MEETING THE AMINO ACID REQUIREMENTS OF GROWING PIGS BY MANIPULATING THE FEEDING SCHEDULE

TRACY SUSAN BUTT
B.Sc. AGRIC., UNIVERSITY OF PRETORIA

Submitted in fulfilment of the academic
requirements for the degree of
MASTER OF SCIENCE IN AGRICULTURE

In the
Discipline of Animal and Poultry Science
University of KwaZulu-Natal
PIETERMARITZBURG

2006

ABSTRACT

Three experiments were designed to find the most efficient and cost-effective method of meeting the changing amino acid requirements of male and female pigs during the growing period, using the minimum number of feeds. Trial one involved 144, and trial two 192 commercial crossbred (Landrace x Large White) pigs, eight to a pen, with sexes separate. Trial three involved 24 commercial crossbred (Landrace x Large White) pigs and 24 Dalland pigs each penned separately. The amino acid requirements (g/d) for the pigs in all three trials were determined for male and female Landrace x Large White pigs, respectively, using the Pig Growth Model (EFG Software Natal, 1995). Parameter values used for males and females were: growth rate (B, /d) 0.0107 and 0.0120; protein at maturity (Pmat, kg) 39.0 and 28.0; and lipid at maturity (Lpmat, kg) 2.60 and 3.89 respectively. In trials 1 and 2 two iso-energetic (DE 13.8 MJ/kg) basal feeds were formulated; Basal A being a high crude protein (CP) (347g CP/kg) feed designed to meet the amino acid requirements of a male at 20 kg liveweight, while Basal B was a low protein feed (134g CP/kg) designed to meet the amino acid requirements of a female at 88 kg, thus providing for the most- and the least-demanding pigs on the trial. In the third trial, two iso-energetic (DE 13.8 MJ/kg) basal feeds were again formulated; Basal A being a high crude protein (CP) (347g CP/kg) feed designed to be 20% higher than the amino acid requirements of a male at 20 kg liveweight, while Basal B was a low protein feed (134g CP/kg) designed to be 20% lower than the amino acid requirements of a female at 88 kg, once again providing for the most- and the least-demanding pigs on the trial.

Trials 1 and 2 began when the median weight of pigs in each pen reached 20kg, and were terminated at a pen median of 85 kg liveweight. In the third trial each pig was started on trial when it reached 20kg and was terminated at a weight of 85kg. The first trial involved a phase feeding schedule (20-40, 40-60 and 60-85kg liveweight). The two basal feeds were blended in different proportions to create three feeds per phase: lysine contents in each of the phases in Treatment 1 (T1) were: 11, 8.68 and 7.26g/kg; in T2 they were 9.93, 7.58 and 6.24g/kg; and in T3, 8.85, 6.48 and 5.22g/kg. From the analysis it was established that ADG and time to reach 85kg were the only variables to show significance. ADG exhibited a significant sex x treatment interaction. There were significant differences between treatments for time taken to reach slaughter weight. In addition to a treatment effect there was a sex x treatment interaction for time to slaughter weight. It was expected that males

on T1 and females on T3 would exhibit the most efficient performance for their respective sex since these treatments were specifically formulated to meet their requirements.

Midway through the trial the pigs contracted enteritis, this affecting the outcome of the trial by inhibiting the potential growth of the pigs. The results of the trial indicated that dietary protein level affected the time taken to reach slaughter weight. This led to the second trial where four treatments were applied. Three of the four treatments followed a fixed feeding schedule, making use of the two basal feeds and a 1:1 blend of these. The fourth treatment followed a phase feeding schedule, differing between the males (20–65, 65-75 and 75-85 kg liveweight) and the females (20-35, 35-75 and 75–85 kg liveweight). This treatment also made use of the two basal feeds and a 1:1 blend of these. From the analysis it was found that there were no significant effects of sex and no interactions between feeding treatments and sex; however, ADG, FI, FCE, back fat thickness, time taken to reach 85kg and cost/kg gain were all significantly affected by the feeding treatments. Carcass lean, carcass lipid and total body lipid were also significantly affected by the feeding treatment. This trial was conducted to determine the extent to which differences in growth rate, food intake and carcass lipid could be altered by dietary means. The effect of the level of feed protein was once again shown to be of importance when feeding growing pigs.

The third trial was designed to test the efficiency with which two strains make use of the dietary protein supplied. Three treatments were applied: T1 was a choice-feeding treatment in which the pigs were offered the two basal feeds simultaneously. T2 and T3 followed a phase feeding schedule (20-40, 40-60 and 60-85kg liveweight). The two basal feeds were blended in various proportions to create three feeds per phase: the lysine contents in each of the phases in T2 were: 12.2, 10.0 and 7.26g/kg; and in T3 8.1, 6.7 and 5.1g/kg. There were significant sex effects as well as strain x feeding treatment interactions. All variables, ADG, FI, FCE, time taken to reach 85kg and cost/kg gain, with the exception of back fat thickness, showed significance. It was expected that the Dalland strain would perform better than the Cross strain; however, this was not the case, indicating the need for further research into the possibility of feeding according to the genetic make-up of the animal. The importance of meeting the amino acid requirements of the growing pig was evident when summarising the results of the three trials reported here.

DECLARATION

The experimental work described in this dissertation was carried out in the Discipline of Animal and Poultry Science, University of KwaZulu Natal, Pietermaritzburg, from January 2003 to December 2004, under the supervision of Professor Rob Gous.

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any University. Where use has been made of the work of others it is duly acknowledged in the text.

T S Butt

R M Gous

LIST OF CONTENTS

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to the following institutions and people:

The National Research Fund of KwaZulu-Natal for the contribution of funds to my research.

The laboratory staff at the University of KwaZulu-Natal for the analysis of my feed samples.

The staff at Ukulinga Research farm for the assistance with my trials.

The Animal and Poultry Science Discipline at the University of KwaZulu-Natal for the help with the interpretation of my statistical analysis and the endless chats in the staff tearoom.

My fellow MSc. students, who kept me in touch with reality. Thank you for always putting your work aside to help me with mine.

Martina Moore and Elaine Lindsay, for being such special people. Not a day goes by that I don't think about how lucky I am to have the both of you in my life. "Sometimes what you are doing is not as important as who you are doing it with".

My family, Dad, Mom and Steve. Thank you for never letting me give up, and for trusting in my abilities.

Finally to my supervisor Prof Gous. You are an inspiration to me, and if I become half the person you are I know I will have achieved great things. Thank you for your guidance and support.

I dedicate this thesis to my Grandpa and Gran – I am so blessed to have grown up with the both of you and I know I am who I am because of the influence you have had on my life. Thank you for your unconditional love.

CHAPTER 1

A LITERATURE REVIEW

1.1 Introduction

Consumers in the developed and developing world continue to utilize a large amount of pork as an energy and protein source (Fredeen and Harmon, 1983). Pork protein is of a high nutritive value and is a source of amino acids as well as other nutrients that are absent, or at very low levels in plant material. The consumer determines the amount and the kind of pork produced, and, certainly in the Western World, the demand is for a lean meat product. For this reason there has been a rapid improvement in the genetic quality of the pig, as well as the implementation of new production strategies in order to produce a highly marketable product. The biggest cost in pork production is the feed, which contributes about 55-85 percent to the total cost. Feed cost is governed by economics and this is unpredictable and uncontrollable. In order to reduce this feed cost the farmer must ensure that feedstuffs that complement each other are utilised. Using data from experiments by Holmes (1970), Robinson and Vohra (1976) determined that the pig is the most efficient of all domesticated animals in converting feed energy to body energy and is ranked after poultry and dairy in efficiency of conversion of feed energy to protein energy (Table 1.1).

Table 1.1 *Efficiency of energy and protein utilization and the energy cost of protein for beef, lamb, pork, poultry, eggs and milk (Holmes, 1970)*

Product	Edible Protein (g/100g consumed)	Edible energy (kJ/100kJ ME consumed)[a]	Edible protein (g/100kJ ME consumed)[a]
Beef	6.0	7.0	2.6
Lamb	3.0	3.0	1.3
Pork	**12.0**	**23.0**	**6.0**
Poultry	20.0	13.0	11.0
Eggs	16.0	15.0	11.0
Milk	23.0	21.0	10.0

[a]ME = metabolisable energy

Pork production is influenced by both intrinsic and extrinsic factors. In order to produce a pork carcass economically the factors that are controllable must be managed correctly and those that are uncontrollable must be monitored to keep a positive economical status on the farm. There are numerous methods that may be used in the production of pork, but the most important factor to consider is feed quality. This must meet the animal's nutritional requirements. Braude (1967) tabulated the factors influencing the pattern of feeding of pigs. These are in Table 1.2 below.

Table 1.2 *Factors influencing the pattern of feeding (Braude, 1967)*

Animal	Feed	Management of feeding
Appetite	Palatability	Self choice
Health	Density	Alternating
Genetics	Bulk	*Ad lib.* vs. restriction
Sex	Grinding	Frequency
Environment	Soaking	Individual vs. group
Behaviour	Heating	Wet vs. dry
Class	Drying	Trough vs. floor
	Pelleting	

As can be seen there are a number of variables involved in the production of pork. The following literature review will highlight three of these, namely, the importance of dietary protein, the influence of sex and genotype on the dietary requirements, and lastly, the management of the feeding regimen, i.e. phase feeding and choice feeding.

1.2 Proteins and Amino Acids

1.2.1 Essential and Non-Essential Amino Acids

The pig does not have a specific requirement for protein, but rather for the amino acids that make up the protein. There are 20 primary amino acids that occur in proteins. An amino acid that can be synthesized by the animal body, using carbon skeletons and amino groups derived from amino acids in excess of their requirements, is termed a non-essential amino acid. Amino acids that cannot be synthesized endogenously, or cannot be synthesized at a sufficient rate to meet their requirements by the pig, are termed essential amino acids

(NRC, 1998). Of the 20 amino acids, ten are considered essential in the diet of the pig. The classification of the amino acids can be seen in Table 1.3 below.

Table 1.3 *Nutritional Classification of Amino Acids (NRC, 1998)*

Essential	Synthesized from limited substrates[a]	Non-essential
Arginine	Tyrosine	Alanine
Lysine	Cystine	Aspartic acid
Histidine	Hydroxylysine	Asparagine
Leucine		Glutamic acid
Isoleucine		Glutamine
Methionine		Hydroxyproline
Threonine		Glycine[b]
Tryptophan		Serine[b]
Phenylalanine		Proline[c]

[a]Tyrosine is synthesized from phenylalanine, cystine from methionine and hydroxylysine from lysine.
[b]Under some conditions glycine or serine synthesis is insufficient for rapid growth; either glycine or serine may need to be supplemented.
[c]When diets composed of crystalline amino acids are used, proline may be necessary to achieve maximum growth.

Some amino acids are essential according to the condition of the pig. Arginine cannot be synthesized by the neonatal pig (Southern and Baker, 1983) but after puberty this amino acid is synthesized at a sufficient rate to meet the pig's requirement (Easter *et al.* 1974). Among the sulphur amino acids, only methionine is essential, but the sulphur containing non-essential amino acid cysteine and its oxidation product cystine can be used to meet approximately 50 percent of the total sulphur amino acid needs, thereby reducing the total need for methionine (Chung and Baker, 1992a). Phenylalanine follows the same ruling, with the non-essential amino acid tyrosine meeting approximately 50 percent of the requirement for these two amino acids (Robbins and Baker, 1977).

The ten essential amino acids must be supplied at a minimum level in order to meet the pig's requirement for the development of body protein. These amino acids must also be provided in the correct proportions for each body protein. Body proteins differ and grow at differing rates, thus the amino acid requirements are constantly changing as the pig matures. Normal pig diets contain adequate amounts of non-essential amino acids, this being true even for low protein diets that are supplemented with crystalline amino acids (Brudevoid and Southern, 1994). Thus the emphasis in feeding the pig is on providing a diet that can meet the requirements for essential amino acids.

1.2.2 Protein Quality and Amino Acid Availability

Since proteins are made up of amino acids, it is not the total amount of protein in the diet, but rather the amino acid profile that is important. Protein quality can be defined as the degree to which the composition of the absorbed amino acid mixture accords with the balance required by the animal (Wang and Fuller, 1989). Protein quality i.e. the digestibility of the protein itself, as well as the balance of amino acids that it contains, is of considerable importance in a pig diet. The quantity of feed protein that is used by the animal to synthesize body tissues has been termed the biological value. The efficiency of this process, and hence, the biological value is dependent on how closely the amino acid content of the feed matches that of the specific tissue(s) to be synthesized. A feed protein will have a high biological value if it has a combination of amino acids which resemble the body protein, and a low biological value if it has an excess or an imbalance of essential amino acids (NRC, 1998).

Because of the chemical structure of certain proteins, or the method used to process the ingredient, there is a proportion of each amino acid that is not biologically available to the animal. This is due to the fact that most proteins are not completely digested, the amino acids are not fully absorbed, and the amino acids that are absorbed are not all metabolically active (NRC, 1998). From studies by a number of authors (Southern, 1991; Lewis and Bayley, 1995) it has been determined that the biological availability of amino acids varies across the range of dietary ingredients, hence when formulating a diet this fact must be taken into consideration.

The bioavailability of an amino acid is determined by measuring the proportion of the dietary amino acid that has disappeared from the gut when digesta reaches the terminal ileum (NRC, 1998). These values are termed "ileal digestibilities" and not bioavailabilities since amino acids may be absorbed in a form that cannot be fully metabolised. Adjustment is also made for endogenous amino acid losses, thus the correct terminology is "apparent ileal digestibility". When determining apparent digestibilities for feedstuffs, those of low protein content are undervalued relative to feedstuffs of higher protein content because of the greater contribution of endogenous amino acids (NRC, 1998). For this reason it was decided to express amino acid digestibilities on a true rather than apparent digestibility basis. When formulating rations it is important to acknowledge the basis on which one is formulating as there is a marked difference between the two. This can be clearly seen in Table 1.4 below. The amino acid requirements based on true ileal digestibility are estimated from the growth model (NRC, 1998).

Table 1.4 *Comparison between True and Apparent Digestibilities of Amino Acids(g/d) over 50-80kg body weight range at three different lean gain(g/d) potentials (NRC, 1998)*

Body weight range	50 – 80 kg					
Lean gain (g/d)	300		325		350	
Amino Acid (g/d)	True[a]	Apparent	True[a]	Apparent	True[a]	Apparent
Arginine	5.60	5.10	6.20	5.70	6.80	6.30
Histidine	5.10	4.80	5.50	5.20	5.90	5.50
Isoleucine	8.70	8.00	9.40	8.70	10.1	9.30
Leucine	15.9	15.3	17.2	16.5	18.5	17.7
Lysine	15.9	14.6	17.1	15.7	18.4	16.9
Methionine	4.30	4.10	4.60	4.40	5.00	4.70
Methionine + Cystine	9.30	8.60	10.0	9.30	10.7	9.90
Phenylalanine	9.40	8.70	10.2	9.40	10.9	10.1
Phenylalanine + Tyrosine	15.0	13.9	16.1	15.0	17.3	16.1
Threonine	10.3	8.90	11.0	9.60	11.8	10.3
Tryptophan	2.90	2.50	3.10	2.70	3.40	2.90
Valine	10.8	9.80	11.6	10.6	12.5	11.4

[a] Estimated from the growth model.

1.2.3 The Ideal Protein Concept

Proteins vary considerably in terms of their amino acid composition and this has led to the requirement of a measure that can be used to determine the nutritional value or quality of the protein. In 1981 the ARC put forward the idea of ideal protein and since then the emphasis has changed from formulating for individual amino acid requirements to looking at the overall amino acid balance. Through the years the amino acid composition of the ideal protein has been revised and improved (Wang and Fuller, 1989; Baker *et al.* 1993) and the current ratios of amino acids in the ideal protein can be seen in Table 1.5. These ratios were determined using true ileal digestibilities (NRC, 1998). All amino acids are expressed as a ratio to lysine since lysine has been found to be the first limiting amino acid in feeds based on maize or wheat.

Table 1.5 *Ideal Ratios of Amino Acids to Lysine for Maintenance, Protein Accretion, Milk Synthesis, and Body Tissue (NRC, 1998)*

Amino Acid	Maintenance[a]	Protein Accretion[b]	Milk Synthesis[c]	Body Tissue[d]
Lysine	100	100	100	100
Arginine	-200	48	66	105
Histidine	32	32	40	45
Isoleucine	75	54	55	50
Leucine	70	102	115	109
Methionine	28	27	26	27
Methionine + Cystine	123	55	45	45
Phenylalanine	50	60	55	60
Phenylalanine + Tyrosine	121	93	112	103
Threonine	151	60	58	58
Tryptophan	26	18	18	10
Valine	67	68	85	69

[a]Maintenance ratios were calculated based on the data of Baker *et al.* (1966a, b), Baker and Allee (1970), and Fuller *et al.* (1989). The negative value for arginine reflects arginine synthesis in excess of the needs for maintenance.

[b]Accretion ratios were derived by starting with the ratios from Fuller et al. (1989) and then adjusting to values that produced blends for maintenance + accretion that were consistent with recent empirically determined values (Baker and Chung, 1992; Baker *et al.* 1993; Hahn and Baker, 1995; Baker, 1997).

[c]Milk protein synthesis ratios were proposed by Pettigrew (1993) based on a survey of the literature; the value of 73 for Valine proposed by Pettigrew was modified to 85.

[d]Body tissue protein ratios were from a survey of the literature (Pettigrew, 1993).

An ideal protein can be described as one which supplies the optimum balance of essential amino acids together with sufficient nitrogen for the synthesis of non-essential amino acids. Protein synthesis cannot occur to the maximum potential of the pig if the amino acids are not provided in the ideal amino acid ratio as seen in Table 1.5.

