an Ultraturrax homogeniser capable of rotating at a minimum rate of 13500 rpm. The homogenised samples were then chilled, chilling and then centrifuging to separate the extract from the fat. The solution was then treated with a derivative and injected into the high performance liquid chromatograph. Data were processed on a data station, and the various components identified. Reagents used were HPLC grade and included:

- Isopropanol: $(\text{CH}_3)_2\text{CHOH}$, solution in water, approximately 95%.

- Dansylhydrazine: $C_{12}H_{15}N_3O_2S$, derivative medium, add 1 ml 95% isopropanol to 10 mg dansylhydrazine in a 10 ml glass bottle (McCartney), sealed with a Teflon top, dissolved in hot water bath (70°C), made up new every morning.
- Boron trifluoride in methanol: BF_3 , 14% solution, catalyst.
- De-ionised water (H_2O).
- Tetrahydrofuran (THF): C_4H_8O , HPLC grade.
- Acetonitrile (ACN): C_2H_3N , HPLC grade
- Buffer solutions for the mobile phase for the HPLC:
 - ◆ Buffer A: 80 volumes of H_2O with 20 volumes of THF.
 - ◆ Buffer B: 35 volumes of THF with 25 volumes of ACN and 40 volumes of H_2O .
 - ◆ Buffer C: 10 volumes of H_2O and 90 volumes of THF.

Buffers were made up once weekly.

- ◆ Wash: used buffer A or when the column was standing longer than a day without being used, 80 volumes of H_2O were mixed with 20 volumes of HPLC grade methanol and the column was then washed with this solution.
- Reference standard solutions for the HPLC.
 - ◆ Internal standard (IS):
Stock solution (100 ppm):
5.0 mg 2-methylindole made up to 50 ml using 95% isopropanol.
Working solution:
100 μ l of 100 ppm stock solution made up to 10 ml with 95% isopropanol.
Solutions were made up weekly and stored at 5°C.

- ◆ Standard solution: consisted of 2-methylindole (IS), 3-methylindole or skatole and 5 α -androst-16-en-3-one.

Stock solutions:

100 ppm solution of skatole - 5.0 mg made up to 50 ml with 95% isopropanol.

100 ppm solution of androstenone - 1.0 mg made up to 10 ml with 95% isopropanol.

Working solution:

250 μ l of internal standard stock solution, 500 μ l of skatole stock solution and 2 ml of androstenone stock solution made up to 10 ml with 95% isopropanol.

- The boar taint components were identified from the chromatograph.
- Calculation

$$\% \text{ component in sample} = \frac{\text{peak area}_{(\text{component})}}{\text{peak area}_{(\text{IS})}} \times \frac{\text{RF}_{(\text{component})}}{\text{RF}_{(\text{IS})}} \times \frac{\text{mass}_{(\text{IS})}}{\text{mass}_{(\text{sample})}} \times 100$$

where RF is the response factor and is given by: $\text{RF} = \frac{\text{mass (mg)}}{\text{peak area}}$

Results and discussion

Trial 1:

The effect of slaughter weight on indole, skatole and androstenone levels is shown in Table 8.1. Unacceptable levels of these compounds in pork is >0.2 μ g/g fat skatole and >1.0 μ g/g fat for androstenone (Zamaratskaia *et al.*, 2005a). Although unacceptable levels of androstenone were not expected because of the sex types of the animals used, increased incidence of skatole may have become prevalent. However, levels of skatole were low for all slaughter groups and could probably be attributed to the management practices

used including slatted floors (25% slats), *ad libitum* fresh water and diets formulated and fed in accordance with heavy pig production standards.

Table 8.1 The effect of slaughter weight on indole, skatole and androstenone levels of fat samples (Mean±s.e.)

Treatment	Indole µg/g fat	Skatole µg/g fat	Androstenone µg/g fat
Live weight (kg)			
Gilts			
93.8	0.020±0.006	0.033±0.020	0.148±0.070
97.8	0.020±0.009	0.024±0.026	0.128±0.057
105.4	0.017±0.010	0.038±0.054	0.133±0.065
106.1	0.021±0.012	0.030±0.023	0.174±0.116
113.7	0.018±0.013	0.030±0.039	0.168±0.057
118.2	0.015±0.011	0.015±0.013	0.144±0.053
Castrates			
90.8	0.018±0.011	0.027±0.024	0.135±0.043
99.7	0.014±0.017	0.042±0.046	0.127±0.047
104.7	0.014±0.008	0.024±0.018	0.124±0.057
108.2	0.013±0.010	0.031±0.031	0.126±0.048
112.9	0.013±0.011	0.031±0.027	0.115±0.038
116.7	0.012±0.010	0.032±0.027	0.150±0.121

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)

Trial 2:

Levels and occurrence of taints (Table 8.2) were low and it is not known whether or not this is representative of the industry. Therefore the findings of this report with regards to this subject should not be seen as conclusive.

A total of 61 samples were analysed for androstenone and skatole. A total of seven samples showed levels of androstenone above 1 µg/g of these five were taken from carcasses above 100kg. Three carcasses were found to have levels of skatole in excess of 0.2 µg/g, two of these carcasses were above 100 kg, and all incidences of unacceptable levels of skatole were associated with unacceptable levels of androstenone. The other carcasses showing unacceptable levels of androstenone and skatole were below 70kg. No incidence of unacceptable skatole and androstenone levels were detected between 70kg and 100kg carcass weight.

The results of this study (Table 8.2) indicated increased levels of androstenone at 62 and 78kg live weight (17 – 19 weeks of age), decreased levels at 86 and 102kg slaughter weight (21 – 23 weeks of age) with an increase from 113kg live weight (25 weeks of age) and a substantial increase above 133kg live weight (29 weeks of age), all averages measured were, however well below the threshold level of 1 µg/g (Zamaratskaia *et al.*, 2005a). Skatole levels measured were, in all instances below the threshold level of 0.2 µg/g fat skatole (Zamaratskaia *et al.*, 2005a). At 62kg live weight the measured levels were the same as for all other slaughter weights while the 78 to 128kg groups (19 – 26 weeks of age) showed levels below that of the 133 and 146kg live weight group (29 – 31 weeks of age). This decrease in skatole levels followed by an increase at a later stage was reported by Babol, Zamaratskaia, Juneja & Lundström (2004) although they reported this increase to occur at 26 weeks of age, the difference between the current study and that of Babol *et al.* (2004) could possibly be attributed to differences in environmental and dietary factors. No significant interactions were observed.

With the current average slaughter weight in South Africa at 62kg and showing and increase with a large number of producers slaughtering at 76kg and aiming to increase to 80kg, which should be reached at an age of no more than 24 weeks, skatole is not expected to be a problem as these expected weight

increases, although substantial for the producer, is still below the threshold weight at which unacceptable levels of taints occur.

Table 8.2 Skatole and androstenone levels measured in pig subcutaneous fat of group housed animals of five genotypes and eight slaughter weights (Mean±s.e.)