1.2.4 Protein Balance and Amino Acid Requirements

Amino acid requirements of growing pigs are influenced by many factors, including dietary protein content, dietary energy density, environmental temperature, and genotype (Lewis *et al.* 1991). It is essential that amino acids are balanced in the diet.

Amino acids must be included in the feed at a sufficient level in order to optimize protein accretion. Some amino acids may, however, antagonise each other when present in excess, and thus reduce growth rate. This usually occurs between amino acids with structural similarities. Leucine given in excess decreases isoleucine and/or valine utilization for protein synthesis (Harper *et al.* 1984). It was thought that excess lysine increased arginine catabolism (Jones *et al.* 1966) following experiments with rats, but this was disproved by Edmonds and Baker (1987). Imbalances in amino acids may also occur and are caused by excessive intakes of an individual amino acid, or a group of amino acids. Imbalances are caused by the aggravation of the deficiency of the most limiting amino acid.

The extent to which amino acids are catabolized is largely determined by the balance of dietary amino acids relative to the requirements of amino acids for maintenance and growth functions. When amino acids are in excess of the requirement they are catabolized by the animal, resulting in excess urinary urea excretion and NH^+ formation. Cromwell *et al.* (1999), when researching the effect of diet on gaseous emissions from manure found that the higher the dietary protein concentration, the higher the ammonium concentration and the pH in the manure, and that this decreased linearly as dietary protein was reduced. Whittemore (1985) demonstrated the effect of excess dietary protein on the daily gains of lean and fat. Excess protein results in an overall decrease in net energy due to the energy cost of deamination of this protein. Thus less energy is available for fat deposition resulting in a lean carcass. This excess protein is expensive and may result in a depressed feed intake and growth performance (Henry, 1985). Stahly *et al.* (1991) found that excess dietary amino acids will result in lower body weight gains and less efficient feed utilization, although carcass fat content generally is reduced slightly. The same consequences occur when the amino acids are provided below the nutritional requirement. More energy is available for fat synthesis as Whittemore (1985) indicated, resulting in a carcass with a higher proportion of lipid.

It is now possible to include synthetic amino acids in feeds, this being the result of an increase in the production of these amino acids, with a resultant decrease in unit costs. This enables the total protein content of the diet to be reduced, which from an economical perspective is an advantage. The type and the amount of synthetic amino acid supplementation depends upon the extent to which the level of dietary crude protein is reduced and the type of feed ingredient used. The limit to which the total protein can be reduced and synthetic amino acids included has been under scrutiny by a number of authors, their research providing contradictory results. Kephart and Sherritt (1990) found, when reducing dietary protein from 17 to 10 percent and supplementing a variety of amino acids in a synthetic form, that early growing pigs (20-24kg) exhibited a reduced gain, feed efficiency and nitrogen retention. Kerr and Easter (1995) fed diets with protein decreasing from 19 to 15 percent, 16 to 12 percent and 14 to 11 percent, respectively, with supplementation of synthetic amino acids and revealed that there were no negative effects on any of the growth parameters but that there was an increase in mean back fat thickness.

1.3 The Nutritional Requirements of Different Sexes and Genotypes

Through a series of biological processes the animal will grow to its maximum body size. This maximum is determined by the genetic makeup of the animal. The growth of the pig as a function of age follows a sigmoidal curve, which is illustrated in Figure 1.1 below.

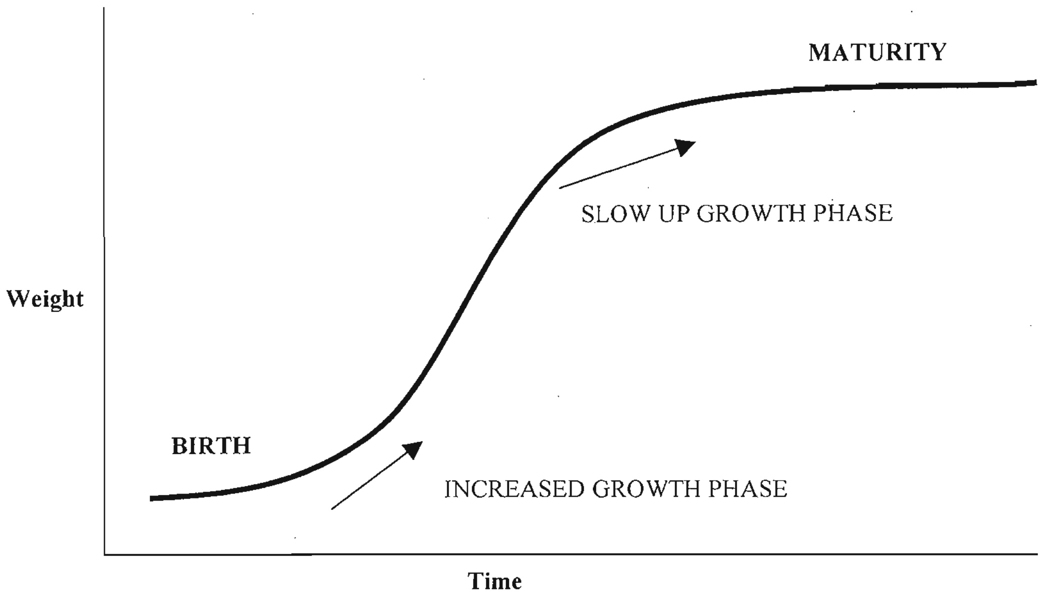
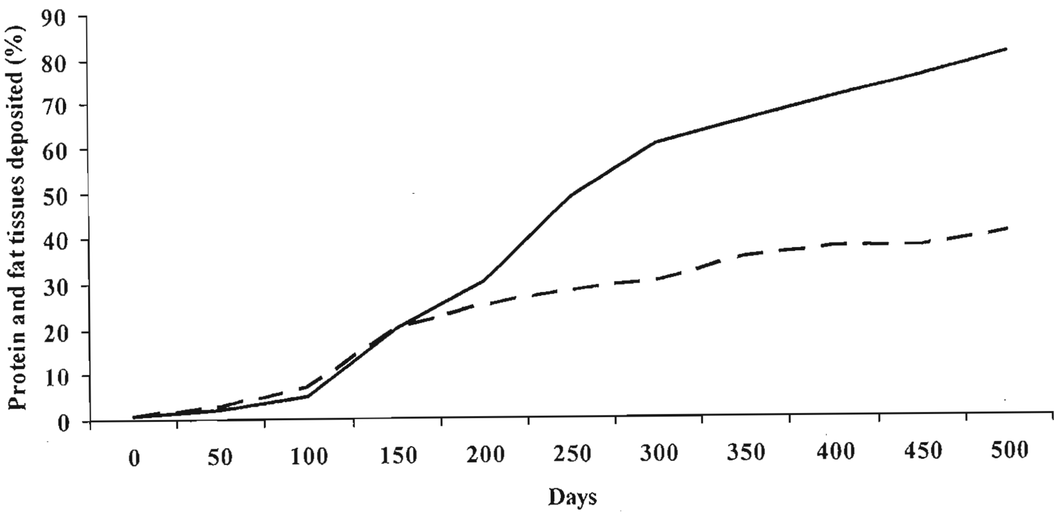


Figure 1.1 *Body weight as a function of age (Whittemore, 1998).*

Subsequent to birth there is a period of acceleratory growth which is followed by a linear growth stage. Following this linear growth is a de-acceleration stage which precedes the final maturity plateau. Up to approximately 150 days of age protein and lipid growth maintain a ratio of 1:1 after which lipid mass exceeds protein mass (Kyriazakis, 1999). This can be seen in Figure 1.2 below.



. **Figure 1.2** *Lipid (—) and muscle (---) gain as a function of age (Kyriazakis, 1999).*

From 150 days lipid mass exceeds protein mass, thus justifying the recommended slaughter age between 130 and 170 days of age. The point at which fat deposition becomes excessive is highly related to genotype and sex of the animal, as well as the feeding level. De Lange *et al.* (1995) found that animals with lower lean production potential reach this plateau earlier than improved animals.

1.3.1 The Amino Acid Requirements of Male and Female Pigs

It is generally accepted that females are fatter than males and that castrates are fatter than females (Blair and English, 1965; Fuller *et al.* 1980). This implies that the female body contains less protein and/or water than the male body and that hormones influence body composition (Siebrits *et al.* 1986). The body composition of a growing pig (from 20-100kg live weight) can be expressed with the allometric relationship, $Y= aX^b$, where Y is the component to be estimated, X is the fasting swine weight (live weight = 1.05 x fasting weight) and b is the growth rate of the component (Y) (Whittemore, 1998). From this equation it can be seen that protein accretion rate is higher in entire males than in barrows, and fat accretion is higher in barrows than in entire males. Females are intermediate for both protein and fat accretion. This is demonstrated in Table 1.6 below.

Table 1.6 *Body chemical components of the growing swine as a function of empty body weight (live weight less digestive tract content) using the relation where Y is the component and X is empty body weight (kg) (Whittemore et al. 1988; 1998)*

Body Components	Entire Males			Barrows			Gilts		
	a	b	Y^a	a	b	Y^a	a	b	Y^a
Protein	0.19	0.96	16.3	0.28	0.85	14.1	0.21	0.93	15.0
Water	0.93	0.86	49.2	1.24	0.78	44.7	1.01	0.83	46.2
Lipid	0.02	1.62	21.9	0.01	1.07	28.4	0.02	1.63	29.1
Ash	0.05	0.92	3.44	0.05	0.90	3.23	0.05	0.92	3.3

Y^a (X=100)

In Figure 1.3 the difference in the deposition of protein for males, females and castrates can be seen. Whittemore *et al.* (2001) used the equation $Pr_{max} = B_p.Pt.\ln(A_p/Pt)$ where B_p is the growth coefficient for protein mass, Pt is protein mass at different growth stages and A_p is the mature protein mass.

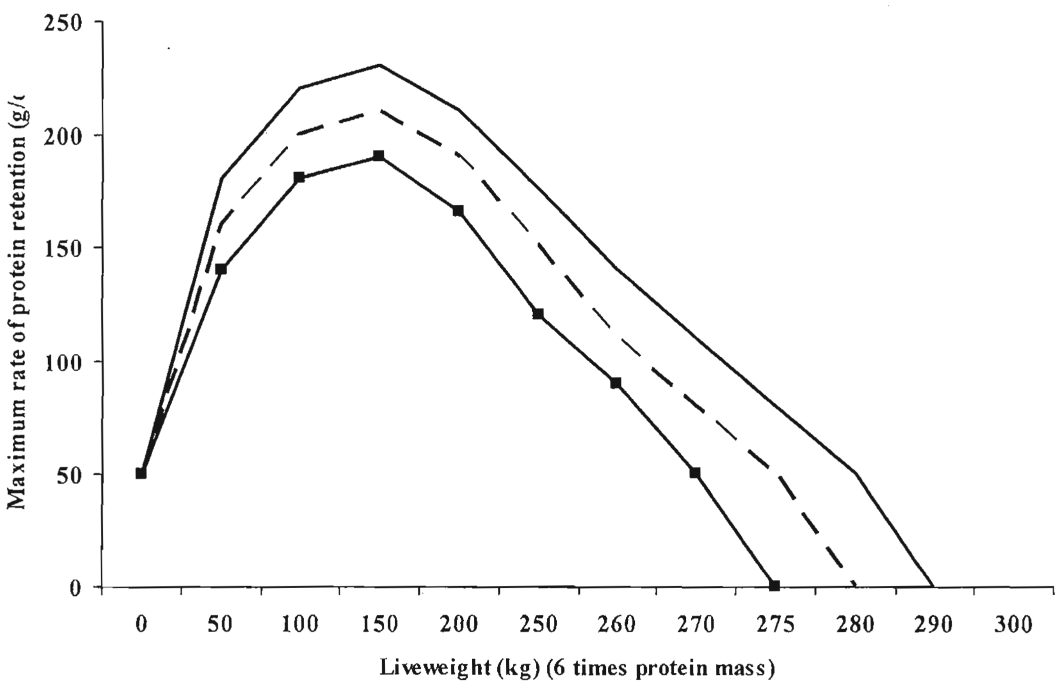


Figure 1.3 *Prediction of the maximum rate of protein retention in male (|), female (¦) and castrate (■) pigs of an improved breed type at different stages of growth (Whittemore* et al. *2001).*

These physiological differences influence the performance of the respective sexes. The maintenance requirement of the male and female will be higher than the castrate due to the higher lean content, this being more metabolically active than fat tissue. Siers (1975) evaluated the differences among Yorkshire sex groups and found that the boars grew about 13 percent faster than the gilts. Campbell *et al.* (1988a) found that with an increase in live weight there was an increase in the differences between the sexes in their response to dietary protein. Above 40kg entire males grew faster and more efficiently than the females. Growth performance in the females was depressed on the higher protein diets. Following research in 1995 by the same author, it was found that the lysine requirements for maximum growth of entire males and females are the same between 20-50kg, and that between 50-90kg, females require 15 percent less lysine. Cromwell *et al.* (1993) found that gilts require higher concentrations of amino acids to maximise lean growth when compared to castrates. Two years later Critser *et al.* (1995) found higher daily weight gain and feed efficiency for gilts as compared to castrates as a function of their higher feed intake. In a literature review concerning the nutritional requirements of boars and castrates, Xue *et al.* (1997) reported that entire males had higher protein and lysine requirements when compared to castrates. The authors also found that for the same weight range, 25-55kg, castrates and gilts require lower lysine levels than entire males. An example of these performance and carcass differences is presented in Table 1.7, from an article by Siers (1975).

Table 1.7 *Performance and Carcass Measurements of Boars, Castrates, and Gilts[a] (Siers, 1975)*

Item	Boars	Castrates	Gilts
No. of animals	36	33	45
Average Daily Gain (g/d)	920	890	810
Feed/gain (kg/kg)	2.85	3.10	3.08
Back fat (cm)	3.04	3.44	3.12
Ham and loin (%)	40.5	39.4	41.2
Loin eye area (cm^2)	33.1	28.6	34.0

[a]Individually fed from 27 to 99.5kg.

1.3.2 The Amino Acid Requirements of Different Genotypes

The nutrient requirements of pigs are influenced by the genotype. The genotype here is broadly defined as a type of pig that differs genetically from others (Knap *et al.* 2003). Depending on the required detail, this could be a breed (e.g. Duroc vs. Pietrain), a strain within a breed (e.g. PIC's PB427 vs. Belgian herd book Pietrain), or an individual within a strain) (Knap *et al.* 2003). The rates at which the biological processes occur at a cellular level in the animal body are determined by the genetic make-up of the animal. This rate will control the level of nutrients needed to satisfy the requirements of the pig. The pig has a genetic predisposition to the amount of protein (Pd_{max}) that it will deposit and feeding excess protein will be an added expense as the pig will only utilize the protein (amino acids) up to its potential (Moughan and Verstegen, 1988).

Table 1.8 *Amino acid requirements (based on total ileal digestibility) of two genotypes over the growing period (NRC, 1998)*

Amino Acid (g/kg)	20 - 50 kg		50 – 80 kg		50 – 80 kg	
	Average Mixed Sex[a]	Superior Mixed Sex[b]	Average Mixed Sex[c]	Superior Mixed Sex[d]	Average Mixed Sex[e]	Superior Mixed Sex[f]
Arginine	2.7	3.3	1.3	1.7	2.4	2.8
Histidine	2.4	2.8	1.5	1.9	2.2	2.5
Isoleucine	4.0	4.7	2.5	3.2	3.8	4.3
Leucine	6.9	8.2	4.8	5.2	6.4	7.5
Lysine	7.4	8.7	4.5	5.8	7.0	8.0
Methionine	1.9	2.3	2.8	3.4	1.8	2.1
Methionine + Cystine	4.2	4.9	2.8	3.4	4.0	4.6
Phenylalanine	4.3	5.0	2.7	3.3	4.0	4.6
Phenylalanine + Tyrosine	6.8	8.0	4.4	5.3	6.3	7.3
Threonine	4.9	5.7	2.9	4.0	4.6	5.3
Tryptophan	1.3	1.6	0.8	1.1	1.3	1.4
Valine	5.0	5.9	3.1	3.9	4.7	5.4

[a] Pigs having average growth potential of lean gain 240 g/d at this production stage
[b] Pigs having average growth potential of lean gain 285 g/d at this production stage
[c] Pigs having average growth potential of lean gain 265 g/d at this production stage
[d] Pigs having average growth potential of lean gain 300 g/d at this production stage
[e] Pigs having average growth potential of lean gain 280 g/d at this production stage
[e] Pigs having average growth potential of lean gain 325 g/d at this production stage

Table 1.8 above indicates the estimated amino acid requirements for the grower and finisher pig from the NRC (1998) model, which is based on whole body lysine and protein accretion rates, and the amino acid profile for maintenance and protein gain. As can be seen from the above table, the amino acid requirements are higher for an animal of superior genetic make-up, thus indicating the need for improved diets to be supplied to these animals, in order for them to achieve their full genetic potential.

A study at Purdue University by Schinckel (1994) demonstrated the effects of genotype on a number of performance traits. The pigs on trial were all fed similar diets under the same environmental conditions. A summary of the results can be seen in Table 1.9 below.

Table 1.9 *Performance traits on a sample of pig genotypes[a] (Schinckel, 1994)*

Genotype	Feed Intake (g/d)	Average Daily Gain (g/d)	Lean gain (g/d)	Fat gain (g/d)	Fat gain/100g lean gain
1	2480	1020	342	293	86
2	2750	940	267	349	130
3	2630	1050	311	253	81
4	2630	960	272	323	119
5	2220	920	316	279	88
6	2600	960	253	326	128

[a]25-117kg body weight; pigs were fed four diets 3.48Mcal ME/kg; 1.3, 1.15, 1.05 and 0.95g lysine; lean gain is fat-free lean gain; fat gain is total lipid in the soft carcass tissue.

Table 1.9 clearly shows the variation in performance traits across pigs of different genetic composition. The amount of fat gained per 100g lean gain is an indication of the quality of the genotype i.e. the superior genotype has a lower percentage of fat gain/lean gain. High lean genetic strains of pigs normally exhibit greater body maintenance processes and proteinaceous tissue growth, but lower rates of fatty tissue accretion (Stahly, 2001). This results in the composition of the body being high in protein, macro minerals and water, and low in energy and fat content. Fabian *et al.* (2003) compared the carcass and meat quality of two distinct genotypes fed similar diets. The selected line pigs i.e. those pigs selected for improved lean growth efficiency, were found to have heavier hearts ($P<0.05$), livers ($P=0.08$), and kidneys ($P<0.05$), implying a higher metabolic activity.

Feed conversion efficiency has been shown to be influenced by a variety of traits as can be seen in Figure 1.4 below.

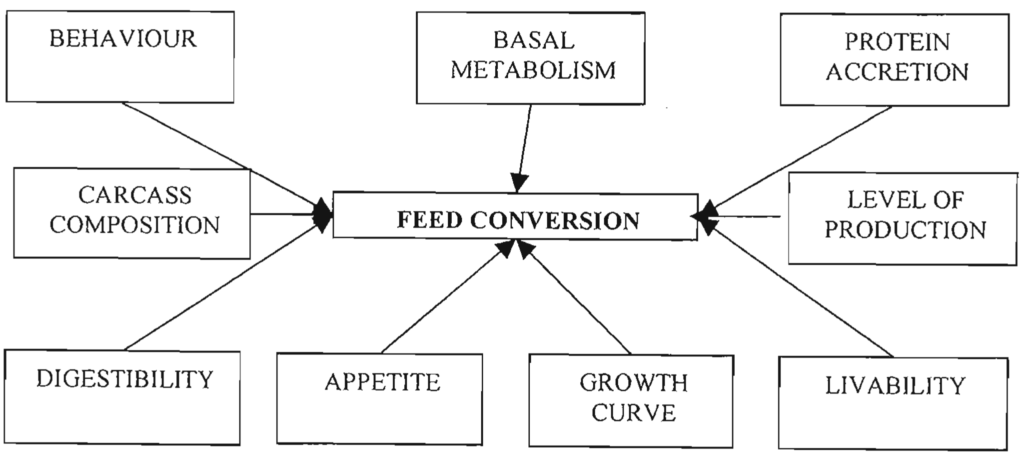


Figure 1.4 *Underlying component traits contributing to feed efficiency.*

An indirect reflection of improved feed conversion efficiency, albeit a crude measure of biological efficiency, can be seen in the growth rate of the animal (Whittemore, 1993). If one compares a fast growing animal to a slow growing animal, both have the same maintenance costs but the slow growing animal will have less product to offset the overall nutrient cost of the feed, thus making it less efficient than the fast growing animal. Feed conversion efficiency is also influenced by the relative amounts of lean and fat in the carcass. The nutrient cost of fatty tissue growth is approximately four times that of lean tissue growth (Whittemore, 1993), therefore an animal selected for lean growth will have a higher feed conversion efficiency to that of a fatter animal (Sather and Fredeen, 1978). This is in conflict with findings by Kyriazakis *et al.* (1994) and Kyriazakis and Emmans (1995) who found that two very different pig breeds use limiting protein with the same net efficiency. Campbell and Taverner (1988) demonstrated in a trial using two strains of male pig, that a faster growing genotype has a higher potential for muscle development than a slower growing type. This higher potential, results in the carcass quality and feed conversion efficiency being more resistant to higher levels of feeding i.e. the faster-growing genotype can be fed at a higher energy level before there is a negative effect on profitability due to carcass quality deterioration. The results of this trial are presented in Figure 1.5 below.

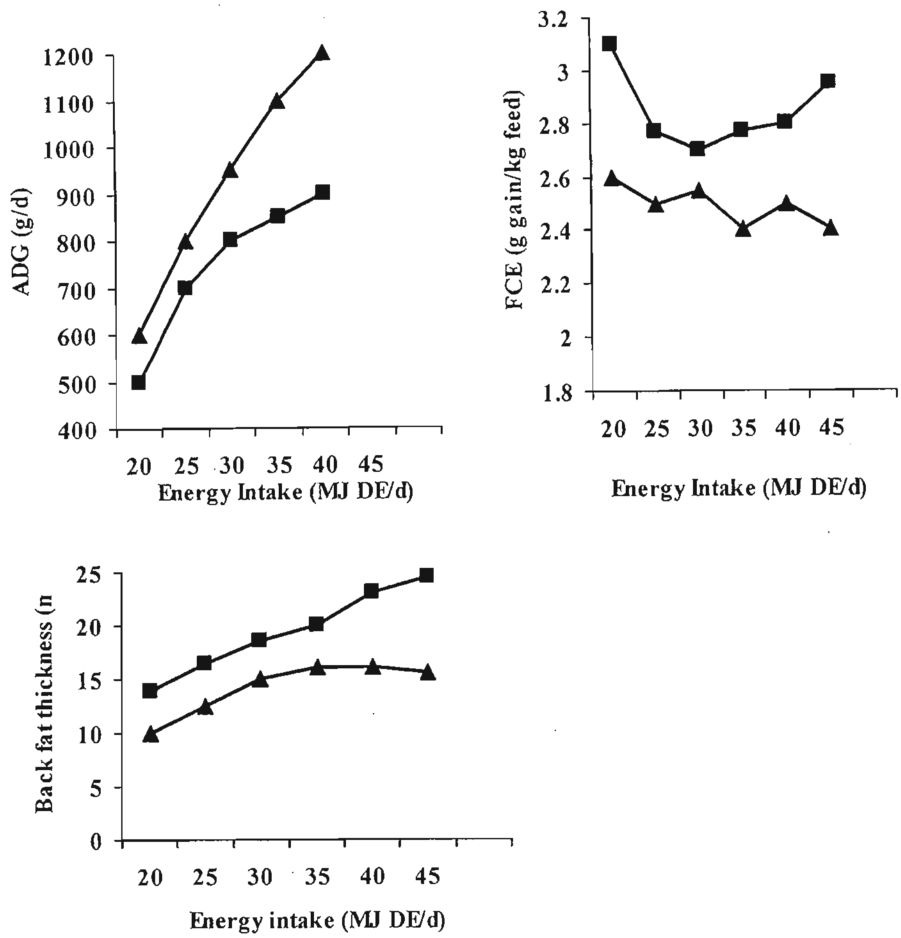


Figure 1.5 *The effects of energy intake between 45 and 90 kg on average daily gain (ADG) feed conversion efficiency (FCE) and back fat thickness of two strains, A (▲) and B (■), of entire male pig (Campbell and Taverner, 1988).*

If all nutrients in the feed are at, or above the requirement, pigs will consume feed to meet their requirement for energy (NRC, 1998). Therefore, as the DE content is decreased, the pig will attempt to maintain energy intake by consuming a greater intake of dry matter. Revell and Williams (1993) have found that with selection for increased leanness, the voluntary feed intake of the pig has been reduced. The implications of this are many, the most important being that a pig of a high genetic quality may have less leeway to deal with a diet of lower energy content. This indicates that there is a strong relationship between energy intake and protein deposition and this must be understood in order for improvements to be made in the production of pork.

1.4 The Application of Feeding Regimens

There are numerous feeding regimens or programmes that have been applied in order to accommodate the changing amino acid requirements of the growing pig. The type of feeding schedule chosen will depend, among other considerations, on the level of management and the feeding equipment available at the growing facility. It has been shown by a number of authors that the pig exhibits compensatory growth after a period of nutritional deprivation, be it in the form of energy or protein (Fabian *et al.* 2002; Whang *et al.* 2003). However, this should not be relied on as a "fall-back" and therefore the pig should be feed according to its nutritional demands over the period of growth.

1.4.1 Phase feeding

Phase feeding is the application of a series of feeds of diminishing protein content, each provided for a given period of time, in order to more closely meet the pigs nutrient requirements. Ferguson (1989) showed that the requirements for most amino acids decrease curvilinearly over time and this is shown graphically in Fig. 1.6. If only one feed is supplied throughout the growing period, this would result in an undersupply of amino acids initially and an oversupply later in the growing period, and this would be uneconomical and physiologically unsound.

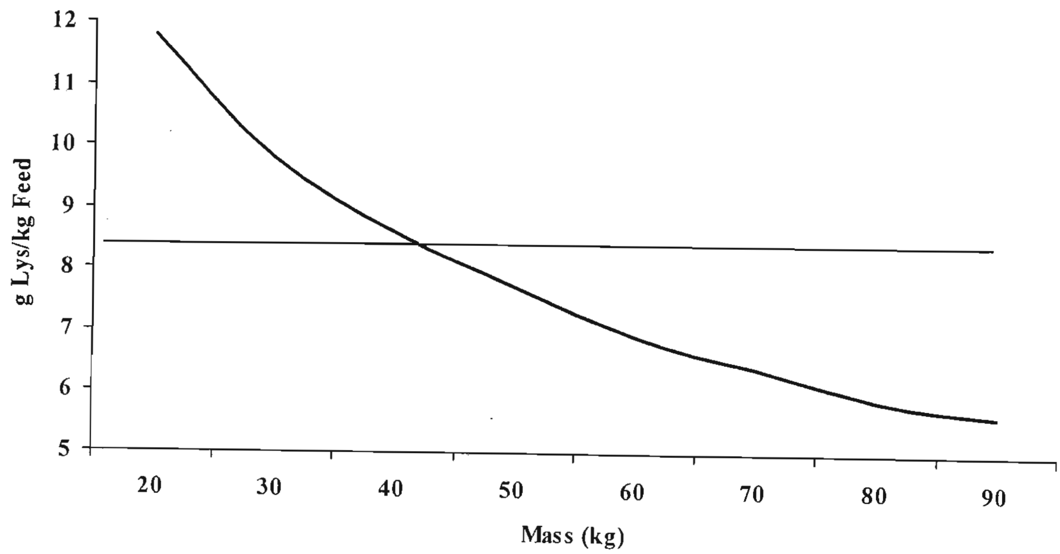


Figure 1.6 *The changing requirements for dietary lysine (g/kg feed) over time for growing pigs calculated using the EFG Pig Growth Model (Ferguson, 1989).*

Feeding less than the requirement initially is likely to result in the initial growth rate being less than the potential of the animal, an increase in feed intake and excess lipid gain (Bradford and Gous, 1992). The pig may also undergo what has been termed compensatory growth i.e. a faster rate of growth relative to age (Bohman, 1955). Kyriazakis *et al.* (1991) conducted trials on weaner pigs using feeds with low, medium and high levels of protein, compared to the NRC (1988) recommendations, but with similar digestible energy content. Two groups of pigs were fed either the low protein feed or the medium protein feed from 6 to 13kg at which point these two groups were further divided into two groups and fed either the medium or the high protein feed until 30 kg body weight. They found that the restricted pigs i.e. those fed the low protein feed, grew slower than those on the medium protein feed. Upon realimentation these previously restricted pigs grew 1.18 times faster, had lower daily feed intake, and had higher feed conversion efficiencies than the non-restricted pigs. The same authors found no significant difference in growth rate between male and female pigs upon realimentation after feeding a low protein diet.

Stamataris *et al.* (1985) showed that the degree and duration of undernutrition will influence the level of compensatory growth in the pig. Work done by De Greef *et al.* (1992) illustrated that two different strains of pigs responded similarly to realimentation. This was in contrast with previous research by Hogberg and Zimmermann (1978), who found that a lean strain of pig exhibited little growth compensation; however, the strains used by the latter authors differed more than those used by De Greef et al. (1992). This conflict in results suggests further research in the level of compensatory growth in different genotypes.

Bradford and Gous (1991b) showed that a phase feeding regimen is an economical and biologically sound method for producers to use, with the best results being obtained with a maximum of three feeds/phases throughout the growing period. The two challenges in phase feeding are to choose the optimum nutrient contents in each feed, and knowing at which point in the growth cycle the feeds should be switched. It is important to establish an objective function when implementing a phase feeding programme i.e. margin over feed cost, lean meat yield, feed conversion efficiency etcetera. One should also consider the feasibility of applying a number of phases over the growing period – the size of the operation and transport costs will influence this decision.

1.4.2 Choice Feeding

The theory behind the use of choice feeding, as a means of meeting the requirements of the growing pig more precisely, is that pigs possess a nutritional wisdom allowing them to select a blend of feeds that will satisfy their nutritional requirements at a particular time in their growth. In experiments by Kyriazakis *et al.* (1990) and Bradford and Gous (1991a,b) pigs were offered two balanced diets varying in their nutrient composition, and both sets of authors found that pigs chose a combination of the two foods that closely met their changing requirements for amino acids, indicating the ability to recognise their inherent nutritional requirements. In 1993, Fairley *et al.* showed that the pig is able to distinguish between two feeds that differed in protein (or amino acid) concentration. In addition they showed that pigs prefer to eat a food that does not contain an excess of a particular nutrient, i.e. an adequately balanced diet. It has also been shown that pigs are able to choose a diet on the basis of its nutrient density (Ferguson *et al.* 1999) as well as palatability; this including the presence of anti-nutritional factors (Ferguson *et al.* 2002). Following an experiment by Kyriazakis *et al.* (1991), it has been suggested that the pigs need time to adjust to the feeds offered as a choice, before they can make correct dietary choices. The authors found that when pigs were given a choice between two feeds differing in protein content, they selected the feed, or combination of feeds to meet their protein requirement, but only if they had had previous experience of both feeds. Morgan *et al.* (2003) found that by placing an individual pig trained to select between two foods in a group of pigs, that the group of pigs selected a diet similar to that of the trained pig, whereas the group of pigs without a trained pig showed initial variation in selection before favouring one particular food.

Rose and Fuller (1995) found that there were no distinct differences between standard and choice feeding regarding production results. In fact, Nam and Aherne (1995) found that choice feeding, when compared with conventional feeding, decreased the efficiency of protein deposition in the pig. These results, together with those of other authors, indicate that the decision to apply choice feeding on the farm should not be taken lightly. A system of choice feeding would be easier to manage on a commercial level than a phase feeding system as the latter requires a high level of management. Choice feeding would also eliminate the problem of the genetic differences in nutrient requirements, as each pig will choose the correct combination of feeds in order for it to maximise its genetic potential for growth. When deciding on the nutrient level of the two diets available one must ensure that the diets, if differing in protein level, are balanced on all other levels of nutrient requirements. This is an integral element in the application of a choice-feeding programme.

1.5 Discussion

Growing pigs for meat is a process similar to any other production process. Two factors exist, namely, the rate of production and the efficiency of production. The rate of production can be seen as the daily live weight gain, and the efficiency of production, the kilogram feed used per kilogram pig sold. The overall process is influenced by the availability of the first limiting resource, most likely the quality of feed and management inputs, and the ability of the pig to make use of the inputs presented to it (Whittemore, 2004). The correct management of the pig unit is essential in achieving optimal results. It is important to select a genotype able to grow high quality meat at the required rate and ratio of lean to fat, and to ensure the provision of a balanced diet in the correct volume (Whittemore, 2004).

There are numerous ways of improving the carcass i.e. manipulating the balance between muscle tissue and adipose tissue such as genetic selection, the use of entire males, different feeding regimens e.g. choice feeding, early slaughter and the use of metabolic modifiers e.g. beta-agonists. The implementation of these strategies depends on the desired goal of the producer. Over the years, the goals have switched from trying to achieve a maximum growth rate (producer-driven), to achieving a given rate of lean tissue gain (consumer-driven). The question now being asked is whether the feeding programme should be designed to meet the needs of the actual, current productivity, or should it be designed to push the envelope and allow the herd to move forward in both performance and profit (Patience and Zilstra, 2004)? The above literature review gives a brief introduction to the variables involved in pig production. The subsequent three chapters test three of these feeding strategies; namely, phase feeding, choice feeding and feeding according to genotype.

CHAPTER 2

PHASE FEEDING AS A MEANS OF MEETING THE AMINO ACID REQUIREMENTS OF GROWING PIGS

2.1 Introduction

The requirement for nutrients, more specifically amino acids, by a growing pig change constantly as the pig grows. Ferguson (1989) showed that the requirements for most amino acids decrease curvilinearly over time and this is shown graphically in Fig. 2.1.

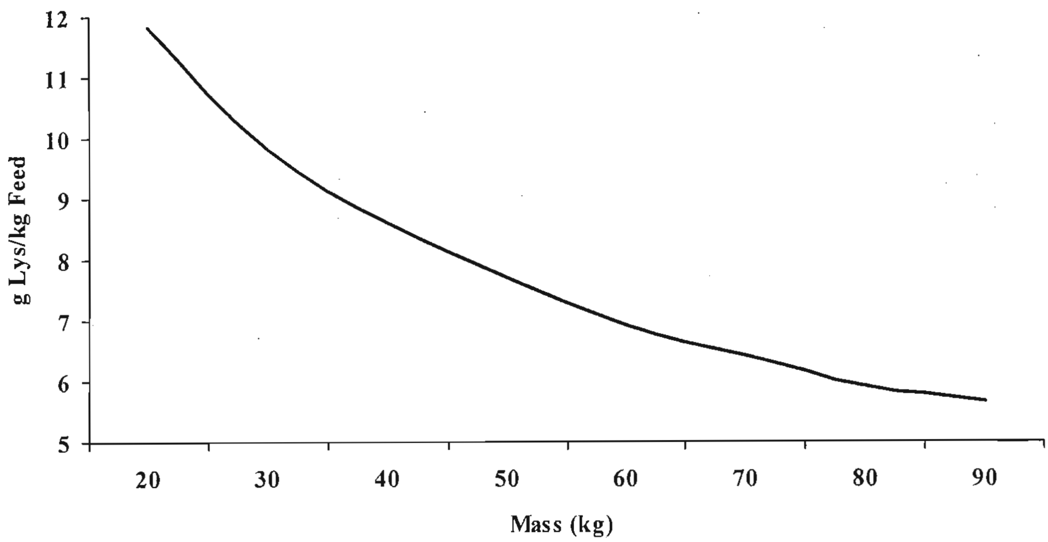


Figure 2.1 *The changing requirements for dietary lysine (g/kg feed) over time for growing pigs calculated using the EFG Pig Growth Model (Ferguson, 1989).*

It is evident from Fig. 2.1 that it would be unwise both biologically and economically to feed only one feed to pigs over their entire growth period, as the amino acids supplied in the feed would initially be below the requirement, and would later be above the requirement. The consequences of under-and over-feeding amino acids are well documented (Harper *et al.* 1970, Lewis, 1991, Whittemore, 1993). It is common practice, therefore, to change the composition of the feed offered to the pigs during the growing period, the choice of the amino acid supply to be used in each phase, the length of time (or the amount) that each feed should be fed, and the number of phases to be used to maximise profit should be based on both biological and economic criteria.