Variable	Androstenone $\mu\text{g/g}$ fat	Skatole $\mu\text{g/g}$ fat
Genotype		
1	0.538±0.110	0.040±0.018
2	0.617±0.116	0.036±0.019
3	0.447±0.110	0.037±0.018
4	0.651±0.116	0.056±0.019
5	0.647±0.122	0.027±0.020
Slaughter weight (kg)		
62	0.588±0.158	0.052 ^{abc} ±0.023
78	0.509±0.133	0.015 ^a ±0.020
86	0.368±0.176	0.019 ^a ±0.026
102	0.342±0.144	0.025 ^{ab} ±0.021
113	0.616±0.125	0.013 ^a ±0.018
128	0.525±0.125	0.022 ^a ±0.018
133	0.763±0.133	0.078 ^{bc} ±0.020
146	0.806±0.144	0.108 ^c ±0.021

Values in columns within groups with different superscripts differ significantly ($P \leq 0.05$)

Trial 3:

Since the highest levels of androstenone and skatole are expected in the oldest and/or heaviest carcasses, fat samples for the third group were analyzed first. Results obtained for this group were so low that analysis of the first two groups aged between 128 and 150 days indicated that the values obtained were below the noise values of the HPLC. Results obtained for the 150 to 160 days age group (Table 8.3) showed that no sample analyzed contained unacceptable

levels of either skatole (≤ 0.2 ppm) or androstenone (≤ 1.0 ppm) (Zamaratskaia *et al.*, 2005a). This observation is in contrast with that reported in Trial 2 above and also in contrast with the reports of Zamaratskaia *et al.* (2005b) who showed increased levels after 26 weeks of age and can probably be attributed to the small age range investigated in the current study.

Table 8.3 Absolute values of skatole (ppm) and androstenone (ppm) levels obtained from fat of boars sampled between 150 and 160 days of age with an average carcass weight of 83.4kg

Sample number	Skatole (ppm)	Androstenone (ppm)	Warm carcass weight (kg)	Age (days)
Fat 1	0.091	0.613	85.2	152
Fat 2	0.082	0.982	81.2	152
Fat 3	0.078	0.887	79.2	157
Fat 4	0.085	0.448	89.2	158
Fat 5	0.084	0.276	87.2	159
Fat 6	0.012	0.981	82.2	152
Fat 7	0.031	0.854	88.2	153
Fat 8	0.022	0.389	92.2	157
Fat 9	0.069	0.473	87.2	157
Fat 10	0.105	0.376	79.2	152
Fat 11	0.022	0.201	80.4	152
Fat 12	0.011	0.113	80.2	157
Fat 13	0.012	0.114	77.4	152
Fat 14	0.020	0.218	82.4	156
Fat 15	0.028	0.208	89.2	151
Fat 16	0.022	0.287	87.6	153
Fat 17	0.025	0.235	81.0	159
Fat 18	0.021	0.270	78.6	152
Fat 19	0.019	0.294	79.6	158
Fat 20	0.160	0.303	81.8	159
Fat 21	0.016	0.581	82.4	152

Conclusion

It can be concluded from the above that, given the production system, management practices and genotype of the pigs under investigation, carcasses of all sex types slaughtered at an age younger than 29 weeks and at a live weight of between 70 and 100kg should not have skatole or androstenone levels in excess of the acceptable levels (≤ 0.2 ppm and ≤ 1.0 ppm, respectively). It must however be remembered that androstenone is, to a certain extent, dependant on genotype with skatole levels correlated to androstenone and also largely dependant on environmental factors. It is therefore recommended that each production unit should be assessed on its own merits in terms of genotype, production system, management, nutrition and weight for age at slaughter in order to determine its suitability for the production of heavier carcasses (>80kg).

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Chapter 9

Discussion and conclusion

It must be kept in mind that the aim of the study was to determine which parameters measured changed with increased slaughter weight and then to describe the changes in these parameters with increased slaughter weight. Because sex type differences have been documented for these parameters by various authors, the trial was designed to accommodate three sex types i.e. boars, castrates and gilts. Data was subsequently analyzed for interactions of sex types with slaughter weight. As it was impossible to obtain all the animals needed for the trial from one farm, five genotypes were selected. These genotypes were selected with the assistance of the South African Pork Producers Organization in such a way as to represent the majority of genotypes slaughtered in South Africa at the time. The genotypes included two synthetic breeds, a line containing 50% Duroc genes, commercial Landrace X Large white and a line originating from the Robuster, a locally developed breed. Genotypic differences observed were generally absent and when significant ($P \leq 0.05$), differences were small, describing less than 10% of variance. Due to a confidentiality agreement with the suppliers of the pigs, the allocation of genotype numbers cannot be disclosed. A general observation of the trial is that practical farming with animals growing to these heavy live weights is possible and relatively easy given sufficient floor space. Limited fighting was observed and no injuries or mortalities occurred due to fighting during the trial.

With live weight being the main tool available for the primary pig producer with which to select animals for the market, it is essential that the effect of changes in live weight on production parameters be properly understood. Live weight was found to increase linearly ($R^2 > 0.91$) throughout the trial (up to 146kg live

weight). Sex type differences observed showed boars to grow faster than gilts and castrates. Cumulative feed intake over time was described using a second order polynomial ($R^2 > 0.95$), the subsequent differentiation of this gave the rate of change in feed intake which was higher for castrates and gilts than for boars. Feed conversion ratio was described using a linear model ($R^2 > 0.81$) and the rate of increase in feed conversion ratio was found to be the most rapid for castrates followed by gilts and then boars. Absolute feed conversions compared over time showed gilts and boars to be equally efficient until 18 weeks of age and thereafter boars became more efficient. Castrates were less efficient from week 11 onwards. Results obtained on production parameters are generally in accordance with that found by other authors. Furthermore, although the magnitudes of differences reported might be different, the principles remain. These observed differences between studies could probably be attributed to environmental factors i.e. nutrition, housing, management and possibly genotype (Bonneau, 1998; Blanchard, Ellis, Warkup, Chadwick & Willis, 1999a); Channon, Kerr & Walker, 2004). In terms of production parameters, it is concluded that the current South African genotypes are fast growing genotypes with the ability to maintain fast growth until a relatively heavy slaughter weight and that the subsequent slaughter of heavy carcasses obtained from these animals will not have a negative impact on production efficiency given good farming practices.

Carcass characteristics represent the first exposure of the abattoir and processor to the carcass. Heavy carcasses are generally perceived as being fat and having a low percentage of lean and low yields. In this study it was found that dressing percentage increased with 0.4 percentage points for every 10kg increase in slaughter weight. Eye muscle area, subcutaneous fat area and intramuscular fat area as well as fat depth and muscle depth showed increases with increased slaughter weight. The rate at which eye muscle area increased was higher than the rate at which subcutaneous fat area increased, and at the same time the rate at which muscle depth increased was higher than

the rate at which fat depth increased. This, together with the increase in percentage marbling, leads to the conclusion that the net effect of increased slaughter weight is therefore positive in terms of carcass characteristics measured. Carcass measurement showed linear increases with increased slaughter weight and the rate of change for ham circumference was higher than for the other measurements. Since South African processors, at present, do not utilize the ham effectively, it is normally sold as an inferior product in the form of trimmings or minced meat, this is not seen as a real benefit unless a consumer demand could be developed for this high quality cut.

Changes in meat quality characteristics with increased slaughter weight were either inconsistent or positive. Muscle pH_1 and pH_u , although showing significant slaughter weight effects, did not change according to weight change and differences observed could probably be attributed to environmental differences. Drip loss showed a decrease ($R^2=0.63$; $P=0.021$) and water binding capacity an increase ($R^2=0.56$; $P=0.019$) with increased slaughter weight. Colour CIELab measurements showed significant slaughter weight differences. L^* values did not change with slaughter weight, the difference observed showed the first group of animals to be slaughtered to have higher L^* values than the other groups. CIELab a^* and b^* values showed increased red and yellow hues and subsequently darker meat at slaughter with increasing slaughter weights.

Carcass yields, in absolute and percentage terms, showed differences for all parameters measured. As expected, observed differences showed absolute yields to increase with increased slaughter weights. Percentage yields of commercial cuts showed a shift in carcass weight with the percentage yield of the head, neck, belly and fillet increasing while the percentage yield of the shoulder, leg and loin decreased, this was however poorly described with a $R^2 \leq 0.30$ indicating that it should have little or no effect for processing plants in

practical terms. Results obtained in this section could not be compared reliably with that reported in the literature as cutting techniques differed.