Previous experiments done by Bradford and Gous (1991b) have shown that the application of a phase feeding schedule, which involves offering a series of feeds that closely match the changing requirements of the pigs at different stages of the growing period, could improve the ultimate performance of the herd of pigs. In the same experiment Bradford and Gous (1991a) offered a group of growing pigs simultaneously two feeds differing in nutrient content, thus allowing the pigs to choose the appropriate combination of the two feeds. They found that the pigs differentiated between the two feeds, with the protein content in the blend chosen being similar to the predicted requirement of the pigs during the growing period. However, such a feeding method ignores the economic aspect of the decision-making process, as the pigs have no knowledge of the relative costs of the two feeds being offered. Consequently, choice feeding may result in lower profits in spite of the pigs being leaner and more efficient.

The ultimate objective of the producer is to minimize the cost to gain ratio and this may only be guaranteed using the phase-feeding method of meeting the changing amino acid requirements of the pig during the growing period. However, because so many factors interact to determine the response of growing pigs to feeds and feeding treatments, it is unlikely that any one feeding experiment would identify the most cost-effective feeding programme. The objective of this experiment was to compare three phase feeding programmes designed to meet the changing amino acid requirements of male and female pigs during the growing period, using three feeding periods.

2.2 Materials and Methods

2.2.1 Experimental Design

The two factors used in this experiment were sex (two levels: entire males and females) and dietary lysine content (nine levels: 11.0, 9.93, 8.85, 8.68, 7.58, 7.26, 6.48, 6.24 and 5.22g lysine/kg feed) in a randomized blocks design.

2.2.2 Animal Description and Management

A total of 144 commercial crossbred (Large White x Landrace) pigs – 72 entire males and 72 gilts were used in the trial. On arrival at Ukulinga (28 July 2003), all pigs were weighed and then randomly allocated to one of the three dietary treatments in three blocks, according to weight. Eight pigs were randomly allocated to each pen, with males and females kept separately, thereby utilizing 18 pens. Each pig was identified with an ear tag. Pigs were given *ad libitum* access to the feeds and water. Individual body weights were measured twice weekly before the trial began to determine the starting point for each pen, this being when the median body weight of the pen reached 20kg. Body weights were measured weekly thereafter to determine individual growth rates and the mean and median weekly weights for each pen. The trial ended as the median body weight of each pen of pigs reached 85kg, when the pigs in that pen were removed from the trial and taken to the Baynesfield abattoir-the last pen of pigs taking 14 weeks to reach this weight.

2.2.3 Housing

The trial was conducted at Ukulinga Research Farm. The pigs were housed in a curtain-sided building with an insulated roof. Each of the 18 pens had 6.86m^2 of available space, i.e. pen area less the space taken up by the feeders, and was provided with two nipple drinkers and two Big Dutchman self-feeding bins placed side by side. The pens were arranged in two rows of nine pens. The pigs were subjected to a 16L: 8D lighting regimen.

2.2.4 Treatments and Feeds

The amino acid requirements (g/d) were determined for Large White x Landrace males and females from 20 to 90 kg live weight, using the EFG Pig Growth Model and parameter values described in Table 2.1 (Ferguson and Kyriazis, 2003).

Table 2.1 *Parameter values used to describe the genotype used in this trial*

Sex	Rate of maturing, B (/d)	Mature protein weight, Pmat (kg)	Lipid: protein ratio at maturity, LPmat (g/g)
Male	0.0107	39.0	2.60
Female	0.0120	28.0	3.89

Assuming a dietary DE content of 13.80 MJ/kg, these amino acid requirements were converted to dietary concentrations for each week of the growing period from 20kg – 90kg, and these are given in Table 2.2 for females and Table 2.3 for males.

Table 2.2 *Predicted amino acid requirements (g/kg) of female pigs at a DE of 13.8MJ/kg at weekly body weight intervals from 20 to 88 kg live weight*

BW (kg)	Lys	Met +Cys	Thr	Trp	Ile	Leu	His	Phe +Tyr	Val
20	10.8	7.1	7.3	2.0	6.4	11.7	4.1	12.9	8.0
24	9.9	6.6	6.7	1.8	5.9	10.7	3.8	11.9	7.3
28	9.1	6.1	6.2	1.7	5.4	9.8	3.5	10.9	6.7
33	8.4	5.6	5.7	1.5	5.0	9.1	3.2	10.1	6.2
38	7.7	5.2	5.3	1.4	4.6	8.4	2.9	9.3	5.7
43	7.2	4.8	5.0	1.3	4.2	7.7	2.7	8.6	5.3
49	6.7	4.5	4.6	1.2	3.9	7.2	2.5	8.0	4.9
55	6.2	4.3	4.3	1.2	3.7	6.7	2.4	7.5	4.6
61	5.8	4.0	4.1	1.1	3.4	6.2	2.2	7.0	4.3
67	5.5	3.8	3.9	1.0	3.2	5.9	2.1	6.6	4.0
74	5.2	3.6	3.7	1.0	3.0	5.5	2.0	6.2	3.8
81	4.9	3.4	3.5	0.9	2.9	5.2	1.9	5.9	3.6
88	4.7	3.3	3.3	0.9	2.7	4.9	1.8	5.6	3.4

Two basal feeds were formulated, both at a DE of 13.8 MJ/kg; the first being a high protein feed (Basal A) designed to meet the amino acid requirements of a male at 20 kg live weight, and the second, (Basal B), a low protein feed, designed to meet the requirements for a female at 88 kg, the rationale being that the requirements of all pigs on trial could be met by blending these two basal feeds appropriately. The ingredient composition of the two basal feeds is presented in Table 2.4 and the chemical composition by formulation and laboratory analysis in Table 2.5.

Table 2.3 *Predicted amino acid requirements (g/kg) of male pigs at a DE of 13.8 MJ/kg at weekly body weight intervals from 20 to 89 kg live weight*

BW (kg)	Lys	Met +Cys	Thr	Trp	Ile	Leu	His	Phe +Tyr	Val
20.0	12.7	8.4	8.6	2.3	7.6	13.8	4.8	15.3	9.4
23.8	12.0	7.9	8.1	2.2	7.1	13.0	4.5	14.3	8.9
27.9	11.2	7.4	7.6	2.1	6.7	12.2	4.3	13.5	8.3
32.5	10.6	7.0	7.2	1.9	6.3	11.5	4.0	12.7	7.8
37.5	10.0	6.6	6.8	1.8	5.9	10.8	3.8	12.0	7.4
42.9	9.4	6.3	6.4	1.7	5.6	10.2	3.6	11.3	6.9
48.6	8.9	6.0	6.1	1.6	5.2	9.6	3.4	10.7	6.5
54.7	8.4	5.7	5.8	1.6	5.0	9.0	3.2	10.1	6.2
61.0	8.0	5.4	5.5	1.5	4.7	8.6	3.0	9.6	5.9
67.7	7.6	5.2	5.3	1.4	4.5	8.1	2.9	9.1	5.6
74.6	7.2	4.9	5.0	1.3	4.2	7.7	2.7	8.7	5.3
81.7	6.9	4.7	4.8	1.3	4.0	7.4	2.6	8.3	5.0
89.0	6.6	4.6	4.6	1.2	3.9	7.0	2.5	7.9	4.8

Table 2.4 *Composition of the two basal feeds (g/kg) used in the trial*

Ingredient	Basal A	Basal B
Maize	272	795
Soybean 44	664	120
Sunflower 37	0	46.4
Vit + Min premix	3.10	3.10
Limestone	0	22.9
Salt	2.90	2.01
Monocalcium Phosphate	56.0	4.35
Sodium Bicarbonate	2.10	5.62

Table 2.5 *Composition (g/kg) of the basal feeds as determined by formulation (digestible) and chemical analysis (as is)*

	Basal A		Basal B	
Nutrient	Calculated	Chemical	Calculated	Chemical
DE (MJ/kg)	13.8	13.7	13.8	14.2
Protein	30.2	33.7	12.4	13.7
Lysine	16.7	20.9	5.00	6.20
Methionine	4.06	3.41	2.28	1.65
Threonine	10.5	11.7	4.33	4.76
Arginine	21.7	24.0	7.96	8.19
Isoleucine	13.0	16.0	4.90	5.89
Leucine	22.7	26.6	12.9	13.0
Histidine	7.62	7.88	3.46	3.25
Phenylalanine	13.7	18.5	5.76	7.31
Valine	13.7	17.2	6.16	7.06
Ash	43.1	94.0	41.8	54.3
Crude Fibre	55.8	104.0	34.9	105.6
Crude Fat	14.5	18.9	29.1	21.4
Calcium	10.9	10.3	9.50	9.30
Phosphorus	18.8	16.7	4.50	3.40

A 3 x 2 factorial design was applied, i.e. three treatments and two sexes. The changing lysine requirements were used as a basis for deciding on a phase feeding schedule. The three phase-feeding treatments were designed to meet the amino acid requirements of males (Treatment one), mixed sexes (Treatment two) and females (Treatment three) by specifying three phases, based on the body weight of the growing pigs (20 – 40; 40 – 60; and 60 – 85kg respectively), and the mean lysine requirement within each phase for the three sex categories, respectively. The lysine contents chosen for each phase for the three treatments are given in Table 2.6. The three treatments were each replicated three times for both sexes.

Table 2.6 *Lysine contents (g/kg) of feeds offered to male and female pigs during three growth phases*

Dietary Treatment	Phase 1 20 – 40kg	Phase 2 40 - 60kg	Phase 3 60 - 85kg
T1	11.0	8.68	7.26
T2	9.93	7.58	6.24
T3	8.85	6.48	5.22

Basal feeds A and B were blended, using the summit-dilution technique, in order to produce the nine feeds used in the phase-feeding treatments (Table 2.7).

Table 2.7 *Blending proportions of Basal feeds A and B in the different growth phases. (Numbers in parenthesis indicate feed number used in trial)*

Growth phase	T1	T2	T3
1	55A: 45B (1)	40A: 60B (2)	30A: 70B (3)
2	30A: 70B (4)	20A: 80B (5)	10A: 90B (6)
3	20A: 80B (7)	10A: 90B (8)	5A: 95B (9)

2.2.5 Calculation of Data

Records kept during the trial, as well as calculations performed are summarized below:

Records kept were the body weights at the start of trial, and weekly thereafter, weekly food intakes, and mortality when this occurred. Records were also kept of the pigs that became sick and subsequently died. At the end of the experimental period, measurements made at the abattoir were slaughter weight, grade and P2 back fat thickness.

Calculations made:

- Average daily gain, g/pig d
- Feed intake, g/pig d
- Feed conversion efficiency, g gain/kg feed consumed
- Period from 20kg to slaughter weight, d
- Cost of feeding, 20-85kg, R/pig
- Cost/kg gain, R/kg

The Genstat Statistical Programme was used to calculate Average Daily Gain (ADG) by fitting a linear regression to the weekly body weights. Feed Intake (FI) was calculated by subtracting the feed remaining each week from the total feed supplied. This was then totaled and divided by the number of days that each specific pen was on trial. Feed Conversion Efficiency (FCE) was calculated by dividing the ADG by the FI. Feeding cost was calculated by multiplying the FI by the cost of the feed. This value was then divided by the ADG, the quotient being the cost per kilogram gain. Total feeding cost was determined by multiplying the daily feeding cost by the number of days on trial. The age of pigs at the start of the trial and the date of slaughter of each pen was recorded to calculate the time taken to reach slaughter weight.

Two equations of Whittemore (1987) were used to determine the total body lipid content of the pigs from their P2 back fat measurement, and the fat depth (Fd).

$$P2 = 0.91Fd + 0.5 \quad (1)$$

$$Fd = 0.89Lt \quad (2)$$

Where P2 (mm) is skin and fat depth, Fd (mm) is fat depth and Lt (kg) is the total body lipid content. Combining these two equations and rearranging yields an equation that determines Lt (kg)

$$Lt = 1.2457(P2 - 0.5) \quad (3)$$

The percentage lean in the carcass was determined using the following equation of Whittemore (1987):

$$\text{Percentage Lean} = 63 - 0.51\ P2 \quad (4)$$

The classification of the Pork Grading System can be found in Appendix Table 1. The price paid for each grade at the time of the trial can be found in Appendix Table 2.

The data were subjected to a 2-way ANOVA using a model from Genstat 6th Edition (Lawes Agricultural Trust, 2002), with feeding treatment and sex as the factors.

2.3 Results

The average body weight at the start of the trial was 20.4 ± 0.19 kg and at the end of the trial 85.6 ± 0.49kg.

Average daily gain (ADG), feed intake (FI), back fat thickness, FCE, time taken to reach 85kg (slaughter weight) and cost/kg gain are presented in Table 2.8.

The only parameters found to show significance were ADG and time taken to reach slaughter weight. There were no significant differences among treatments in FI, back fat thickness, FCE or cost/kg gain. Average daily gain exhibited a significant sex x treatment interaction. Males on T3 had the highest ADG (839g/d) with males on T1 having the lowest (717g/d). There were significant differences among treatments for time taken to reach slaughter weight, with T3 (80.5 d) being shorter than T1 and T2 (87.7 d and 87.0 d, respectively). The sex x treatment interaction for time to slaughter weight was also significant. Males on T1 took 90.0 days to reach slaughter weight, which was the longest time on trial whereas males on T3 grew the fastest and took only 77.3 days to reach 85kg. The highest feed intake was by males on T2 (1964g/d). Back fat thickness was not influenced significantly by treatment. It is also interesting to note similarity between male and female pigs. Males consuming T2 converted feed into body tissue with the greatest efficiency (463g gain/kg feed). Males on T3 had the highest cost/kg gain (R5.02).

The mean carcass composition as determined from equations by Whittemore is presented in Table 2.9. As with the previous results there were no significant differences found in any of the carcass characteristics among feeding treatments.

The cost of the feeds (R/ton) used in the trial are presented in Table 2.10 and the cost of feeding the pigs over the trial period is presented in Table 2.11. The feed cost includes transport and mixing fees. The amount of protein in a diet affects the cost of that diet and this can be seen in Table 2.10. T1 had the highest protein content and thus was the most expensive treatment. This followed through to Table 2.11 where again pigs on T1 had the highest feeding cost (R376/pig) and pigs on T3 the lowest (R331/pig).

Table 2.8 *The mean Average daily gain (ADG), Feed intake (FI), Feed conversion efficiency (FCE), Back fat thickness, time taken to 85kg and cost/kg gain of male and female pigs on the three dietary treatments*

Treatment	Sex	ADG (g/d)	FI (g/d)	FCE (g gain/kg feed)	Back fat Thickness (mm)	Time taken to 85kg (days)	Cost/kg Gain (R)
T1	M	717	1800	400	12.5	90.0	11.05
	F	775	1784	437	11.3	85.3	5.67
	Mean	746	1792	419	11.9	87.7	8.36
T2	M	803	1739	463	11.5	84.7	5.41
	F	753	1896	397	11.6	89.3	6.14
	Mean	778	1817	430	11.6	87.0	5.78
T3	M	839	1964	428	11.9	77.3	5.02
	F	764	1955	391	11.9	83.7	5.34
	Mean	801	1960	409	11.9	80.5	5.18
Grand Mean		775	1856	419	11.8	85.1	6.44
Mean	M	786	1834	430	11.9	84.0	7.16
	F	764	1878	409	11.9	86.1	5.72
RMS		1646	13261	1239	0.712	12.61	137
SED (T)		23.42	66.5	20.3	0.487	2.05	1.80
SED (S)		19.12	54.3	16.6	0.398	1.67	1.47

Table 2.9 *The mean proportions of lean and lipid in the carcass, and the total weight of body lipid as determined from equations by Whittemore (1987) for the three treatments and both sexes*

Treatment	Sex	Carcass Lean (g/kg)	Carcass lipid (g/kg)	Total body lipid (kg)
T1	M	566	170	14.9
	F	572	156	13.4
	Mean	569	163	14.2
T2	M	571	157	13.7
	F	571	160	13.8
	Mean	571	159	14.2
T3	M	570	166	14.1
	F	569	165	14.2
	Mean	570	166	14.2
Grand Mean		570	162	14.0
Mean	M	569	164	14.2
	F	571	161	13.8
RMS		17.9	145	1.08
SED (T)		2.45	6.95	0.600
SED (S)		2.00	5.68	0.490

Table 2.10 *Cost of feed (R/ton) used in the trial*

Treatment	Phase 1 (20-40kg)	Phase 2 (40-60kg)	Phase 3 (60-85kg)
T1	2451	2218	2125
T2	2311	2124	2031
T3	2217	2031	1985

Table 2.11 *The cost of feeding pigs (R/pig) over the trial period*

Treatment	Sex	Feeding Cost (R/pig)
T1	M	380
	F	372
	Mean	376
T2	M	311
	F	366
	Mean	338
T3	M	319
	F	344
	Mean	331
Grand Mean		349
Mean	M	337
	F	361

2.4 Discussion

It is important to identify the objective of the trial and determine whether this was met. Unfortunately some of the results of the trial did not follow the expected outcome. It was expected that males on T1 and females on T3 would exhibit the most efficient performance for their respective sex since these treatments were specifically formulated to meet their requirements. However, productivity of the males on T1 was significantly poorer than on any other treatment. Midway through the trial the pigs contracted enteritis and there were 8 mortalities. It was found that the supplier had not administered the second dosage of M+PAC©, which is a preventative antibiotic given to pigs at weaning. This resulted in the pigs being abnormally at risk of bacterial infection. Following antibiotic treatment the growth of the affected pigs was lower than normal and this would have had an effect on the outcome of the trial. A chi-square test was performed in order to determine whether the mortality was due to the treatment imposed, but the result indicated that this was not the case (Chi Square - 1.853, p-value 0.763). Thus, the disease affected the outcome of the trial by inhibiting the potential growth of the pigs, and may have affected males on T1 more than pigs on other treatments. A sick pig cannot grow as well as a healthy one as there is the added burden of bacterial contamination.

Females on T1 and males on T3 performed better than the opposite sexes on these treatments, which was converse to the expected outcome, and could well have been due to the disease outbreak during the trial. Pigs on T3 had the best overall ADG (801g/d) compared to those on T1 (746g/d). However, pigs on T1 converted feed into body protein with a greater efficiency than those on T3 (419 *vs.* 409 g gain/kg feed), although this was not statistically significant. This can be explained by the higher protein (amino acid) content in T1 compared to those in T3. The higher protein content of T1 may also explain the lower feed intake by the pigs on this treatment compared with those on T3. They were able to eat less of the feed in order to satisfy their requirements. When looking at back fat thickness it is very interesting to note the similarity among all treatments and between sexes. This is an indication of significant genetic progress that has been made and may allow more variability when formulating diets since the females may not be as different from the males as was previously thought.

Males on T1 had a very high cost/kg gain (R11.05) and this is due to their slow growth rate and resultant low FCE. This high value was influenced by the exceptionally poor growth rate in the fourth week of the trial which offset the average cost/kg gain for the trial period. These pigs were also on trial for the longest time period (90 days), therefore consuming an overall greater amount of food, but not making the expected weight gains for such a high FI. This poor performance was probably brought about by the enteritis infection that may have affected them more severely than it did other pigs in the trial. The sex x treatment interaction in ADG and time to reach 85kg was also the result of the lower-than-expected growth rates of males on T1. Females on all three treatments grew at the same rate, whereas growth rate in the males was inversely proportional to the protein content of the feed on offer. Looking back at the diet offered to the pigs, the soybean content was much higher than the recommended inclusion. The gastro-intestinal tract of young pigs is still developing physiologically and may be unable to withstand higher than normal levels of protein. This may have been the cause of the high incidence of diarrhoea, which may have then contributed to the susceptibility to enteritic infection.

Because of the unexplained poor performance of males on T1, conclusions regarding the most cost-effective feeding programme to use should be made without considering males on this treatment. The male pigs on T3 reached slaughter weight faster than those on T2 (77.3 d *vs.* 84.7 d), therefore ultimately consuming less feed and hence having a better cost/kg gain (R5.02 *vs.* R5.41). The back fat thickness, although not significant, was less on T2 compared to T3 and had the treatments varied more in their protein content, there may have been a larger difference in the back fat measurements.

If the females only are considered, T3 had the lowest cost/kg gain (R5.34) and T2 the highest (R6.14), so in this case, the feeding programme designed for the females proved to be the most cost-effective. The cost of protein is the important factor in this case, as food intake on T3 was 171g/d higher than on T1 yet feeding cost was R28/pig lower. As with the male pigs, back fat thickness and fat content increased as dietary protein content was reduced, and this may have resulted in downgrading had the differences been greater, resulting in lower revenue for the females on the lowest protein feed. However, in this case all females fell within the same grade, with back fat thicknesses increasing from 11.3 through 11.6 to 11.9 on T1, T2 and T3, respectively.

The performance of males on T1 was contrary to expectations and previous reports in that they took longer to reach the final weight and they had the highest lipid contents, in other words, their performance should not be considered when drawing conclusions from this trial. The fact that pigs on the lowest protein feed program reached the target weight before the others was partly due to their higher rate of daily feed intake on that treatment. This is expected, in that the pigs would have been attempting to consume sufficient of the limiting nutrient; and in so doing they should have been fatter than those on the highest protein feed. This they were, but only marginally so. Some doubt must be expressed about the performance on the high protein feed; generally, pigs and poultry do not perform as well on feeds with excessive amounts of protein, as energy becomes limiting (Kyriazakis and Emmans 1992a, Gous and Swatson, 2000), thereby reducing the efficiency with which protein is utilised by the animal.

Following completion of the trial it was discovered that the protein content of the high protein feed was higher than it needed to be, because an incorrect amount of isoleucine was specified in the feed. This was due to a fault in the EFG Pig Growth Model that swapped the requirements for isoleucine and leucine. The results indicate that this must have played some role in reducing the performance of the pigs on this treatment, and even that on some of the blends between the high and the low protein feeds. The fact that performance was best on the low protein feed should therefore not be regarded as being a common truth, but would be specific to this trial, where the high protein feed could be regarded as being unnecessarily high in protein.

It was also discovered after the trial that the diets offered to the pigs were not balanced in terms of the calcium:phosphorus ratio. When formulating Basal A limestone was inadvertently left out of the ingredients offered and hence a high level of monocalcium phosphate was used, thus unbalancing the ratio between calcium and phosphorus, with a new Ca:P ratio of 1:1.7. This unbalanced ratio may explain the results obtained. The required Ca:P ratio is 2:1 (NRC, 1998.). A low level of calcium results in poor growth of the pig (NRC, 1998). It may also influence the availability of magnesium and zinc (NRC, 1998). It has been shown that the ratio is less critical if the diet contains excess phosphorus (Prince *et al.* 1984, Hall *et al.* 1991).

From the results of this trial it can be said that the protein level of the diet will affect the time taken to reach slaughter weight. It is also important to note the interaction between sex and treatment. The two sexes utilised their feed differently. The aim of any pork producer is to have efficient growth of his pigs. With the cost of feeding being so high, the pigs need to eat the minimum amount of food, but have the maximum amount of growth. This can be achieved by ensuring adequate levels of protein in the diet throughout the growing period.

CHAPTER 3

THE EFFECT OF CONSTANT OR CHANGING DIETARY PROTEIN CONTENTS ON THE PERFORMANCE OF GROWING PIGS

3.1 Introduction

In the first trial reported in this thesis the feeding schedule was designed to meet the protein requirements of the male and female pigs based on outputs from the EFG Pig Growth Model. Pigs were fed diets varying in protein content throughout their growing period. Research by Fowler (1984) has shown that the response in daily lean tissue growth to increasing protein supply is linear until energy becomes limiting or protein supply becomes excessive to the demands of the animal to achieve its maximum rate of daily lean tissue growth. Whittemore (1985) depicted the response to increasing protein concentration in Figure 3.1 below.

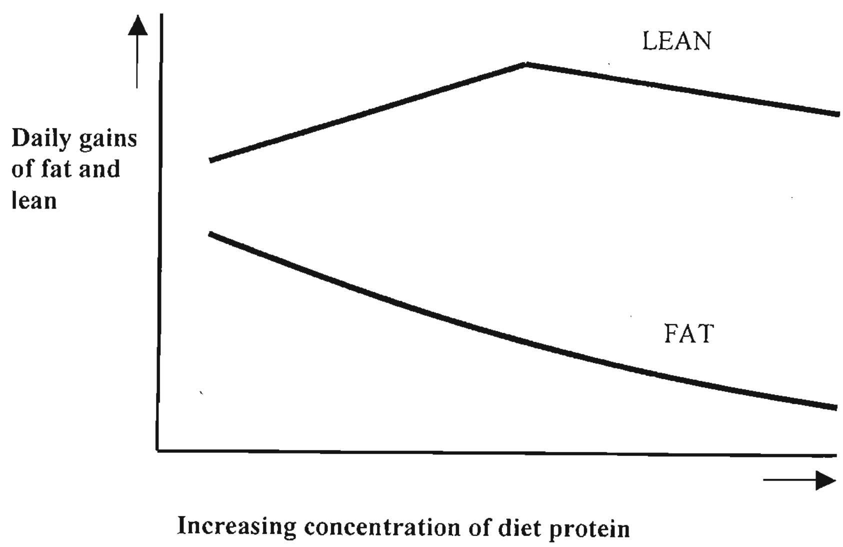


Figure 3.1 *Influence of increasing concentration of protein in the diet (a widening of the ratio MJ DE:g CP) upon the daily gains of fat and lean tissues (Whittemore, 1985).*

This figure indicates how diets that do not provide adequately for the requirement of ideal protein fail to allow maximum lean tissue growth (Whittemore, 1985). Had dietary protein supply been adequate, energy would have been used for protein synthesis; inadequate protein in the diet results in more energy being available for fat synthesis. If the diet contains an excess level of protein, energy is used for deamination and excretion, thereby decreasing the net pool of energy available to the body for potential fat synthesis. The animal is therefore leaner (Whittemore, 1985). This figure allows for a clearer understanding of the poor results of the previous trial.

The objective of this trial was to determine the most profitable method of feeding growing pigs by testing the above research results. The use of extreme differences in dietary protein content would give an indication of the range in carcass lipid contents and days to slaughter weight that could be expected of pigs of the strain used in this trial. The inclusion of a phase feeding treatment would enable a comparison to be made of constant *vs.* changing protein contents during the growing period, and could be used to determine the optimum economic method of feeding growing pigs.

3.2 Materials and Methods

3.2.1 Experimental Design

Four dietary treatments were used in this experiment, namely three fixed dietary lysine contents (12.7, 8.7 and 4.7g/kg) and a phase-feeding treatment. Two sexes were used, resulting in a 4 x 2 randomized blocks design.

3.2.2 Animal Description and Management

A total of 192 commercial crossbred (Large White x Landrace) pigs – 96 entire males and 96 gilts were used in the trial. On arrival at Ukulinga (21 November 2003), all pigs were weighed and then randomly allocated to one of the four dietary treatments in two blocks, according to weight. Eight pigs were randomly allocated to each pen, with males and females being kept separately, thereby utilizing 24 pens. Each pig was identified with an ear tag. Pigs were given *ad libitum* access to the feeds and water. Individual body weights were measured twice-weekly before the trial began to determine the starting point for each pen, this being when the median body weight of the pen reached 20kg. Body weights were measured weekly thereafter to determine individual growth rates and the mean and median weekly weights for each pen. The trial ended when the median weight of the pen reached 85kg when the pigs in that pen were removed from the trial and taken to the Baynesfield abattoir. The trial lasted 14 weeks.

3.2.3 Housing

The trial was conducted at Ukulinga Research Farm. The pigs were housed in a curtain-sided building with an insulated roof. Each of the 24 pens had 6.86m^2 of available space, i.e. pen area less the space taken up by the feeders, and was provided with two nipple drinkers and two Big Dutchman self-feeding bins placed side by side. The pens were arranged in two rows of twelve pens. The pigs were subjected to a 16L: 8D lighting regimen.

3.2.4 Treatments and Feeds

The amino acid requirements (g/d) of male and female Large White x Landrace pigs between 20 and 85kg live weight, were determined using the EFG Pig Growth Model and parameter values described in Table 2.1

The two basal feeds used in this trial are the same as used in the previous trial, these being presented in Tables 2.4 and 2.5.

Three of the four treatments followed a fixed feeding schedule, making use of the two basal feeds and a 1:1 blend of these. The fourth treatment followed a phase feeding schedule, thereby allowing the changing protein requirements of the pig over time to be met with greater accuracy. The four treatments, and their respective feeding schedules, together with the proportions of Basal A and Basal B fed to male and female pigs, are given in Table 3.1.

Table 3.1 *A description of the four dietary treatments and the proportions of each basal feed used over the growing period for male and female pigs*

Treatment	Feeding period, kg body weight		Proportions used	
	Males	Females	Basal A	Basal B
T1	20 - 85	20-85	1.00	
T2	20 - 85	20-85	0.50	0.50
T3	20 – 85	20-85		1.00
T4	20 – 65	20-35	1.00	
	65 - 75	35-75	0.50	0.50
	75 - 85	75-85		1.00

The phase feeding schedules used in treatment 4 were designed, according to the lysine requirements as calculated by the EFG Pig Growth Model, to meet as closely as possible the requirements of male and female pigs, respectively, using only three phases and using only basal A, basal B and a 1:1 blend of the two.

3.2.5 Calculation of Data

Records kept during the trial, as well as calculations performed are summarized below:

Records kept were the body weights at the start of trial, and weekly thereafter, weekly food intakes, and mortality when this occurred. Records were also kept of the pigs that became sick and subsequently died. At the end of the experimental period, measurements made at the abattoir were slaughter weight, grade and P2 back fat thickness.

Calculations made:

- Average daily gain, g/pig d
- Feed intake, g/pig d
- Feed conversion efficiency, g gain/kg feed consumed
- Period from 20kg to slaughter weight, d
- Cost of feeding, 20-85kg, R/pig
- Cost/kg gain, R/kg

The Genstat Statistical Programme was used to calculate Average Daily Gain (ADG) by fitting a linear regression to the weekly body weights. Feed Intake (FI) was calculated by subtracting the feed remaining each week from the total feed supplied. This was then totaled and divided by the number of days that each specific pen was on trial. Feed Conversion Efficiency (FCE) was calculated by dividing the ADG by the FI. Feeding cost was calculated by multiplying the FI by the cost of the feed. This value was then divided by the ADG, the quotient being the cost per kilogram gain. Total feeding cost was determined by multiplying the daily feeding cost by the number of days on trial. The age of pigs at the start of the trial and the date of slaughter of each pen was recorded to calculate the time taken to reach slaughter weight.

The equations of Whittemore (1987) were used to determine the total body lipid content of the pigs from their P2 back fat measurement, and the fat depth (Fd). A description of these equations are in Chapter 2, paragraph 2.2.5.

The classification of the Pork Grading System is in Appendix Table 1. The price paid for each grade at the time of the trial is in Appendix Table 2.

The data were subjected to a 2-way ANOVA using a model from Genstat 6th Edition (Lawes Agricultural Trust, 2002), with feeding programme, sex and strain as the variables.

3.3 Results

The average body weight at the start of the trial was 20.8 ± 0.24 kg and at the end of the trial 85.1 ± 0.46 kg. Average daily gain (ADG), feed intake (FI), feed conversion efficiency (FCE), back fat thickness, time taken to reach 85kg (slaughter weight) and cost/kg gain are presented in Table 3.2 for each of the four feeding treatments and two sexes. There were no significant effects of sex and no interactions between feeding treatments and sex.

All the parameters were significantly affected by the feeding treatments. Pigs on T3 had significantly slower growth rates ($P<0.05$) than those on T2 and T4. Pigs on T2 had the highest ADG (784g/d) and T3 the lowest (636g/d), these differences being significant at $P<0.05$. Feed intake of pigs on T4 was significantly higher ($P<0.05$) than on T2 and T3. Females on T4 had the highest FI (2018g/d) and males on T2 the lowest (1744g/d). It follows from the ADG and FI that the highest FCE (438g gain/kg feed), would have been on T2, and this proved to be significantly higher ($P<0.05$) than that of the other three treatments. There was a significant difference in back fat thickness, with pigs on T3 (13.7mm) having significantly more fat ($P<0.05$) than those on T1, T2 and T4 (11.1mm, 11.2mm and 1 1.1mm, respectively). Pigs on T3 took significantly longer ($P<0.05$) to reach slaughter weight compared to those on T1, T2 and T4 (98.2 d *vs.* 90.0d, 82.8d and 85.2d, respectively). The cost/kg gain was significantly affected by treatment with T1 and T4 costing significantly higher than T2 and T3 ($P<0.05$). T3 had the lowest cost/kg gain (R6.12/kg) with T1 having the highest (R8.31/kg). The feed cost includes transport and mixing fees. The feeding cost of the four treatments varied considerably, with T1 being the highest (R480/pig) and T3 the lowest (R362/pig).

Table 3.2 *Average daily gain (ADG), Feed intake (FI), Feed conversion efficiency (FCE), Back fat thickness, time taken to reach 85kg and cost/kg gain for male and female pigs on the four dietary treatments*

Treatment	Sex	ADG (g/d)	FI (g/d)	FCE (g gain/kg feed)	Back fat Thickness (mm)	Time taken to 85kg (d)	Cost/kg gain (R)	*Feeding Cost (R/pig)
T1	M	717	1877	382	10.6	91.0	8.54	497
	F	707	1881	375	11.6	89.0	8.08	464
	Mean	712	1879	379	11.1	90.0	8.31	480
T2	M	784	1744	450	10.7	81.7	6.47	360
	F	784	1843	426	11.7	84.0	5.77	376
	Mean	784	1794	438	11.2	82.8	6.12	370
T3	M	623	1899	330	14.8	98.0	6.24	351
	F	649	1831	356	12.7	98.3	6.33	373
	Mean	636	1865	343	13.7	98.2	6.29	362
T4	M	745	1987	374	10.0	86.3	8.38	454
	F	779	2018	387	12.1	84.0	6.67	417
	Mean	762	2003	381	11.1	85.2	7.53	436
Grand Mean		723	1885	385	11.8	89.0	7.06	411
Mean	M	717	1877	384	11.5	89.2	7.41	415
	F	730	1893	386	12.0	88.8	6.72	407
RMS		4573	11165	1390	2.47	43.6	14.0	16082
SED (T)		39.0	61.0	21.5	0.907	3.81	0.557	18.9
SED (S)		27.6	43.1	15.2	0.642	2.70	0.394	13.4

* Cost of Basal A R2.87/kg, and of Basal B R1.94/kg

Carcass lean, carcass lipid and total body lipid, calculated with the use of the equations of Whittemore (1987) are given in Table 3.3. All three parameters were affected by the treatments with T3 being significantly higher (P<0.05) than the other three treatments for carcass lipid and total body lipid, and significantly lower (P<0.05) for carcass lean. Pigs on T1, T2 and T4 did not differ significantly with respect to these carcass characteristics.