The yield of processable lean meat showed significant increases as slaughter weight increased, percentage yields however remained relatively constant as slaughter weight increased, indicating that the gain in the different tissues comprising the cut remained relatively constant. Processing yields of the bacons showed constant decreases in brine uptake as the commercial bacon cuts got heavier. As brining took place in a brining vat and not with an injector, the ability of the cut to absorb brine would be related to the ratio of the surface area relative to the weight ($W^{0.66}$). The proportional surface available for brine uptake decreases as cut weight increases, thus brine uptake in larger cuts would be compromised should immersion rather than injection be used. Fresh to smoke losses decreased with increased slaughter weight. Overall, increased slaughter weight had a positive effect on processing yields. This could probably be attributed to the increased water binding capacity and decreased drip loss observed and discussed earlier.

Sensory attributes were evaluated using a 10 member trained panel. Three processed and one fresh sample were evaluated. Slaughter weight differences observed were often inconsistent, not changing with slaughter weight (off flavor intensity, cooked pork fat aroma intensity, off aroma intensity). Parameters that did change with slaughter weight included overall flavor intensity (decreased), juiciness (increased) and tenderness (decreased). These observed differences were however, small and of little practical value. Factors associated with sex type showed boars to have a higher incidence of off flavors.

In total it can be concluded that considering all parameters measured it would be to the benefit of the producer, abattoir, processor and ultimately the consumer if pigs were slaughtered at weights of up to 146kg live weight. A

warning sign however appears with the higher incidence of off flavors in heavy boar carcasses leading to a conclusion that even though all factors measured and calculated in this study indicate that it is possible and advisable to produce heavy carcasses, and preferably intact males, it must be borne in mind that boar taint, as a complex factor, should not be forgotten. Not all producers have management practices, feeding systems, nutrition, housing etc. that would allow them to produce heavy carcasses, and especially heavy boar carcasses. It is therefore recommended that, before an abattoir or processor decides to allow a specific producer to supply heavy carcasses, especially intact males, the total production system on farm should be evaluated in order to assess the risks involved.

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Chapter 10

Final conclusions and recommendations

In terms of production parameters the current research showed that, given the characteristics of the fast growing South African genotypes, growth is maintained until a relatively heavy slaughter weight and that the subsequent slaughter of heavy carcasses obtained from these animals will not have a negative impact on production efficiency given good farming practices. A number of practical issues must however be kept in mind. This increased slaughter weight will increase the standing time of animals on farm which in return will necessitate additional grower space which entails capital expenditure. The viability of such a venture should be investigated for individual production units. Another aspect of utmost importance is the nutrition of animals within these production systems. A very important factor is the reduced feed efficiency and proper diets should be formulated and fed during the final stage of production in order to minimize deposition of back fat and the occurrence of taints.

If good farming procedures and optimal nutrition is practiced, it can be accepted that carcasses of heavy pigs will be of good quality and that the slaughter of these carcasses will be of benefit to the abattoir due to the increased dressing percentage (less offal and waste per kilogram meat slaughtered) realized. Furthermore, the rate of increase in eye muscle area and depth was higher than the rate of change in subcutaneous fat area and depth, implying a net positive effect with heavier carcasses. Factors associated with increased slaughter weight that impact on the abattoir is the increase in carcass length. This has implications not only during the transport of intact carcasses but also during the hanging and moving of carcasses on the slaughter line. Most South African

refrigerated trucks have been designed in such a manner as to load smaller carcasses; the heads of the heavier (longer) carcasses tend to touch the truck floors thereby becoming a potential health hazard. The sale and transport of carcasses with heads removed should be considered. Furthermore the total weight of meat per volume of cooler room will be increased and therefore it is essential that abattoirs ensure that rate of cooling of carcasses is sufficient in order to maintain meat quality and safety.

Increased slaughter weight had a net positive effect on meat quality characteristics with a decrease in drip loss, increase in water binding capacity and enhanced color characteristics. These effects are to the benefit of the processors and are seen in decreased fresh to smoke losses for processed products. It must however be kept in mind that the volume of a cut increases at a different rate to the surface area of the cut. Brining by means of immersion is probably not suitable for larger cuts and injection should be used for cuts obtained from heavier carcasses.

A rather contentious issue of heavier carcasses and especially heavy boar carcasses is the possibility of the occurrence of taints. Although the current report shows very little danger in this regard this issue must by no means be underestimated. It is recommended that a survey be done that will include all production systems, abattoirs and genotypes in order to determine the effect of these on the occurrence and level of boar taint. Alternatively management procedures on farm must aim at minimizing the danger of the occurrence of taints. Castration is widely used but a welfare cry has started which could soon lead to the banning of this procedure. Alternatives to castration for decreasing androstenone levels include immunization. Recent results have shown that this is a cost effective, safe alternative to castration while maintaining growth characteristics of intact males. Skatole levels can be decreased through diet manipulation and management of environmental factors.

Overall it can be said that increasing slaughter weight could be of benefit to all involved in the pork production chain and ultimately to the consumer.

Further research required:

1. *Model development* – a computer model based on the data generated from the current study should be developed. This model should have the capacity for refinement with on farm production data enabling the producer to determine optimum slaughter weight. This model should further act as a decision support system to the processor enabling him to decide on the most appropriate use of a carcass with certain characteristics.
2. *Review of the classification system* - A review of the current classification system is proposed. This should be done in order to guarantee accurate classification and fair remuneration of carcasses produced. A movement away from the current classes toward a linear system could prove to be more accurate and fair.
3. *Weight limit for classification* – The weight limit for classification has, due to the current research, been increased from 90 to 100kg, this limit should however, be increased further. Since the data was collected in the current trial only validation would be necessary in order to facilitate this.
4. *Product development* – Heavier carcasses pose opportunities for development of exciting value added products more in line with the current South African consumer profile. This could lead to increased per capita consumption of pork and a subsequent growth in the industry.
5. *Boar taint* – Research is needed in order to determine the true extent and occurrence of boar taint in South Africa. Pro-active research also needs to be done in terms of management tools available for controlling and minimizing boar taint. These should include the identification of tainted carcass on the slaughter line as well as alternatives to castration.

Chapter 11

ADDENDUM A

This addendum contains data that were gathered and statistically analysed but does not fall within the scope of the thesis and will therefore be published in an appropriate journal.

The data contained herein represent absolute and percentage deboning yields of commercial cuts.