Table 3.3 *The mean proportions of lean and lipid in the carcass, and the total weight of body lipid as determined using equations of Whittemore (1987) for the four feeding treatments and two sexes*

Treatment	Sex	Carcass lean (g/kg)	Carcass lipid (g/kg)	Total body lipid (kg)
T1	M	576	146	12.6
	F	571	165	13.9
	Mean	573	155	13.2
T2	M	576	145	12.6
	F	570	163	13.9
	Mean	573	154	13.2
T3	M	555	210	17.8
	F	566	179	15.1
	Mean	560	194	16.5
T4	M	579	136	11.8
	F	568	168	14.5
	Mean	573	152	13.2
Grand Mean		570	164	14.0
Mean	M	571	159	13.7
	F	569	169	14.3
RMS		63.46	504	3.83
SED (T)		4.60	13.0	1.13
SED (S)		3.25	9.16	0.799

The outputs expected from the trial by the EFG Pig Growth Model are listed in Table 3.4 below.

Table 3.4 *A comparison of the feed intakes (g/d), time taken to reach slaughter weight (d), cost/kg gain (R/kg) and back fat thickness (mm) of male and female pigs on four feeding treatments with that predicted by the EFG Pig Growth Model*

Variable	Treatment	Male response		Female response	
		Predicted	Actual	Predicted	Actual
Feed intake	T1	1643	1877	1928	1881
	T2	1652	1744	1843	1843
	T3	1987	1899	1831	1831
	T4	1686	1987	2018	2018
Time to slaughter weight	T1	86	91	86	89
	T2	82	82	90	84
	T3	98	98	93	98
	T4	86	86	87	84
Cost/kg gain	T1	6.08	8.54	7.24	8.08
	T2	5.62	6.47	5.96	5.77
	T3	5.80	6.24	5.81	6.33
	T4	5.81	8.38	6.05	7.53
Back fat thickness	T1	13.6	10.6	16.4	11.6
	T2	16.6	10.7	16.9	11.7
	T3	23.2	14.8	24.3	12.7
	T4	14.8	10.0	17.1	12.1

This above table shows the wide variation between the predicted and actual responses for the listed variables.

3.4 Discussion

This trial was conducted to determine the extent to which differences in growth rate, food intake and carcass lipid (as measured by back fat thickness) could be altered by dietary means. In three of the feeding treatments used, a constant level of protein (high, medium and low) was fed throughout the growth period, resulting in protein excess throughout, an initial period of deficiency followed by protein being provided in excess of requirements, and a protein deficiency throughout. There are countless examples in the literature describing the implications of supplying a diet too high or too low in protein (Yen *et al.* 1986; Fabian *et al.* 2002). The pig has an elevated tolerance for high protein intakes and shows few problems, with the exception of mild diarrhoea (NRC, 1998) and the possibility of a reduction in the efficiency with which it utilises the protein, when the energy:protein ratio falls below a critical value (Kyriazakis and Emmans, 1992a). But, a high protein diet is expensive and results in under-utilization of the amino acids supplied i.e. amino acids in excess of requirement are excreted. A low protein diet, on the other hand, may result in an increased or a decreased feed intake, depending on the extent of the deficiency, and this invariably leads to impaired growth and general unthriftiness. A low amino acid supply will always lead to a greater fat deposition, as energy is being consumed in excess of the ability of the pig to deposit protein (Whittemore, 1985).

In this trial the high protein treatment was expected to result in a rapid growth rate and produce pigs with a lean carcass at slaughter, whilst the low protein treatment was expected to yield a pig with a carcass of a greater lipid content to that of the high protein treatment. The medium protein treatment was expected to yield intermediate results, with the amino acid content of the feed being below the requirement for half the period, and above the requirement for the remainder. The consequence of such a feeding treatment on lipid deposition is difficult to predict other than with the aid of a simulation model, as this would depend on the relative lengths of over-and under-supply of the amino acids in relation to the genotype of the pig. The fourth feeding treatment used in the trial was a phase feeding schedule designed specifically for either males or females, the proviso being that only three phases would be used, and that the feeds would be blends of the two basal feeds formulated. This feeding treatment was designed to minimize the differences between the requirement and the supply of protein, and was expected to produce pigs more efficiently than on the other treatments.

The protein content of the feed influences the ADG. T3 had the lowest ADG, which can be expected due to the low protein content of the diet. This poor growth rate resulted in the pigs taking longer to reach the desired weight, subsequently leading to a lower mean daily food intake. The pigs on T3 were on trial for the longest period of time, with a poor FCE, therefore resulting in an uneconomical production of pork. This research supported the work of Henry (1985) who determined that feed intake and growth performance was depressed when there was a severe deficiency in the limiting dietary amino acid and an excessive supply of total protein. This proves the importance of changing the protein content of the diet over time in order to reduce the excesses and deficiencies that occur when feeding a single protein level throughout the growth period. Conversely, T1 protein level was too high and this is demonstrated by the poor FCE (379g gain/kg feed). The pigs were unable to efficiently convert feed protein into body protein. The pig will only utilize protein (amino acids) up to its genetic potential, the excess amino acids being excreted. T1 had the highest cost/kg gain (R8.31) and was therefore also not an economical diet to feed.

Back fat thickness will determine the grade, and hence the price/kg paid to the farmer by the abattoir. It is surprising that T1, T2 and T4 had the same back fat thicknesses given the differences in the protein content of the feeds supplied. That T3 had a significantly higher back fat thickness was not surprising, given that these pigs were fed a low protein diet throughout the growing period. The back fat thickness on each of the treatments would have increased initially, given that the protein supply would have been below the requirement initially, but this fat would have been used as an energy source later, enabling the pig to consume less feed whilst utilising the excess fat as an energy source (Kyriazakis and Emmans, 1992a). The results indicate that final back fat thickness is relatively insensitive to dietary protein content and is only affected when the dietary protein level is below the pig's inherent ability to utilise it effectively, when it will deposit excess fat. T1, T2 and T4 were evidently meeting the protein requirements of the pig so as not to have unnecessary back fat, whereas T3 had a protein level which was too low and hence the back fat increased.

Phase feeding allows the farmer to more closely meet the nutritional requirements of the pig. It was therefore expected that T4 would have the best results but this did not occur. This may be explained by looking at the individual performance of the male and female pigs on this treatment. The males had a lower ADG compared with the females (745g/d vs. 779 g/d, respectively). They also consumed less feed. The overall cost/kg gain was much higher for the males than the females and this was likely due to the length of time spent eating the high protein feed; females only consuming this from 20-35kg with males consuming it from 20-65kg. Since the same diets were used in this trial as in the previous trial, it is most likely that the excessively high protein content of Basal A would have again influenced the performance of the pigs. This high protein diet was the most expensive feed, ultimately contributing to the high cost/kg gain for the males. If one compares the results of this trial to those of the overall results of the first trial, the pigs on the first trial performed better than those on the phase feeding treatment of this trial. This is most likely due to the requirements for protein being better met in the first trial than in the present trial.

As in the first trial, since the same feeds were used, the unbalanced calcium: phosphorus ratio resulting from a formulation error may explain the results obtained. The required ratio is Ca: P ratio of 2:1 (NRC, 1998). This unbalanced ratio may have had an effect on the performance of the pigs on T1, since they were being underfed on calcium.

The EFG Pig Growth Model allowed a number of predictions to be made for the trial. Unfortunately these predictions were not as accurate as the final results indicated. (See Table 3.4). When the observed feed intakes, time taken to reach slaughter weight, cost/kg gain and back-fat thickness were compared with those predicted by the EFG Pig Growth Model (Table 3.5), the time to reach slaughter weight was the only parameter accurately predicted. Back fat thickness was considerably lower than predicted (by 5.5mm for males and 6.7mm for females), cost/kg gain was higher than predicted (males being on average R1.58/kg gain higher and females R0.66/kg) and feed intake had varied results with a general trend of being higher than predicted for males (135g/d) and lower than predicted for females (86g/d). This may be explained by the inputs into the modeling programme, with the feeds not being adequately described in the Model.

In conclusion, one can see from the results that it is of utmost importance for the protein requirements of the pig to be met. This will result in a uniform herd with good growth rates and ultimately high FCE, thereby saving money on the feeding costs. From the results, if given no other option, it will be best to follow T2 rather than the other three treatments as this was the cheapest treatment and produced a carcass with a low back fat thickness. T2 also had the best FCE (438g gain/kg feed).

CHAPTER 4

A COMPARISON OF THE PERFORMANCE OF TWO PIG STRAINS FED A HIGH OR A LOW PROTEIN FEED, OR A CHOICE BETWEEN THE TWO

4.1 Introduction

The nutrient requirements of the pig are influenced by many factors, some internal (to do with the genotype) and some external (dealing with the feed and the environment). In the previous two chapters the effects of two of these factors on the subsequent performance of the pig were studied, namely, sex and feeding regimen. It was found that the two sexes produced significant differences in performance and that the implementation of various feeding schedules as well as differing dietary protein levels influenced the rate of gain and carcass composition of the pigs. The South African Pig Industry has embarked on the importation of strains that have a greater potential protein growth than the traditional strains used previously, so these genotypes are likely to respond differently to external factors than do the traditional strains.

A number of experiments have been performed in the last few years that have demonstrated that genotypes may respond differently to feeds, and that they may even utilize some nutrients with varying levels of efficiency (Campbell and Taverner, 1988; McPhee *et al.* 1991; Whittemore, 1993) The genetic merit of the pig will determine the rate at which it can grow muscle and other body proteins, commonly referred to as the maximum protein deposition rate (PDR). The age at which the maximum PDR is reached is proportional to the mature size of the animal and hence will vary according to the genotype. Kyriazakis (1999) showed that the PDR followed a rainbow-like curve with improved animals having a PDR which peaked higher, that is, the mature weight of the animal was higher, and declined slower than slow-growing pigs. Unless these faster-growing genotypes have the ability to consume more food at the same liveweight than the slow-growing pigs, it follows that as the PDR is increased, the dietary amino acid supply would need to be increased in order to exploit the improvement in genetic capability. The experiment reported here was designed to determine whether two strains available to pig producers in South Africa would respond differently to feeds varying in protein content. The objective of the trial was therefore to compare the rates of gain, food conversion efficiencies and back fat thicknesses of two strains (Dalland *vs*. Large White x Landrace) fed above and below their predicted amino acid requirements, and when given a choice between two feeds widely differing in protein content. Of interest was whether the Dalland strain, purported to grow faster than the other strain, would benefit more from the high protein feed than the Large White x Landrace strain; whether the two strains would be equally able to over-consume energy in order to consume sufficient of the low protein feed offered; and whether the relative amounts of high and low protein consumed by the two strains and sexes would differ during the growing period.

4.2 Materials and Methods

4.2.1 Experimental Design

The three factors used in this experiment were sex (two levels: entire males and females), strain (two levels: Large White x Landrace and Dalland) and dietary lysine content (two levels: 15.24g/kg and 3.76g/kg) in a completely randomized design.

4.2.2 Animal Description and Management

A total of 48 pigs was used in the trial, 24 commercial crossbred (Large White x Landrace) pigs – 12 entire males and 12 gilts, and 24 Dalland pigs – 12 entire males and 12 gilts. On arrival (10 May 2004), all pigs were ear tagged, weighed and randomly allocated to one of the three dietary treatments. Individual body weights were measured twice-weekly before the trial began to determine the starting point for each pen, this being when the body weight of the pig reached 20kg. At this point the pig was put on trial. Body weights were measured every week thereafter in order to determine individual growth rates. Pigs were given *ad libitum* access to feed and water. The trial ended when the body weight of the individual pigs reached 85kg. They were then removed from the trial and sent to the Baynesfield abattoir. The trial lasted 14 weeks.

4.2.3 Housing

The trial was conducted at Ukulinga Research Farm. The pigs were housed in a curtain-sided building with an insulated roof. Each of the 48 pens had 1.72m^2 of available space, i.e. pen area less the space taken up by the feeders, and was provided with one nipple drinker and either one or two Big Dutchman self-feeding bins depending on the feeding treatment, i.e. the pigs given a choice between the two feeds were supplied with two feeder bins. The pigs were subjected to a 16L: 8D lighting regimen.

4.2.4 Treatments and Feeds

The amino acid requirements (g/d) of male and female Landrace x Large White pigs between 20 and 85kg live weight were determined using the EFG Pig Growth Model and parameter values described in Table 2.1. The parameter values describe a typical Large White x Landrace genotype. The Dalland strain has a higher potential growth rate than the Large White x Landrace cross and the amino acid requirements are therefore higher (Topigs, SA, 2003). Assuming a dietary DE content of 13.80 MJ/kg, these amino acid requirements were converted to dietary concentrations for each week of the growing period from 20kg – 90kg, and these are given in Table 2.2 for females and Table 2.3 for males. The recommended amino acid requirements for the Dalland genotype are given in Table 4.1 below (Topigs, SA, 2003).

Table 4.1 *Predicted amino acid requirements (g/kg) of Dalland pigs at a DE of 13.8MJ/kg at body weight intervals from below 5kg to greater than 50 kg live weight*

BW (kg)	Lys	Met +Cys	Met	Trp	Thr
< 5	17.0	9.70	5.10	3.10	11.0
5 – 6.8	16.0	8.80	4.40	3.00	10.4
6.8 – 11.3	13.5	7.60	3.80	2.70	8.90
11.3 – 22.7	12.5	7.00	3.50	2.60	8.40
25 – 50	10.3	6.50	3.40	2.20	6.80
>50	8.80	5.70	2.90	1.70	5.60

Two basal feeds were formulated, both at a DE of 13.8 MJ/kg; the first being a high protein feed (Basal A) designed to be 20% higher than the amino acid requirements of a Cross strain male at 20 kg live weight, (15.24g/kg lys) and the second, (Basal B), a low protein feed, designed to be 20% lower than the requirements for a Cross strain female at 88 kg (3.76g/kg lys). All requirements between these two extremes could thus be met by appropriately blending the two basal feeds. The ingredient composition of the two basal feeds is presented in Table 4.2 and the chemical composition by formulation and laboratory analysis in Table 4.3.

Table 4.2 *Composition (g/kg) of the two basal feeds used in the trial*

Ingredient	High protein	Low protein
Yellow maize	281	731
Wheat Bran	128	135
Molasses	40.0	40.0
Soybean full fat	71.1	35.9
Soybean 44	300.	
Sunflower 37	84.2	
Fishmeal 65	44.5	
L-lysine HCL	3.17	1.28
DL methionine	3.00	
L-threonine	1.91	
Vit + Min Premix	1.50	1.50
Limestone	14.8	17.1
Monocalcium Phosphate	1.90	12.4
Sodium Bicarbonate	4.46	4.69
Oil-Soya	20.0	20.0
Salt		1.29

Because the required amino acid content in the feed decreases as pigs grow, the protein content of the two single-feed treatments needed to be reduced during the growing period. Three phases were chosen (20-40, 40-60 and 60-85kg liveweight) and the two basal feeds were blended in appropriate proportions to meet the lysine requirements calculated to be 20% higher than the most demanding strain, and 20% below the requirements of the least-demanding strain, within each of these phases of growth. The resultant lysine contents for the high protein treatment (Treatment 2) were 12.2, 10.0 and 8.1g lys/kg feed, and for Treatment 3, 8.1, 6.7 and 5.1g lys/kg feed. Treatment 1 was a choice-feeding treatment in which the pigs were offered the two basal feeds simultaneously, and allowed to choose their own blend of the two feeds on each day of the growing period. The three feed treatments were replicated four times each for males and for females of each strain. This produced a 3 x 2 x 2 factorial design.

Table 4.3 *Composition (g/kg) of the two basal feeds used in the trial as determined by formulation (digestible) and chemical analysis (as is)*

	High protein basal		Low protein basal	
Nutrient	Calculated	Chemical	Calculated	Chemical
DE (MJ/kg)	13.8	13.2	13.8	13.8
Protein	270	268	99.6	94.8
Lysine	15.2	21.6	3.8	4.4
Methionine	6.8	6.03	1.6	1.26
Threonine	10.3	14.7	2.8	2.27
Arginine	17.2	10.5	4.7	4.44
Isoleucine	10.2	12.5	2.9	3.12
Leucine	18.2	24.5	9.5	8.67
Histidine	6.2	8.8	2.5	2.5
Phenylalanine	10.6	11.8	3.7	4.02
Valine	11.3	15.9	4.1	4.57
Ash	62.9	68.4	38.3	47.8
Crude Fibre	60.6	168	31.5	128
Crude Fat	49.8	63.7	53.3	66.4
Calcium	9.0	9.1	9.0	8.0
Phosphorus	7.0	7.0	7.0	4.5

4.2.5 Calculation of Data

Records kept during the trial, as well as calculations performed are summarized below:

Records kept were the body weights at the start of trial, and weekly thereafter, weekly food intakes, and mortality when this occurred. Records were also kept of the pigs that became sick and subsequently died. At the end of the experimental period, measurements made at the abattoir were slaughter weight, grade and P2 back fat thickness.