ADDENDUM A

Table 11.1 Absolute commercial deboning yields of heads obtained from carcasses of group housed animals for three sex types, five genotypes and eight slaughter weights

Variable	Whole cut (kg)	Tongues (kg)	Cheeks (kg)	Ears (kg)	Skull (kg)
	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.
Sex type					
Boar	7.42±0.234	0.461±0.018	2.237±0.096	0.441±0.016	4.276±0.131
Gilt	6.94±0.226	0.455±0.017	2.156±0.093	0.131±0.016	3.879±0.127
Castrate	7.09±0.215	0.459±0.016	2.262±0.088	0.446±0.015	3.922±0.121
Genotype					
1	6.79±0.283	0.435±0.022	2.189±0.116	0.425±0.020	3.737±0.159
2	7.38±0.288	0.477±0.022	2.316±0.118	0.438±0.020	4.146±0.161
3	7.51±0.312	0.460±0.024	2.216±0.128	0.485±0.022	4.341±0.175
4	7.32±0.284	0.476±0.022	2.323±0.117	0.420±0.020	4.101±0.159
5	6.75±0.287	0.444±0.022	2.051±0.118	0.435±0.020	3.796±0.161
Slaughter weight (kg)					
62	4.62a±0.141	0.395 ^a ±0.019	1.342 ^a ±0.083	0.340 ^a ±0.017	2.545 ^a ±0.086
78	5.42b±0.141	0.307 ^b ±0.019	1.560 ^a ±0.083	0.311 ^a ±0.017	3.238 ^b ±0.086
86	6.32c±0.143	0.401 ^a ±0.019	2.205 ^b ±0.084	0.430 ^b ±0.017	3.246 ^b ±0.087
102	6.55c±0.141	0.408 ^{ab} ±0.019	1.952 ^c ±0.083	0.511 ^c ±0.017	3.673 ^c ±0.086
113	7.29d±0.137	0.455 ^b ±0.019	2.035 ^{bc} ±0.080	0.353 ^a ±0.016	4.443 ^d ±0.084
128	8.48d±0.13	0.533 ^c ±0.017	2.562 ^d ±0.076	0.563 ^d ±0.015	4.830 ^e ±0.079
133	9.14e±0.142	0.561 ^c ±0.019	3.162 ^e ±0.073	0.452 ^b ±0.017	4.958 ^e ±0.086
146	9.44e±174	0.626 ^d ±0.023	3.045 ^e ±0.102	0.533 ^{cd} ±0.021	5.229 ^f ±0.106
Means within columns with different superscripts differ significantly (P≤0.05)					

ADDENDUM A

Table 11.2 Absolute commercial deboning yields of necks obtained from carcasses of group housed animals for three sex types, five genotypes and eight slaughter weights

Variable	Whole cut (kg)	Bones (kg)	Rind (kg)	Fat (g)	Processable lean meat (kg)	Trimming (kg)
	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.
Sex type						
Boar	4.53±0.214	0.781±0.030	0.310±0.016	445.5 ^a ±39.6	1.982 ± 0.093	1.141 ±0.051
Gilt	4.24±0.206	0.693±0.029	0.258±0.016	491.2 ^{ab} ±38.4	1.841 ±0.090	0.967 ±0.049
Castrate	4.51±0.197	0.737±0.028	0.265±0.015	586.5 ^b ±36.5	1.899 ±0.086	1.070 ±0.047
Genotype						
1	4.14±0.256	0.702±0.036	0.257±0.019	529.1±48.0	1.789 ±0.112	1.145 ±0.062
2	4.5±0.268	0.785±0.037	0.272±0.020	520.1±49.5	1.867 ±0.114	1.179 ±0.063
3	4.76±0.285	0.747±0.040	0.295±0.021	562.9±52.6	2.174 ±0.124	0.998 ±0.068
4	4.66±0.26	0.696±0.036	0.275±0.020	530.6±47.4	1.974 ±0.113	1.048 ±0.062
5	4.15±0.26	0.754±0.037	0.287±0.020	422.0±49.0	1.752 ±0.114	1.014 ±0.063
Slaughter weight (kg)						
62	2.63 ^a ±0.135	0.536 ^a ±0.036	0.190 ^a ±0.019	253.9 ^a ±44.7	1.029 ^a ±0.059	0.551 ^a ±0.060
78	3.18 ^b ±0.135	0.461 ^a ±0.036	0.288 ^b ±0.019	240.8 ^a ±43.8	1.307 ^b ±0.059	0.772 ^b ±0.060
86	3.20 ^b ±0.138	0.703 ^b ±0.037	0.217 ^a ±0.020	297.9 ^a ±42.4	1.372 ^b ±0.060	0.953 ^c ±0.061
102	3.74 ^c ±0.135	0.731 ^b ±0.036	0.413 ^c ±0.019	416.9 ^b ±41.6	1.580 ^c 0.059	1.293 ^d ±0.060
113	4.31 ^d ±0.132	0.849 ^c ±0.035	0.227 ^a ±0.019	613.2 ^c ±39.5	1.982 ± 0.093	1.141 ±0.051
128	5.92 ^e ±0.139	0.862 ^c ±0.033	0.366 ^c ±0.018	557.6 ^c ±37.2	1.841 ±0.090	0.967 ±0.049
133	5.99 ^e ±0.136	0.860 ^c ±0.036	0.198 ^a ±0.019	821.2 ^d ±40.7	1.899 ±0.086	1.070 ±0.047
146	6.94 ^f ±0.168	0.859 ^c ±0.045	0.299 ^b ±0.024	868.1 ^d ±50.0	2.951 ^g ±0.073	1.138 ^{cd} ±0.074

Means within columns with different superscripts differ significantly (P<0.05)

ADDENDUM A

Table 11.3 Absolute commercial deboning yields of shoulders obtained from carcasses of group housed animals for three sex types, five genotypes and eight slaughter weights

Variable	Whole cut (kg)	Trotters (kg)	Shank (kg)	Bones (kg)	Fat(kg)	Rind (kg)	Trimming(kg)	Processable lean meat (kg)
	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.
Sex type								
Boar	6.27±0.204	0.369 ^a ±0.010	0.863±0.028	0.748±0.025	479.2 ^a ±53.7	0.576 ^a ±0.016	243.0±20.3	2.826±0.092
Gilt	5.83±0.197	0.321 ^b ±0.010	0.813±0.027	0.650±0.024	495.4 ^a ±51.5	0.499 ^b ±0.015	246.4±21.2	2.670±0.089
Castrate	6.03±0.188	0.328 ^b ±0.010	0.806±0.026	0.676±0.023	684.4 ^b ±48.8	0.520 ^b ±0.014	206.6±19.4	2.693±0.085
Genotype								
1	5.71±0.247	0.315 ^a ±0.013	0.791±0.034	0.608 ^a ±0.030	553.3±62.4	0.512±0.019	217.0±26.1	2.560±0.111
2	6.27±0.251	0.355 ^b ±0.013	0.866±0.034	0.721 ^{bd} ±0.031	577.0±63.3	0.547±0.019	230.2±26.8	2.764±0.113
3	6.4±0.272	0.365 ^b ±0.014	0.861±0.037	0.767 ^{cd} ±0.033	611.6±71.9	0.544±0.021	258.8±27.1	2.867±0.122
4	6.26±0.247	0.330 ^{ab} ±0.013	0.839±0.034	0.692 ^{acd} ±0.030	613.9±64.2	0.526±0.019	224.7±25.8	2.813±0.111
5	5.58±0.250	0.330 ^{ab} ±0.013	0.777±0.034	0.670 ^{ab} ±0.031	436.9±70.3	0.524±0.019	224.3±25.0	2.644±0.113
Slaughter weight (kg)								
62	3.52 ^a ±0.143	0.220 ^a ±0.009	0.532 ^a ±0.021	0.438 ^a ±0.020	213.8 ^a ±55.9	0.334 ^a ±0.019	110.2 ^a ±33.6	1.697 ^a ±0.070
78	4.68 ^b ±0.144	0.269 ^b ±0.009	0.661 ^b ±0.021	0.512 ^b ±0.020	314.8 ^{ab} ±56.0	0.487 ^b ±0.019	179.0 ^{ab} ±35.0	2.144 ^b ±0.070
86	5.17 ^c ±0.146	0.298 ^c ±0.009	0.644 ^b ±0.022	0.593 ^c ±0.021	341.6 ^{ab} ±60.3	0.565 ^c ±0.019	212.7 ^b ±33.4	2.347 ^c ±0.071
102	6.11 ^d ±0.145	0.322 ^c ±0.009	0.795 ^c ±0.021	0.686 ^d ±0.020	382.3 ^b ±54.5	0.508 ^b ±0.019	266.2 ^b ±32.0	2.556 ^d ±0.070
113	6.67 ^e ±0.140	0.374 ^d ±0.009	1.054 ^d ±0.021	0.651 ^d ±0.020	567.7 ^c ±53.0	0.538 ^{bc} ±0.018	246.1 ^b ±30.8	2.870 ^e ±0.068
128	7.11 ^f ±0.132	0.395 ^d ±0.008	0.991 ^e ±0.020	0.840 ^e ±0.019	580.8 ^c ±49.7	0.632 ^d ±0.017	272.1 ^b ±27.8	3.279 ^f ±0.064
133	7.11 ^f ±0.144	0.391 ^d ±0.009	0.934 ^e ±0.021	0.838 ^e ±0.020	940.6 ^d ±52.7	0.564 ^c ±0.019	218.5 ^b ±30.6	3.359 ^g ±0.070
146	7.99 ^g ±0.177	0.445 ^e ±0.011	0.984 ^e ±0.026	0.976 ^f ±0.025	1216.3 ^e ±66.0	0.599 ^{cd} ±0.023	274.7 ^b ±37.0	3.543 ^g ±0.086

Means within columns with different superscripts differ significantly (P<0.05)

ADDENDUM A

Table 11.4 Absolute commercial deboning yields of legs obtained from carcasses of group housed animals for three sex types, five genotypes and eight slaughter weights

Variable	Whole cut (kg)	Trotters (kg)	Shank (kg)	Bones (kg)	Rind (kg)	Trimblings (kg)	Lean meat for processing (kg)	Topside (kg)	Silverside (kg)	Rump (kg)	Fat (kg)
	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.
Sex type											
Boar	11.97±0.45	0.677 ^a ±0.020	1.361±0.047	1.061±0.035	0.913±0.031	0.821±0.077	6.415±0.228	1.462±0.056	1.622±0.062	2.025±0.062	823 ^a ±122
Gilt	11.55±0.434	0.600 ^b ±0.019	1.277±0.045	0.964±0.034	0.883±0.030	0.716±0.074	6.152±0.220	1.411±0.054	1.586±0.060	1.931±0.059	1112 ^{ab} ±115
Castrate	11.93±0.414	0.615 ^b ±0.018	1.293±0.043	1.008±0.032	0.897±0.028	0.776±0.071	6.171±0.210	1.358±0.052	1.558±0.057	1.884±0.057	1262 ^b ±106
Genotype											
1	11.47±0.544	0.581 ^a ±0.024	1.286±0.056	0.934±0.042	0.903±0.037	0.755±0.092	6.052±0.276	1.377±0.068	1.582±0.075	1.867±0.074	1173±141
2	11.74±0.553	0.645 ^{ab} ±0.024	1.331±0.057	1.035±0.043	0.891±0.038	0.702±0.094	5.994±0.280	1.377±0.059	1.437±0.076	1.917±0.076	1132±142
3	12.68±0.6	0.713 ^b ±0.027	1.361±0.062	1.100±0.047	0.964±0.041	0.854±0.103	6.745±0.304	1.514±0.075	1.688±0.083	2.036±0.082	925±154
4	12.15±0.545	0.617 ^a ±0.024	1.319±0.056	1.030±0.042	0.916±0.037	0.729±0.094	6.511±0.276	1.473±0.068	1.705±0.075	2.018±0.075	1169±144
5	11.14±0.551	0.600 ^a ±0.024	1.250±0.057	0.961±0.043	0.813±0.037	0.823±0.095	5.945±0.279	1.313±0.069	1.528±0.076	1.884±0.075	1022±153
Slaughter weight (kg)											
62	6.76 ^a ±0.229	0.415 ^a ±0.018	0.828 ^a ±0.039	0.642 ^a ±0.028	0.610 ^a ±0.030	0.247 ^a ±0.100	3.688 ^a ±0.150	0.912 ^a ±0.055	0.969 ^a ±0.047	1.418 ^a ±0.064	335 ^a ±138
78	8.61 ^b ±0.23	0.495 ^b ±0.018	1.031 ^b ±0.039	0.778 ^b ±0.028	0.787 ^b ±0.030	0.279 ^a ±0.101	4.773 ^b ±0.150	1.140 ^b ±0.055	1.149 ^b ±0.047	1.423 ^a ±0.064	480 ^a ±139
86	9.44 ^c ±0.234	0.544 ^b ±0.019	1.110 ^b ±0.040	0.829 ^b ±0.028	0.845 ^b ±0.030	0.621 ^b ±0.102	5.037 ^b ±0.152	1.140 ^b ±0.056	1.211 ^b ±0.048	1.692 ^c ±0.065	410 ^a ±134
102	11.56 ^d ±0.23	0.609 ^c ±0.018	1.265 ^c ±0.039	1.052 ^c ±0.028	0.959 ^c ±0.030	1.177 ^c ±0.101	6.039 ^c ±0.150	1.209 ^b ±0.056	1.504 ^c ±0.047	2.058 ^c ±0.064	764 ^{ab} ±202
113	12.22 ^e ±0.224	0.693 ^d ±0.018	1.304 ^c ±0.038	0.981 ^c ±0.027	0.716 ^b ±0.030	1.110 ^c ±0.099	6.439 ^c ±0.146	1.486 ^c ±0.054	1.762 ^c ±0.046	2.161 ^{cd} ±0.063	674 ^{ab} ±128
128	14.57 ^f ±0.211	0.739 ^d ±0.017	1.583 ^d ±0.036	1.239 ^d ±0.025	1.131 ^d ±0.028	0.943 ^{cd} ±0.092	7.719 ^d ±0.138	1.699 ^d ±0.051	2.029 ^d ±0.043	2.301 ^d ±0.059	1199 ^b ±121
133	15.01 ^f ±0.231	0.736 ^d ±0.018	1.590 ^d ±0.040	1.228 ^d ±0.028	0.988 ^c ±0.030	0.732 ^{bd} ±0.112	7.807 ^d ±0.150	1.790 ^d ±0.056	1.973 ^d ±0.047	2.184 ^{cd} ±0.064	2142 ^c ±140
146	16.58 ^g ±0.283	0.802 ^e ±0.022	1.767 ^e ±0.048	1.315 ^d ±0.034	1.132 ^d ±0.037	1.068 ^c ±0.124	8.396 ^e ±0.184	1.850 ^d ±0.068	2.068 ^d ±0.058	2.294 ^d ±0.079	2300 ^c ±172

Means within columns with different superscripts differ significantly ($P \leq 0.05$)

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Table 11.5 Absolute commercial deboning yields of belly obtained from carcasses of group housed animals for three sex types, five genotypes and eight slaughter weights