Calculations made:

- Average daily gain, g/pig d
- Feed intake, g/pig d
- Feed conversion efficiency, g gain/kg feed consumed
- Period from 20kg to slaughter weight, d
- Cost of feeding, 20-85kg, R/pig

- Cost/kg gain, R/kg

The Genstat Statistical Programme was used to calculate Average Daily Gain (ADG) by fitting a linear regression to the weekly body weights. Feed Intake (FI) was calculated by subtracting the feed remaining each week from the total feed supplied. This was then totaled and divided by the number of days that each specific pen was on trial. Feed Conversion Efficiency (FCE) was calculated by dividing the ADG by the FI. Feeding cost was calculated by multiplying the FI by the cost of the feed. This value was then divided by the ADG, the quotient being the cost per kilogram gain. Total feeding cost was determined by multiplying the daily feeding cost by the number of days on trial. The age of pigs at the start of the trial and the date of slaughter of each pen was recorded to calculate the time taken to reach slaughter weight.

The equations of Whittemore (1987) were used to determine the total body lipid content of the pigs from their P2 back fat measurement, and the fat depth (Fd). A description of these equations are in Chapter 2, paragraph 2.2.5.

The classification of the Pork Grading System is in Appendix Table 1. The price paid for each grade at the time of the trial is in Appendix Table 2.

The data were subjected to a 2-way ANOVA using a model from Genstat 6th Edition (Lawes Agricultural Trust, 2002), with feeding programme, sex and strain as the variables.

4.3 Results

The average body mass at the start of the trial was 20.31 ± 0.12 kg and at the end of the trial 84.89± 0.25 kg.

Average daily gain (ADG), feed intake (FI), feed conversion efficiency (FCE), back fat thickness, time taken to reach 85kg (slaughter weight) and cost/kg gain are presented in Table 4.4. There were significant sex effects as well as strain x feeding treatment interactions. All variables, with the exception of back fat thickness, showed significance.

Male pigs grew significantly ($P<0.05$) faster rate than females (863 *vs.* 786g/d respectively). There was no significant strain effect in ADG ($P>0.05$). The male Cross-bred pigs on T2 had the highest ADG (918g/d), with the female Cross-bred pigs on the same treatment having the lowest ADG (761g/d). The Dalland strain consumed significantly more feed, 2240g/d, compared to 2099g/d consumed by the Cross-bred strain ($P<0.05$). Males had a greater FI (2189g/d) than females (2150g/d) although this was not significant ($P>0.05$) The Cross-bred strain were able to convert feed protein into meat significantly better than the Dalland strain (392 *vs.* 371g gain/kg feed, respectively). This could also be seen in the sex of the pig with male pigs having a significantly higher ($P<0.05$) FCE (396g gain/kg feed) than female pigs (367g gain/kg feed). The Cross-bred male pigs on T2, the high protein treatment, had a FCE of 451g gain/kg feed which was significantly better ($P<0.05$) than either of the sexes on the three treatments.

There was no significant difference in back fat thickness ($P>0.05$) between strains, sexes or feed treatments. Dalland males on T3 had the highest back fat thickness (15.3mm) and the Cross-bred females on T2 had the lowest (11.5mm). Time taken to reach 85kg was significantly ($P<0.05$) shorter for male pigs (75.1d) than for females (82.2d). The Dalland males on T3 reached slaughter weight in the shortest period of time (75.0d) with Dalland females on the same treatment taking the longest to reach 85kg (84.3d). There was a significant sex effect for cost/kg gain, with female pigs having a higher cost/kg gain than male pigs (R7.51/kg gain *vs.* R6.74/kg gain). A strain x treatment interaction occurred for the same variable, with Dalland pigs on T2 costing significantly more (R8.43/kg gain) than the other treatments except the Cross-bred pigs on T1 (R7.34). Male Cross-bred pigs on T2 had the lowest cost/kg gain (R5.90), with female Dalland strain pigs on the same treatment being the most expensive to feed (R9.39). The feed cost includes transport and labour fees. T1 and T2 were significantly higher ($P<0.05$) than T3 for total feeding cost. The least expensive treatment was T3 with a feeding cost of R382/pig for the entire trial period. Pigs on T1 had the highest feeding cost of R420/pig. Dalland pigs were significantly more expensive to feed than the Cross-bred pigs (R416/pig *vs.* R391/pig). This was also apparent for the sexes with female pigs being significantly ($P<0.05$) more expensive to feed than male pigs (R416/pig vs. R391/pig). A significant ($P<0.05$) strain x treatment interaction was also apparent for feeding cost: Dalland pigs on T2 were the most expensive to feed (R445/pig) with the Cross-bred pigs on the same treatment being the least expensive to feed (R373/pig).

Carcass lean, carcass lipid and total body lipid, calculated with the use of the equations of Whittemore (1987) are given Table 4.5. There were no significant differences in the proportions of lean and lipid in the carcass, or for total weight of body lipid among the treatments.

Table 4.4 *Average daily gain(ADG), Feed intake(FI), Feed conversion efficiency(FCE), Back fat thickness, time taken to reach 85kg and cost/kg gain for male(M) and female(F) pigs of the Dalland(D) and Large White x Landrace strains (C)*

Treatment	Sex	ADG (g/d)		FI (g/d)		FCE (g gain/kg feed)		Back Fat Thickness (mm)		Time taken to reach 85kg (d)		Cost/kg Gain (R/kg)		Feeding Cost (R/pig)	
		C	D	C	D	C	D	C	D	C	D	C	D	C	D
T1	M	838	842	2278	2101	372	402	12.9	14.0	75.0	74.8	7.31	6.36	417	388
	F	783	822	2177	2258	360	363	14.0	12.9	80.5	79.0	7.36	7.04	435	439
	Mean	821		2204		374		13.5		77.3		7.02		420	
T2	M	918	830	2041	2316	451	358	13.0	12.9	72.5	79.3	5.90	7.48	369	447
	F	761	793	1925	2203	401	360	11.5	12.5	83.2	82.8	7.51	9.39	377	442
	Mean	826		2121		392		12.5		79.4		7.57		409	
T3	M	818	932	2083	2313	394	402	13.1	15.3	78.5	70.5	7.03	6.39	359	364
	F	784	772	2091	2247	375	344	14.3	12.5	83.5	84.3	6.94	6.82	387	416
	Mean	826		2183		379		13.8		79.2		6.80		382	
Grand Mean		824		2169		382		13.2		78.6		7.13		403	
Mean	M	863		2189		396		13.5		75.1		6.74		391	
	F	786		2150		367		13.0		82.2		7.51		416	
Mean	C	817		2099		392		13.1		78.9		7.01		391	
	D	832		2240		371		13.3		78.4		7.25		416	
RMS		8269		46775		1192		5.241		66.5		25.55		16745	
SED(Feed)		32.1		76.5		12.2		0.809		2.88		0.478		12.23	
SED (Strain and Sex)		26.3		62.4		9.96		0.661		2.35		0.390		9.98	

Table 4.5 *The mean proportions of lean and lipid in the carcass, and the total weight of body lipid as determined using equations by Whittemore (1987) for the three feeding treatments, two sexes(M and F) and two strains(C and D)*

Treatment	Sex	Carcass lean (g/kg)		Carcass lipid (g/kg)		Total body lipid (kg)	
		C	D	C	D	C	D
T1	M	564	559	184	199	15.4	16.8
	F	559	564	202	181	16.8	15.4
	Mean	561		191		16.1	
T2	M	564	565	180	180	15.5	15.4
	F	572	566	164	175	13.9	14.9
	Mean	567		175		14.9	
T3	M	563	552	186	212	15.7	18.4
	F	557	566	204	179	17.2	14.9
	Mean	560		195		16.5	
Grand Mean		563		187		15.8	
Mean	M	561		190		16.2	
	F	564		184		15.5	
Mean	C	563		186		15.7	
	D	562		188		16.0	
RMS		140.0		1170		8.181	
SED (Feed)		4.18		12.1		1.011	
SED (Strain and Sex)		3.42		9.88		0.826	

The proportion of high protein feed chosen by the pigs on T1 is presented in Table 4.6 below. A single and multiple linear regression performed on the results showed no significance for sex or strain on the choice of high and low protein feed over the trial period.

Table 4.6 *The proportion of high protein feed (%) chosen by the two strains (Dalland and Cross-bred) and two sexes (male and female) over the trial period*

Week	Dalland		Cross	
	Male	Female	Male	Female
1	40.5	46.0	63.1	49.4
2	68.6	40.8	32.8	64.3
3	49.6	36.8	42.6	56.9
4	39.9	54.2	51.7	66.8
5	48.3	56.2	62.3	56.0
6	48.6	70.9	57.2	59.6
7	48.3	52.3	77.9	61.4
8	51.3	63.5	62.8	70.4
9	58.8	82.5	78.9	38.5
10	71.8	58.3	59.1	63.5
11	12.3	59.5	76.4	45.5
12	51.6	38.0	38.6	41.9

4.4 Discussion

This trial was conducted to determine the efficiency with which two strains make use of the dietary protein level supplied. The strains used were examples of superior (Dalland) and normal (Large White x Landrace) strains. The hypothesis at the start of the trial was that the Dalland strain would perform better than the Cross-bred strain due to its superior genotype. This was, however, not the case, the performance of the two strains being the same overall, but with the Dalland strain consuming significantly more feed than the other strain.

Kemm *et al.* (1988) studied the performance of pigs highly divergent in growth rate. This growth rate was shown by Siebrits (1984) to be affected by the genotype of the pig, with pigs of a superior genotype having a higher growth rate to those of a lower genotype. In the same paper, Siebrits related growth rate and feed intake allometrically. Thus, a pig with a high potential for daily lean tissue growth rate will be a more efficient converter of dietary energy and protein. Therefore, it will deposit more lean and less fat than its fat counterpart and thus have a higher potential for growth rate on the same amount of feed (Kemm *et al.* 1988). In a review on feed intake regulation by growing pigs Henry (1985) concluded that feed or energy intake is closely related to the potential for muscular growth and the capacity of fat deposition. Since the Dalland strain apparently has a higher potential for muscle growth, according to Henry, they should also have a high feed intake. However, in this trial the additional food intake was not converted to lean tissue growth, resulting in the Dalland strain exhibiting a significantly lower FCE than the cross-bred strain. There appears to be no logical explanation for the poor performance of the Dalland strain on the high protein feed; growth by this strain on the low protein food was significantly better than that by the other strain on this food, mainly because of the significantly higher food intake by the Dalland strain; the FCE was the same between the two strains on this low protein feed indicating that the additional growth by the Dalland strain was entirely due to the increased food intake. The question is why the males of the Dalland strain, which consumed so much of the high protein feed, did not respond appropriately in lean tissue gain, showing a particularly low FCE on this treatment.

Chiba *et al.* (2002) reported that pigs selected for lean growth efficiency may need to be offered a feed containing adequate amino acid concentrations to optimize overall growth performance. The best performance in this trial was by the male Dalland pigs on the low protein treatment, suggesting that there is no need to provide the Dalland strain with a particular high protein feed in order to obtain maximum growth and efficiency. Although this additional intake resulted in a higher body lipid content (15.3 *vs.* 13.1mm back fat) the Dalland strain demonstrated that they have the ability to overconsume energy when needing to meet their requirements for protein on a low-protein feeding schedule.

A number of authors have found strain differences regarding body composition and protein deposition. Fielder and Curran (1970) found that the Pietrain strain had a higher nitrogen retention rate, on average, (6g N/d) than the Large White and a greater efficiency of N retention than Landrace pigs. Davies (1974a and b) found a higher proportion of lean in the Pietrain compared to the Large White, illustrating the effect of genotype on body composition. Both the Dalland and the Cross-bred strains include the above three strains in their genotype, with the Dalland strain having a greater proportion of the Pietrain strain in its genotype. This results in the Dalland being a leaner strain than the Cross-bred. There was no significant difference overall in the back fat thicknesses of the two strains in spite of the difference reported above. The pig has a genetic predisposition to the amount of protein that it will deposit and feeding excess protein will be an added expense as the pig will only utilize up to its potential (Clausen, 1965).

When comparing the Dalland strain with the Cross-bred strain on the choice-feeding treatment T1, it appears that females of the Dalland strain were more able to satisfy their amino acid requirements by choosing a more appropriate combination of the two feeds offered throughout the trial. This can be seen in the ADG and FI of the female, which were higher than those for the Cross-bred strain pigs, but resulted in the same FCE. Males of the Dalland strain exhibited a higher FCE than the Cross-bred strain, indicating that they had a greater ability to convert the chosen dietary protein to body protein. These results are contrary to those found after regression analysis which yielded no significant findings. It would appear therefore that at a base level there is no significance in the sex or strain on the choices made, but when analyzing performance variables, these factors (sex and strain) do play a role in the choice made.

The results of this trial show that the application of a theory may not result in the expected outcome. The hypothesis was disproved indicating the requirement for further research into the possibility of designing a feeding programme according to the genetic make-up of the animal. Currently the various pig genotypes do not seem to differ as dramatically as would be needed in order to see the full benefit of feeding to their genetic composition. This, however, may change with the improvements in breeding.

CHAPTER 5

GENERAL DISCUSSION

The marketing of pork as "the other white meat" has placed an added burden on the producer to ensure that the product meets the standards set by the consumer. These standards dictate a carcass with a high ratio of lean meat to fat tissue. Manipulating the chemical composition of a carcass can be achieved nutritionally and has been demonstrated by many researchers. A new generation of research is now upon us, that of genetic manipulation. The aim of the research in the current thesis was to demonstrate the degree to which the producer is able to manipulate the growth of his/her animal, by using different methods of feeding.

The application of a phase feeding schedule is the most common method of feeding the pig in current production facilities. Although this method does not meet the nutritional requirements of the pig precisely through the growth cycle, from a practical point of view it is a useful method in that the protein content is reduced in phases, resulting in a rough but practical manipulation of the feed as the animals grow. The method does not precisely match the dietary specifications with the nutrient requirements, nor does it account for differences in genotype within a group of pigs; its success rests on the ability of pigs to consume what they need to meet their requirement for the limiting nutrient in the feed, but this is not infallible given the wide range of requirements within a mixed-sex group and given the vagaries of the weather.

Allowing the pig to choose between two feeds differing in protein level, but balanced in all other aspects is therefore a method of feeding with a greater chance of success in meeting more precisely the nutrient requirements of each pig. The theory behind choice feeding makes this method an accepted form of feeding, but unfortunately, requires a higher level of management as each feed must be available at all times to allow the pig to make a conscious choice of which feed to consume. Also, as stated before in this thesis, the pig may choose the correct feed, but is unaware of the cost implications of the choice it is making.

Feeding according to the genetic make-up of the animal may be the most economical method of feeding in the future. As stated earlier in this thesis, the ability of the pig to convert feed protein into body protein is governed by the genotype. Determining the level of genetic capability on a digestive plane, may allow the farmer to more accurately meet the nutritive requirements of the pig through the growth period. This would allow for a reduced wastage of feed on the farm since the pig would be receiving the correct level of nutrients at any given growth stage.

The driving force of any feeding programme is economics, and the most profitable option should be chosen, this varying with the cost of the feed at any given time. With current feed costs at a low, the application of a choice-feeding programme may be justified, but if the costs rise, this may not be the most economical method of feeding. Ultimately the decision between phase feeding, choice feeding and feeding according to genotype depends on the available equipment and level of management on the farm.

REFERENCES

Baker, D.H., Becker, D.E., Norton, H.W., Jensen, A.H. & Harmon, B.G., 1966a. Quantitative evaluation of the Threonine, Isoleucine, Valine and Phenylalanine needs of adult swine for maintenance. J. Nutr. 88, 391-396.

Baker, D.H., Becker, D.E., Norton, H.W., Jensen, A.H. & Harmon, B.G., 1966b. Quantitative evaluation of the Tryptophan, Methionine and Lysine needs of the adult swine for maintenance. J. Nutr. 89, 441-447.

Baker, D.H. & Allee, G.L., 1970. Effect of dietary carbohydrate on assessment of the Leucine need for maintenance of adult swine. J. Nutr. 100, 277-280.

Baker, D.H. & Chung, T.K., 1992. Ideal protein for swine and poultry. BioKyowa Technical Review–4. Chesterfield, MO: Nutri-Quest, Inc.

Baker, D.H., Hahn, J.D., Chung, T.K. & Han, Y., 1993. Nutrition and Growth: The concept and application of an ideal protein for swine growth. In: G.R. Hollis (Ed.). Growth of the pig. CAB International, Wallingford, Oxfordshire, U.K. pp. 133-139.

Baker, D.H., 1997. Ideal amino acid profiles for swine and poultry and their applications in feed formulation. Biokyowa Techincal Review–9. Chesterfield, M.O: Nutri-Quest. Inc.

Blair, R. & English, P.R., 1965. The effect of sex on growth and carcass quality in the bacon pig. J. Agric. Sci. 64, 169.

Bohman, V. R., 1955. Compensatory growth of beef cattle. The effect of hay maturity. J. Anim. Sci. 14, 249.

Bradford, M.M.V. & Gous, R.M., 1991a. The response of growing pigs to a choice of diets differing in protein content. Anim. Prod. 52, 323-330.

Bradford, M.M.V. & Gous, R.M., 1991b. A comparison of phase feeding and choice feeding as methods of meeting the amino acid requirements of growing pigs. Anim. Prod. 52, 323-330.

Bradford, M.M.V. & Gous, R.M., 1992. The response of weaner pigs to a choice of foods differing in protein content. Anim. Prod. 55, 227-232.

Braude, R., 1967. The effect of changes in feeding patterns on the performance of pigs. Proc. Nutr. Soc. 26(2), 163-181.