Variable	Whole cut (kg)	Sparerib (kg)	Rind (kg)	Trimming (kg)	Processable lean meat (kg)
	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.
Sex type					
Boar	7.53±0.35	1.193±0.047	1.099±0.038	2.760±0.157	2.082±0.119
Gilt	7.51±0.337	1.124±0.045	1.147±0.037	2.776±0.152	2.030±0.115
Castrate	7.72±0.321	1.167±0.044	1.137±0.035	2.783±0.145	2.279±0.110
Genotype					
1	7.30±0.422	1.081±0.057	1.063±0.047	2.573±0.190	2.075±0.144
2	7.98±0.429	1.221±0.058	1.194±0.047	2.745±0.193	2.226±0.147
3	8.03±0.466	1.249±0.063	1.179±0.051	3.022±0.210	2.275±0.159
4	7.82±0.424	1.143±0.057	1.077±0.047	3.049±0.191	2.234±0.145
5	6.89±0.428	1.122±0.058	1.138±0.047	2.505±0.193	1.889±0.146
Slaughter weight (kg)					
62	3.38 ^a ±0.197	0.562 ^a ±0.035	0.680 ^a ±0.045	1.084 ^a ±0.118	0.865±0.094
78	5.03 ^b ±0.198	0.829 ^b ±0.035	1.275 ^b ±0.045	1.565 ^b ±0.118	1.241±0.094
86	6.19 ^c ±0.201	1.003 ^c ±0.035	1.123 ^c ±0.046	2.091 ^c ±0.120	1.686±0.096
102	7.36 ^d ±0.198	1.179 ^d ±0.035	1.229 ^{bc} ±0.045	2.722 ^d ±0.118	2.170±0.094
113	8.73 ^e ±0.192	1.355 ^e ±0.034	0.969 ^d ±0.044	3.356 ^e ±0.115	2.389±0.092
128	9.56 ^f ±0.182	1.428 ^e ±0.032	1.162 ^b ±0.041	3.545 ^e ±0.109	2.641±0.086
133	9.80 ^f ±0.198	1.367 ^e ±0.035	1.297 ^{bc} ±0.045	3.566 ^e ±0.119	2.866±0.094
146	10.90 ^g ±0.244	1.521 ^f ±0.043	1.235 ^{bc} ±0.055	4.372 ^f ±0.146	3.411±0.116
Means within columns with different superscripts differ significantly (P<0.05)					

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Table 11.6 Absolute commercial deboning yields of loins obtained from carcasses of group housed animals for three sex types, five genotypes and eight slaughter weights

Variable	Whole cut (kg)	Bones (kg)	Rind (kg)	Processable lean meat (kg)
	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.
Sex type				
Boar	6.08±0.252	0.549±0.019	0.272±0.009	1.701±0.088
Gilt	6.10±0.243	0.499±0.018	0.258±0.009	1.667±0.085
Castrate	6.24±0.231	0.540±0.017	0.256±0.009	1.842±0.081
Genotype				
1	6.02±0.304	0.500 ^a ±0.023	0.259 ^{ab} ±0.011	1.754±0.107
2	6.10±0.309	0.496 ^a ±0.023	0.240 ^a ±0.012	1.596±0.108
3	6.45±0.335	0.594 ^b ±0.025	0.289 ^b ±0.013	1.908±0.118
4	6.45±0.305	0.546 ^{ab} ±0.023	0.272 ^a ±0.011	1.849±0.107
5	5.74±0.308	0.519 ^a ±0.023	0.251 ^a ±0.016	1.614±0.108
Slaughter weight (kg)				
62	3.84 ^a ±0.148	0.397 ^a ±0.023	0.206 ^a ±0.013	0.922 ^a ±0.061
78	4.65 ^b ±0.148	0.395 ^a ±0.023	0.291 ^c ±0.013	1.030 ^{ab} ±0.061
86	4.53 ^b ±0.151	0.735 ^a ±0.023	0.246 ^b ±0.013	1.179 ^b ±0.062
102	5.47 ^c ±0.148	0.545 ^b ±0.023	0.286 ^c ±0.013	1.172 ^c ±0.061
113	6.28 ^d ±0.144	0.604 ^{bc} ±0.022	0.211 ^{ab} ±0.013	1.988 ^d ±0.060
128	7.81 ^e ±0.136	0.611 ^c ±0.021	0.301 ^c ±0.012	2.205 ^e ±0.056
133	7.90 ^e ±0.149	0.611 ^c ±0.023	0.244 ^b ±0.013	2.455 ^f ±0.061
146	8.82 ^f ±0.182	0.634 ^c ±0.028	0.301 ^c ±0.016	2.426 ^f ±0.075
Means within columns with different superscripts differ significantly (P<0.05)				

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Table 11.7 Percentage deboning yields of heads obtained from carcasses of group housed animals for three sex types, five genotypes and eight slaughter weights

Variable	% of carcass	Tongue (%)	Cheeks (%)	Ears (%)	Skull (%)
	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.
Sex type					
Boar	8.97±0.113	6.32±0.186	29.81±0.539	6.10±0.203	57.75 ^a ±0.585
Gilt	9.80±0.109	6.60±0.180	30.90±0.520	6.38±0.196	55.83 ^b ±0.564
Castrate	9.63±0.104	6.58±0.171	31.59±0.499	6.40±0.187	55.68 ^b ±0.538
Genotype					
1	8.65±0.137	6.48±0.225	31.95 ^c ±0.652	6.40±0.246	55.10 ^a ±0.707
2	8.88±0.139	6.56±0.229	31.42 ^{bc} ±0.670	6.08±0.250	56.40 ^{ab} ±0.718
3	8.65±0.151	6.19±0.248	28.93 ^a ±0.717	6.54±0.271	58.23 ^b ±0.779
4	8.74±0.137	6.65±0.226	31.59 ^c ±0.654	5.88±0.247	55.95 ^a ±0.709
5	9.01±0.138	6.63±0.228	29.97 ^{ab} ±0.661	6.66±0.249	56.35 ^{ab} ±0.716
Slaughter weight (kg)					
62	9.89 ^a ±0.133	8.54 ^a ±0.240	28.70 ^{ab} ±0.743	7.43 ^a ±0.247	55.13 ^a ±0.695
78	8.98 ^b ±0.130	5.69 ^b ±0.234	29.04 ^{ab} ±0.728	5.77 ^b ±0.241	59.58 ^b ±0.679
86	9.49 ^c ±0.137	6.40 ^c ±0.247	34.45 ^d ±0.745	6.90 ^{ac} ±0.254	51.26 ^c ±0.715
102	8.30 ^d ±0.134	6.31 ^b ±0.240	30.70 ^{bc} ±0.760	7.80 ^a ±0.248	56.24 ^{ad} ±0.696
113	8.27 ^d ±0.130	6.26 ^b ±0.233	27.85 ^a ±0.728	4.85 ^d ±0.241	60.94 ^b ±0.677
128	8.55 ^{de} ±0.133	5.94 ^b ±0.240	29.87 ^{abc} ±0.745	6.68 ^{ce} ±0.247	57.69 ^{bd} ±0.695
133	8.73 ^{be} ±0.134	6.15 ^b ±0.241	34.03 ^d ±0.736	4.98 ^d ±0.248	54.33 ^{ad} ±0.698
146	8.26 ^d ±0.139	7.03 ^c ±0.250	31.82 ^c ±0.779	5.99 ^{be} ±0.258	55.05 ^{ad} ±0.724

Means within columns with different superscripts differ significantly (P<0.05)

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Table 11.8 Percentage deboning yields of necks obtained from carcasses of group housed animals for three sex types, five genotypes and eight slaughter weights

Variable	% of carcass	Bones (%)	Rind (%)	Fat (%)	Processable lean meat (%)	Trimmings (%)
	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.
Sex type						
Boar	5.50±0.083	17.37±0.522	7.05±0.370	8.91 ^a ±0.565	42.45±0.753	24.95±0.762
Gilt	5.27±0.080	16.96±0.503	6.32±0.360	11.05 ^b ±0.549	43.32±0.726	22.55±0.735
Castrate	5.43±0.077	16.62±0.480	6.12±0.340	12.04 ^b ±0.521	41.37±0.692	24.09±0.700
Genotype						
1	5.37±0.101	16.84 ^{ab} ±0.631	6.39±0.447	11.78±0.685	41.82 ^{ab} ±0.909	23.66 ^{ab} ±0.920
2	5.45±0.10	17.61 ^b ±0.641	5.91±0.454	10.48±0.707	40.07 ^a ±0.924	26.26 ^a ±0.935
3	5.37±0.111	16.11 ^a ±0.695	6.68±0.493	11.05±0.751	45.38 ^c ±1.1003	21.61 ^b ±1.015
4	5.31±0.101	15.68 ^a ±0.632	6.46±0.448	11.24±0.677	43.44 ^{bc} ±0.912	23.42 ^{ab} ±0.923
5	5.49±0.102	18.52 ^b ±0.639	6.92±0.460	9.19±0.699	41.28 ^{ab} ±0.922	24.19 ^{ab} ±0.933
Slaughter weight (kg)						
62	5.34 ^{ab} ±0.126	21.38 ^c ±0.667	6.98 ^c ±0.406	9.90 ^a ±0.810	41.11 ^{bc} ±0.890	21.61 ^{ab} ±1.026
78	5.02 ^a ±0.123	15.33 ^{ab} ±0.652	9.28 ^d ±0.396	7.95 ^a ±0.778	43.09 ^c ±0.870	25.00 ^{cd} ±1.002
86	5.33 ^{ab} ±0.129	19.90 ^c ±0.687	6 ^{bc} ±0.424	8.22 ^a ±0.779	39.42 ^b ±0.916	26.58 ^{de} ±1.056
102	5.61 ^{bc} ±0.126	16.73 ^b ±0.669	9.44 ^d ±0.407	9.18 ^a ±0.754	36.2 ^a ±0.892	28.95 ^e ±1.028
113	5.60 ^{bc} ±0.122	17.30 ^b ±0.650	4.58 ^a ±0.395	12.50 ^b ±0.716	41.52 ^{bc} ±0.867	24.00 ^{bd} ±0.999
128	5.70 ^c ±0.126	15.34 ^{ab} ±0.668	6.79 ^c ±0.406	8.90 ^a ±0.736	45.64 ^d ±0.891	22.98 ^{bc} ±1.027
133	5.30 ^{ab} ±0.126	15.26 ^{ab} ±0.671	5.67 ^{ab} ±0.406	14.74 ^c ±0.738	43.21 ^{cd} ±0.895	22.52 ^{bc} ±1.031
146	5.34 ^{ab} ±0.131	14.07 ^a ±0.696	4.97 ^{ab} ±0.423	14.40 ^{bc} ±0.765	49.08 ^e ±0.928	18.75 ^a ±1.069

Means within columns with different superscripts differ significantly (P≤0.05)

ADDENDUM A

Table 11.9 Percentage deboning yields of shoulders obtained from carcasses of group housed animals for three sex types, five genotypes and eight slaughter weights

Variable	% of carcass	Trimmings (%)	Shank (%)	Bones (%)	Fat (%)	Rind (%)	Trotters (%)	Processable lean meat (%)
	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.
Sex type								
Boar	7.31±0.077	3.92±0.334	14.36±0.258	12.33 ^a ±0.197	6.57 ^a ±0.606	9.74±0.245	6.11 ^a ±0.075	46.64±0.502
Gilt	7.14±0.074	3.62±0.326	14.44±0.249	11.61 ^b ±0.190	7.71 ^a ±0.585	9.07±0.237	5.74 ^b ±0.072	47.58±0.484
Castrate	7.10±0.071	3.25±0.308	13.97±0.237	11.55 ^b ±0.181	10.15 ^b ±0.557	9.14±0.226	5.67 ^b ±0.069	46.13±0.462
Genotype								
1	7.06±0.093	3.37±0.404	14.39±0.312	11.03 ^a ±0.238	9.28 ^a ±0.732	9.45±0.296	5.73 ^{ab} ±0.090	46.32±0.607
2	7.21±0.094	3.29±0.417	14.52±0.317	12.00 ^{bc} ±0.242	8.78 ^a ±0.744	9.25±0.301	5.96 ^b ±0.092	46.11±0.617
3	7.14±0.102	4.19±0.446	14.00±0.344	12.37 ^c ±0.262	8.39 ^a ±0.808	9.01±0.327	5.94 ^b ±0.099	45.92±0.669
4	7.09±0.093	3.28±0.405	14.13±0.313	11.56 ^{abc} ±0.239	8.87 ^a ±0.734	9.08±0.297	5.56 ^a ±0.091	47.16±0.608
5	7.39±0.094	3.81±0.409	14.15±0.316	12.17 ^{bc} ±0.241	5.96 ^b ±0.742	9.70±0.300	5.97 ^b ±0.093	48.18±0.615
Slaughter weight (kg)								
62	7.54 ^a ±0.106	2.29±0.516	15.11 ^b ±0.309	12.45 ^c ±0.287	5.48 ^a ±0.743	9.50 ^d ±0.273	6.24 ^d ±0.113	48.28 ^c ±0.795
78	7.48 ^a ±0.103	3.22±0.493	14.51 ^b ±0.302	11.37 ^b ±0.280	6.50 ^a ±0.726	10.77 ^e ±0.266	5.94 ^{bcd} ±0.110	47.63 ^{bc} ±0.776
86	7.38 ^{ab} ±0.109	3.82±0.520	13.13 ^a ±0.318	12.10 ^{bc} ±0.295	5.61 ^a ±0.765	11.62 ^f ±0.281	6.07 ^{cd} ±0.118	47.70 ^{bc} ±0.818
102	6.95 ^c ±0.106	4.38±0.505	14.49 ^b ±0.310	12.52 ^c ±0.287	6.54 ^a ±0.745	9.25 ^{cd} ±0.273	5.86 ^{bc} ±0.113	46.68 ^{abc} ±0.797
113	7.13 ^{bc} ±0.103	3.56±0.491	16.82 ^c ±0.301	10.29 ^a ±0.279	8.76 ^b ±0.724	8.55 ^{bc} ±0.266	5.96 ^{bcd} ±0.110	45.55 ^{ab} ±0.774
128	7.07 ^c ±0.106	4.21±0.505	14.44 ^b ±0.310	12.02 ^c ±0.287	6.71 ^a ±0.744	9.48 ^d ±0.273	5.71 ^{ab} ±0.113	46.88 ^{abc} ±0.796
133	6.91 ^c ±0.106	2.99±0.507	12.94 ^a ±0.311	11.62 ^b ±0.288	12.73 ^c ±0.747	7.84 ^{ab} ±0.274	5.42 ^a ±0.113	46.19 ^{abc} ±0.799
146	6.99 ^c ±0.110	3.21±0.526	12.53 ^a ±0.322	12.10 ^{bc} ±0.299	14.50 ^c ±0.775	7.28 ^a ±0.284	5.48 ^a ±0.117	44.80 ^a ±0.829

Means within columns with different superscripts differ significantly (P≤0.05)

ADDENDUM A

Table 11.10 Percentage deboning yields of legs obtained from carcasses of group housed animals for three sex types, five genotypes and eight slaughter weights