Brudevoid, A.B. & Southern, L.L., 1994. Low-protein, crystalline amino acid supplemented, sorghum-soybean meal diets for the 10 to 20 kilogram pig. J. Anim. Sci. 72, 638-647.

Campbell, R.G., Taverner, M.R. & Curic, D.M., 1988a. The effects of sex and live weight on the growing pig's response to dietary protein. Anim. Prod. 46, 123-130.

Campbell, R.G. & Taverner, M.R. 1988. Genotype and sex effects on the relationship between energy intake and protein deposition in growing pigs. J. Anim. Sci. 66(3), 676-686.

Chiba, L.I., Kuhlers, D.L., Frobish, L.T., Jungst, S.B., Huff-Lonergan, E.J., Lonergan, S.M. & Cummins, K.A., 2002. Effect of dietary restrictions on growth performance and carcass quality of pigs selected for lean growth efficiency. Livest. Prod. Sci. 74, 93-102.

Chung, T.K. & Baker, D.H., 1992a. Maximal portion of the young pig's sulphur amino acid requirement that can be furnished by cystine. J. Anim. Sci. 70, 1182-1187.

Clausen, H., 1965. The protein requirements of growing meat type pigs. World Rev. Anim. Prod. 1965.

Critser, D.J., Miller, P.S. & Lewis, A.J., 1995. The effects of dietary protein concentration on compensatory growth in barrows and gilts. J. Anim. Sci. 73, 3376-3383.

Cromwell, G.L., Cline, T.R., Crenshaw, J.D., Ewan, R.C., Hamilton, C.R., Lewis, A.J., Mahan, D.C., Miller, E.R., Pettigrew, J.E., 1993. The dietary protein and (or) lysine requirements of barrows and gilts. J. Anim. Sci. 71(6), 1510-1519.

Cromwell, G. L., Turner, L. W., Gates, R. S., Taraba, J. L., Lindemann, M. D., Taylor, S. L. & Dozier, W.A., 1999. Manipulation of swine diets to reduce gaseous emissions from manure that contributes to odor. J. Anim. Sci. 77:69(Suppl. 1).

Davies, A.S., 1974a. A comparison of tissue development in Pietrain and Large White pigs from birth to 64kg live weight. 1. Growth changes in carcass composition. Anim. Prod. 19, 367.

Davies, A.S., 1974b. A comparison of tissue development in Pietrain and Large White pigs from birth to 64kg live weight. 2. Growth changes in muscle distribution. Anim. Prod. 19, 377.

De Greef, K.H., Kemp, B. & Verstegen, M.W.A., 1992. Performance and body composition of fattening pigs of two strains during protein deficiency and subsequent realimentation. Live. Prod. Sci. 30, 141.

De Lange, C.F.M., Birkett, S.H. & Morel, P.C., 1995. Protein, fat and bone tissue growth in swine. In: Lewis, A.J. Swine Nutrition.

Easter, R.A., Katz, R.S. & Baker, D.H., 1974. Arginine: A dispensible amino acid for postpubertal growth and pregnancy of swine. J. Anim. Sci. 39, 1123-1128.

Edmonds, M.S. & Baker, D.H., 1987. Failure of excess dietary lysine to antagonize arginine in young pigs. J. Nutr. 117, 1396-1401.

EFG Software Natal, 1995. Advanced Computer Software for the Animal Industry. http://www.efgsoftware.com/ (accessed February 2004).

Fabian, J., Chiba, L.I., Kuhlers, D.L., Frobish, L.T., Nadarajah, K., Kerth, C.R., McElhenney, W.H. & Lewis, A.J., 2002. Degree of amino acid restrictions during the grower phase and compensatory growth in pigs selected for lean growth efficiency. J. Anim. Sci. 80, 2610-2618.

Fabian, J., Chiba, L.I., Kuhlers, D.L., Frobish, L.T., Nadarajah, K. & McElhenney, W.H. 2003. Growth performance, dry matter and nitrogen digestibilities, serum profile, and carcass and meat quality of pigs with distinct genotypes. J. Anim. Sci. 81, 1142-1149.

Fairley, R.A.C., Rose, S.P. & Fuller, M.F., 1993. Selection of dietary lysine and threonine concentration by growing pigs. Anim. Prod. 56, 468-469.

Ferguson, N.S., 1989. An approach to modeling feed intake, body composition and nutrient requirements in growing pigs. M. Sc. Agric. Thesis. University of Natal, Pietermaritzburg.

Ferguson, N.S., Nelson, L. & Gous, R.M., 1999. Diet selection in pigs: choices made by growing pigs when given foods differing in nutrient density. Anim. Sci. 68, 691-699.

Ferguson, N.S., Bradford, M.M.V. & Gous, R.M., 2002. Diet selection priorities in growing pigs offered a choice of feeds. S. Afr. J. Anim. Sci. 32(2) 136-143.

Ferguson, N.S. & Kyriazis, S.T., 2003. Evaluation of growth parameters of six commercial crossbred pig genotypes 1. Under commercial housing conditions in individual pens. 2. Under ideal temperature conditions in chambers. S. Afr. J. Anim. Sci. 33, 11-26.

Fielder, R.E. & Curran, M.K., 1970. Nitrogen metabolism in Pietrain, Large White, Landrace and Landrace x Pietrain pigs. Anim. Prod. 12, 373.

Fowler, V.R., 1984. Improving efficiency in Pig Production. S. Afr. J. Anim. Sci. 14, 147.

Fredeen, H. & Harmon, B.G., 1983. The Swine Industry: changes and challenges. J. Anim. Sci. 57 (Suppl. 2), 100.

Fuller, M.F., Gordon, J.G. & Aitken, R., 1980. Energy and protein utilization by pigs of different sex and genotype. In: Energy Metabolism. Ed. Mount, L.E. EAAP. Publ. no 26. Butterworths: London. Pp. 169-174.

Fuller, M.F., McWilliam, R., Wang, T.C. & Giles, L.R., 1989. The optimum dietary amino acid pattern for growing pigs. 2. Requirements for maintenance and for tissue protein accretion. Br. J. Nutr. 62, 255-267.

Gous, R.M. & Swatson, H.K., 2000. Mixture experiments: a severe test of the ability of a broiler chicken to make the right choice. Br. Poult. Sci. 41(2), 136-140.

Hahn, J.D. & Baker, D.H., 1995. Optimum ratio of lysine to threonine, tryptophan, and sulphur amino acids for finishing swine. J. Anim. Sci. 73, 482-489.

Hall, D.D., Cromwell, G.L. & Stahly, T.S., 1991. Effects of dietary calcium, phosphorus, calcium:phosphorus ratio and vitamin K on performance, bone strength and blood clotting status of pigs. J. Anim. Sci. 69, 646-655.

Harper, A.E., Benevenga, N.J. & Wohlheuter, R.M., 1970. Effect of ingestion of disproportionate amounts of amino acids. Physiolog. Rev. 50, 428-558.

Harper, A.E., Miller, R.H. & Block, K.P., 1984. Branched-chain amino acid metabolism. Annual Rev. Nutr. 4, 409-454.

Henry, Y., 1985. Dietary factors involved in feed intake regulation in growing pigs: A review. Livest. Prod. Sci. 12, 339.

Hogberg, M.G. & Zimmerman, D.R., 1978. Compensatory responses to dietary protein, length of starter period and strain of pig. J. Anim. Sci. 47, 893.

Holmes, W., 1970. Animals for Food. Proc. Nutr. Soc. 29, 237.

Jones, J.D., Wolters, R. & Burnett, P.C., 1966. Lysine-arginine-electrolyte relationships in the rat. J. Nutr. 89, 171-188.

Kemm, E.H., Coetzee, S.E., Coetzer, R.A. & Viljoen, J., 1988. Feed intake, growth rate and feed utilization patterns of pigs highly divergent in growth rate. S. Afr. J. Anim. Sci. 18, 55-58.

Kephart, K.B. & Sherritt, G.W., 1990. Performance and nutrient balance in growing swine fed low protein diets supplemented with amino acids and potassium. J. Anim. Sci. 68, 1999-2008.

Kerr, B.J. & Easter, R.A., 1995. Effect of feeding reduced protein, amino acid supplemented diets on nitrogen and energy balance in grower pigs. J. Anim. Sci. 73, 3000-3008.

Knap, P.W., Roehe, R., Kolstad, K., Pomar, C. & Luiting, P., 2003. Characterisation of pig genotypes for growth modeling. J. Anim. Sci. 81(E. Suppl. 2), E187-E195.

Kyriazakis, I., Emmans, G.C. & Whittemore, C.T., 1990. Diet selection in pigs: Choices made by growing pigs given feeds of different protein content. Anim. Prod. 51, 189-200.

Kyriazakis, I., Emmans, G.C. & Whittemore, C.T., 1991a. The ability of pigs to control their protein intake when fed in three different ways. Physiol. Behav. 50(6), 1197-1203.

Kyriazakis, I., Stamataris, C., Emmans, G.C. & Whittemore, C.T., 1991b. The effects of food protein content on the performance of pigs previously given foods with low or moderate protein content. Anim. Prod. 52, 165.

Kyriazakis, I. & Emmans, G.C., 1992a. The effects of varying protein and energy intakes on the growth and body composition of pigs. 1. The effects of energy intake constant, high protein intake. Br. J. Nutr. 68(3), 603-613.

Kyriazakis, I. & Emmans, G.C., 1992b. The effects of varying protein and energy intakes on the growth and composition of pigs. 2. The effects of varying both energy and protein intake. Br. J. Nutr. 68(3), 615-625.

Kyriazakis, I., Dotas, D. & Emmans, G.C., 1994. The effect of breed on the relationship between feed composition and the efficiency of protein utilization by pigs. Br. J. Nutr. 71(6), 849-859.

Kyriazakis, I. & Emmans, G.C., 1995. Do breeds of pig differ in the efficiency with which they use a limiting protein supply? Br. J. Nutr. 74(2), 183-195.

Kyriazakis, I., 1999. A Quantitative Biology of the Pig. CAB International, Wallingford, England.

Lawes Agricultural Trust (2002). Genstat 6th Edition, Version 6.1.0.205. VSN International, Oxford, UK.

Lewis, A.J., Cromwell, G.L. & Thewis, A., 1991. Effects of supplemental biotin during gestation and lactation on reproductive performance of sows: a cooperative study. J. Anim. Sci. 69, 207-214.

Lewis, A.J., 1991. Amino acids in swine nutrition. In: Miller, E.R., Ullrey, D.E. & Lewis, A.J. (eds), Swine Nutrition. Butterworths-Heinermann, Boston, Massachusets, pp. 147-164.

Lewis, A. J. & Bayley, H. S., 1995. Amino acid bioavailability. In: Bioavailability of Nutrients for Animals: Amino Acids, Minerals, and Vitamins. Pp. 35-65. Eds. Ammerman, C.B., Baker, D.H. & Lewis, A. J. San Diego, CA: Academic Press.

McPhee, C. P., Williams, K.C. & Danials, L. J., 1991. The effect of selection for rapid lean growth on the dietary lysine and energy requirements of pigs fed to scale. Livest. Prod. Sci. 7, 185–198.

Morgan, C.A., Kyriazakis, I., Lawrence, A.B., Chirnside, J. and Fullam., H., 2003. Diet selection by groups of pigs: effect of a trained individual on the rate of learning about novel foods differing in protein content. British Soc. Anim. Sci. 76.

Moughan, P.J. & Verstegen, M.W.A., 1988. The modeling of growth in the pig. Netherl. J. Agric. Sci. 36, 145.

Nam, D.S. & Aherne, F.X., 1995. A comparison of choice and phase feeding for growing-finishing pigs. Can. J. Anim. Sci. 75(1), 93-98.

National Research Council. 1988. Nutrient Requirements of Swine. (9^{th} revised ed.). National Academy Press, Washington, D.C.

National Research Council. 1998. Nutrient Requirements of Swine. (10^{th} revised ed.). National Academy Press, Washington, D.C.

Patience, J.F. & Zilstra, R.T., 2004. Amino acid requirements based on protein deposition rates. Prairie Swine Centre.

Pettigrew, J.E., 1993. Amino acid nutrition of gestating and lactating sows. BioKyowa Technical Review – 5. Chesterfield, M.O: Nutri-Quest.

Prince, T.S., Hays, V.W. & Cromwell, G.L., 1984. Interactive effects of dietary calcium, phosphorus and copper on performance and liver copper stores of pigs. J. Anim. Sci. 69, 646-655.

Revell, D.K. & Williams, I.H., 1993. A review: physiological control and manipulation of voluntary food intake. In: Manipulating Pig Production IV, ed. E.S. Batterham. APSA, Attwood, Victoria., Australia, pp. 55-80.

Robbins, K.R. & Baker, D.H., 1977. Phenylalanine requirement of the weanling pig and its relationship to tyrosine. J. Anim. Sci. 45, 113-118.

Robinson, D.W. & Vohra, P., 1976. Feedstuffs, February 23, p. 20.

Rose, S.P. & Fuller, M.F. 1995. Choice feeding systems for pigs. Recent Advances in Animal Nutrition. Nottingham University Press, 211-222.

Sather, A.P. & Fredeen, H.T., 1978. Effect of selection for lean growth rate upon feed utilization by the market hog. Can. J. Anim. Sci. 58, 285-289.

Schinckel, A.P., 1994. Nutrient requirements for modern pig genotypes. In (Garnsworthy, P.J. & Cole, D.J.A. ed.) : Recent advances in animal nutrition. Univ. of Nottingham press, Nottingham, U.K. pp. 133-169.

Siebrits, F.K., 1984. Some aspects of chemical and physical development of lean and obese pigs during growth. D.Sc (Agric) Thesis, University of Pretoria.

Siebrits, F.K., Kemm, E.H., Ras, M.N. & Barnes, P.M., 1986. Protein deposition in pigs as influenced by sex, type and livemass. 1. The pattern and composition of protein deposition. S. Afr. J. Anim. Sci. 16, 23-27.

Siers, D.G., 1975. Chromic oxide determined coefficients and their relationship to rate of gain and feed efficiency in individually fed Yorkshire boars, barrows and gilts. J. Anim. Sci. 41, 522.

Stahly, T.S., Cromwell, G.L. & Turhune, D., 1991. Responses of high, medium and low lean growth genotypes to dietary amino acid regimem. J. Anim. Sci 69(Suppl. 1), 364.

Stahly, T.S., 2001. Nutrient needs of High Lean Pigs. Department of Animal Science. Iowa State University, Ames, Iowa, USA.

Stamataris, C., Hillyer, G.M., Whittemore, C.T., Emmans, G.C., Taylor, A.G. & Phillips, P., 1985. Performance and body composition of young pigs following a period of growth retardation by food restriction. Anim. Prod. 40, 536 (Abstr.).

Southern, L.L. & Baker, D.H., 1983. Arginine requirement of the young pig. J. Anim. Sci. 7, 402-412.

Southern, L.L., 1991. Digestible Amino Acids and Digestible Amino Acid Requirements for Swine. BioKyowa Technical Review—2. Chesterfield, MO: Nutri-Quest, Inc.

Wang, T.C. & Fuller, M.F., 1989. The optimum dietary amino acid pattern for growing pigs. 1. Experiments by amino acid deletion. Br. J. Nutr. 62, 77-89.

Whang, K.Y., Kim, S.W., Donovan, S.M., McKeith, F.K. & Easter, R.A., 2003. Effects of protein deprivation on subsequent growth performance, gain of body components, and protein requirements in growing pigs. J. Anim. Sci. 81, 705-716.

Whittemore, C.T., 1985. The application of the principles of nutrition to the feeding of breeding sows and the production of meat from growing pigs. S. Afr. J. Anim. Sci. 15, 97-101.

Whittemore, C.T., 1987. Elements of Pig Science. 1st Ed. Longman Scientific and Technical, Hong Kong.

Whittemore, C.T., Tullis, J.B. & Emmans, J.C., 1988. Protein growth in pigs. Anim. Prod. 46, 437-445.

Whittemore, C.T., 1993. The Science and Practice of Pig Production. Longman Scientific and Technical, Essex, UK.

Whittemore, C.T., 1998. The Science and Practise of Pig Production. 2nd edition London, UK: Blackwell Science.

Whittemore, C.T., Green, D.M. & Knap, P.W., 2001. Technical review of the energy and protein requirements of growing pigs:protein. Anim. Sci. 73, 363-373.

Whittemore, C.T., 2004. Production Control Systems for Pigs. London Swine Conference. Building Blocks for the Future, 1-2 April, 2004.

Xue, J.L., Dial, G.D. & Pettigrew, J.E., 1997. Performance, carcass and meat quality advantages of boars over barrow: a literature review. Swine Health and Production, 5, 21-28.

Yen, H.T., Cole, D.J.A. & Lewis, D., 1986. Amino acid requirements of growing pigs. 7. The response of pigs from 22 to 55 kg live weight to dietary ideal protein. Anim. Prod. 43, 141-154.

APPENDIX

An explanation of the PORCUS classification system used in South Africa is given in Table 1 below.

Appendix Table 1 *Explanation of the PORCUS Classification System*

Class	Estimated percentage lean of carcass	Fat thickness measured by means of an intrascope (mm)
P	70 and more	At least 1 but not more than 12
O	At least 68, but not more than 6	More than 12 but not more than 17
R	At least 66, but not more than 67	More than 17 but not more than 22
C	At least 64, but not more than 65	More than 22 but not more than 27
U	At least 62, but not more than 63	More than 27 but not more than 32
S	61 and less	More than 32

The price paid per kg lean meat for the respective classes is given in Table 2 below. These prices were current at the time of the experiments.

Appendix Table 2 *Price paid per kg lean meat for the respective classes*

Carcass Grade	Price (R/kg)
P	11.00
O	10.40
R	9.50
C	9.50
U	7.00
S	7.00