Variable	% of carcass	Trotters (%)	Shank (%)	Bones (%)	Rind (%)	Trimming (%)	Processable lean meat (%)	Topside (%)	Silverside (%)	Rump (%)	Fat (%)
	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.
Sex type											
Boar	14.41±0.122	5.76 ^a ±0.082	11.68 ^a ±0.133	9.28 ^a ±0.116	7.84±0.220	17.32±0.632	53.92 ^a ±0.514	12.24 ^a ±0.270	13.47±0.216	17.29±0.402	5.55 ^a ±0.697
Gilt	14.51±0.118	5.25 ^b ±0.079	11.31 ^{ab} ±0.128	8.23 ^b ±0.112	7.92±0.212	15.59±0.609	53.58 ^a ±0.496	12.34 ^a ±0.261	13.73±0.209	17.06±0.387	8.03 ^b ±0.672
Castrate	14.32±0.112	5.29 ^b ±0.076	11.15 ^b ±0.122	8.85 ^b ±0.107	7.77±0.202	15.49±0.581	52.13 ^b ±0.472	11.49 ^b ±0.248	13.14±0.199	16.31±0.369	9.73 ^b ±0.641
Genotype											
1	15.46±0.147	5.20 ^a ±0.100	11.40±0.160	8.48 ^a ±0.141	8.09±0.265	15.48±0.763	52.96 ^{ab} ±0.621	11.53±0.533	13.85 ^a ±0.261	16.73±0.485	9.02±0.842
2	14.18±0.150	5.61 ^b ±0.101	11.49±0.163	9.59 ^d ±0.143	7.92±0.270	17.27±0.776	51.67 ^b ±0.631	11.12±0.516	12.06 ^b ±0.265	16.42±0.493	8.30±0.856
3	14.30±0.162	5.64 ^b ±0.120	11.31±0.177	9.02 ^{bc} ±0.155	7.86±0.293	16.32±0.842	53.55 ^a ±0.685	12.22±0.688	13.42 ^a ±0.288	16.56±0.535	6.78±0.929
4	14.31±0.148	5.18 ^a ±0.100	11.24±0.161	8.74 ^{ab} ±0.141	7.75±0.266	15.67±0.765	59.96 ^a ±0.623	11.39±0.516	14.08 ^a ±0.262	17.17±0.487	8.25±0.844
5	14.78±0.149	5.51 ^b ±0.101	11.39±0.162	9.22 ^{cd} ±0.142	7.59±0.269	15.74±0.773	53.95 ^a ±0.629	11.26±0.533	13.72 ^a ±0.265	17.36±0.492	6.98±0.853
Slaughter weight (kg)											
62	14.42 ^{bc} ±0.182	6.16 ^a ±0.106	12.29 ^a ±0.172	9.32 ^{bc} ±0.171	9.05 ^d ±0.226	9.48 ^a ±0.823	54.80 ^{cd} ±0.776	13.47 ^d ±0.400	14.39 ^c ±0.325	21.06 ^e ±0.465	5.72 ^{ab} ±0.948
78	14.21 ^{ac} ±0.178	5.77 ^b ±0.103	12.02 ^{ab} ±0.168	8.95 ^{abc} ±0.167	9.14 ^d ±0.221	14.36 ^b ±0.804	55.33 ^d ±0.758	13.12 ^{cd} ±0.391	13.28 ^{ab} ±0.318	16.37 ^c ±0.454	5.90 ^{ab} ±0.926
86	14.15 ^{ab} ±0.187	5.78 ^b ±0.109	11.81 ^a ±0.177	9.48 ^c ±0.176	8.99 ^d ±0.233	17.68 ^{cd} ±0.847	53.44 ^{bcd} ±0.799	11.77 ^b ±0.412	12.53 ^a ±0.335	17.75 ^d ±0.479	3.25 ^a ±0.976
102	14.68 ^c ±0.183	5.27 ^c ±0.106	10.96 ^c ±0.173	9.27 ^{bc} ±0.171	8.28 ^c ±0.226	15.65 ^{bc} ±0.824	52.26 ^{ab} ±0.778	10.62 ^a ±0.401	13.22 ^{ab} ±0.326	18.02 ^d ±0.466	8.62 ^{cd} ±0.950
113	13.85 ^a ±0.177	5.47 ^{cd} ±0.103	11.65 ^b ±0.168	9.19 ^{bc} ±0.166	5.85 ^a ±0.220	1	52.71 ^{abc} ±0.756	11.69 ^{ab} ±0.390	13.88 ^{bc} ±0.317	17.01 ^{cd} ±0.453	8.74 ^{cd} ±0.924
128	14.69 ^c ±0.182	5.18 ^{de} ±0.106	10.91 ^c ±0.173	8.57 ^a ±0.171	7.92 ^c ±0.226	18.45 ^d ±0.824	53.74 ^{bcd} ±0.777	11.76 ^b ±0.401	14.11 ^{bc} ±0.326	16.16 ^{bc} ±0.466	6.88 ^{bc} ±0.949
133	14.26 ^{abc} ±0.183	4.94 ^{ef} ±0.106	10.64 ^c ±0.173	8.48 ^a ±0.171	6.61 ^b ±0.227	17.89 ^{cd} ±0.827	52.03 ^{ab} ±0.780	12.25 ^{bc} ±0.402	13.51 ^{bc} ±0.327	15.04 ^{ab} ±0.467	11.18 ^{de} ±0.953
146	14.53 ^{bc} ±0.190			8.80 ^{ab} ±0.178	6.77 ^b ±0.236	17.51 ^{cd} ±0.858	50.65 ^a ±0.809	11.19 ^{ab} ±0.417	12.47 ^a ±0.339	13.76 ^a ±0.485	13.59 ^e ±0.989

Means within columns with different superscripts differ significantly (P<0.05)

ADDENDUM A

Table 11.11 Percentage deboning yields of bellies obtained from carcasses of group housed animals for three sex types, five genotypes and eight slaughter weights

Variable	% of carcass	Sparerib (%)	Rind (%)	Trimming (%)	Processable lean meat (%)
	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.	Mean ± s.e.
Sex type					
Boar	8.95±0.143	16.04 ^a ±0.268	15.67±0.686	35.39±0.730	26.62 ^a ±0.578
Gilt	9.17±0.138	15.24 ^b ±0.258	16.66±0.662	36.16±0.704	26.43 ^a ±0.558
Castrate	9.20±0.131	15.16 ^b ±0.248	15.49±0.635	34.67±0.671	28.53 ^b ±0.531
Genotype					
1	8.91±0.173	15.23 ^{ab} ±0.323	16.06±0.829	35.05±0.882	27.81±0.698
2	9.18±0.176	15.89 ^b ±0.329	16.52±0.843	33.91±0.896	27.61±0.710
3	9.11±0.190	15.56 ^b ±0.356	15.36±0.913	36.03±0.973	27.22±0.770
4	9.28±0.173	14.54 ^a ±0.324	14.72±0.832	37.29±0.884	27.59±0.700
5	9.08±0.175	16.12 ^b ±0.332	16.99±0.851	34.63±0.894	26.05±0.708
Slaughter weight (kg)					
62	7.26 ^a ±0.155	16.51 ^a ±0.402	20.07 ^a ±0.593	31.88 ^{ab} ±0.988	25.09 ^{ab} ±0.848
78	8.60 ^b ±0.151	15.77 ^{ab} ±0.402	24.11 ^b ±0.593	30.08 ^a ±0.965	23.68 ^a ±0.828
86	9.38 ^{cd} ±0.160	16.09 ^{ab} ±0.414	17.92 ^c ±0.611	33.53 ^{bc} ±1.017	26.65 ^{bc} ±0.873
102	9.64 ^d ±0.155	15.62 ^{ab} ±0.403	16.26 ^c ±0.595	35.75 ^{cd} ±0.990	28.22 ^{cde} ±0.850
113	9.76 ^d ±0.151	15.72 ^{ab} ±0.392	11.19 ^d ±0.578	38.90 ^e ±0.962	27.70 ^{cd} ±0.826
128	9.60 ^d ±0.155	15.13 ^{bc} ±0.402	13.72 ^e ±0.593	37.07 ^{de} ±0.989	27.40 ^{bcd} ±0.849
133	9.09 ^c ±0.156	14.42 ^c ±0.403	12.68 ^{de} ±0.595	37.09 ^{de} ±0.993	29.71 ^{de} ±0.852
146	9.64 ^d ±0.162	10.07 ^c ±0.419	11.24 ^d ±0.619	38.94 ^e ±1.030	30.30 ^e ±0.884
Means within columns with different superscripts differ significantly (P<0.05)					