EFFECTS OF TWO LEVELS OF DIETARY ENERGY SUPPLEMENTATION AND REARING SYSTEMS ON GROWTH AND CARCASS CHARACTERISTICS OF GROWER PIGS

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EFFECTS OF TWO LEVELS OF DIETARY ENERGY SUPPLEMENTATION AND REARING SYSTEMS ON GROWTH AND CARCASS CHARACTERISTICS OF GROWER PIGS

by

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DECLARATION AND COPYRIGHT

I, Makgothi Onkabetwse Gogakgamatsamang, student number 209082046, declare that this dissertation: **The effects of two energy levels and rearing systems on growth and carcass characteristics of grower pigs** submitted to the Central University of Technology, Free State for the degree MAGISTER TECHNOLOGIAE: AGRICULTURE is my own independent work and that all sources used and quoted have been duly acknowledged by means of complete references; and complies with the Code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology; and has not been submitted before to any institution by myself or any other person in fulfilment (or partial fulfilment) of the requirements for the attainment of any qualification. I also disclaim this dissertation in the favour of the Central University of Technology, Free State.

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Onkabetswe G. Makgothi Date

DEDICATION

The study is dedicated to the family of Solly Solomon Makgothi and all the scientists that are working tirelessly to improve the quality of lives of people through animal science.

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GENERAL ABSTRACT OF THE STUDY

The eight-week study was conducted to evaluate the effects of rearing system (indoor vs. outdoor) and energy level on digestibility, growth performance and on the carcass characteristics and visceral organs of pigs. A total of 48 Large Whites (LW) X Landrace (LR) male grower pigs were randomly selected at average weights of 27 ± 4.6.kg and divided into two equal groups that were either raised indoors or outdoors. Within each rearing system, half the pigs were fed on a diet formulated to contain either a normal energy level (14 MJ DE/kg) or high energy level (16.1 MJ DE/kg) resulting in a 2 X 2 factorial design. The pigs were fed *ad libitum* and water was freely available. Pigs were housed in pairs and each indoor and outdoor pig was offered a space allowance of 0.51 and 13.5 m^2 respectively. Indoor pigs were raised in a temperature controlled house consisting of a concrete floor pen while outdoor pigs were on a pasture that predominantly consisted of Kikuyu. Movable gates were used to construct outdoor camps and empty feed bags were used to construct a shade for use as shelter. Faecal collection for digestibility determination took place during week 7 while the growth performance trial was still in progress. Chromium oxide was used to evaluate digestibility and faeces were grabbed before they fell to the ground and sampled. With the exception of ether extracts (EE), the digestibilities of crude protein (CP), digestible energy (DE), crude fibre (CF), neutral detergent fibre (NDF), acid detergent fibre (ADF) and organic matter (OM) were reduced ($P < 0.05$) by rearing pigs outdoors. EE followed the same trend. Feeding the high energy (HE) diet significantly ($P > 0.05$) improved the digestibilities of all the nutrients except for CP. There were no significant interactions ($P > 0.05$) between rearing system and diet for the digestibility of nutrients. Daily gains were similar ($P > 0.05$) between indoor and outdoor pigs. Daily feed intakes and conversions were significantly ($P < 0.05$) lower in indoor pigs. There were no significant ($P > 0.05$) differences between the daily gains and feed conversions of pigs fed either the normal energy (NE) or the HE diet. Indoor pigs fed the HE diet had lower ($P < 0.05$) feed intakes compared to pigs on the other treatments. In general, average daily feed intakes (ADFI) of the HE fed pigs were significantly ($P < 0.05$) lower than those of the NE fed pigs. The carcass measurements of the indoor and outdoor pigs were similar. The gastro-intestinal tract (GIT) and the liver weights of the outdoor reared pigs were significantly ($P < 0.05$) heavier than those of the indoor reared pigs. Feeding the HE diet led to significantly ($P < 0.05$) higher carcass weights and dressing percentages.

Interactive effects ($P <0.05$) of diet and rearing system were found for lean meat percentage (Lean P) and eye muscle area (EMA). Indoor pigs fed on the NE diet had higher Lean P and EMA while an opposite effect was obtained in the outdoor system. The liver of the NE diet fed pigs was significantly ($P < 0.05$) heavier than that of the pigs fed the HE diet. It can be concluded that with regard to growth performance and carcass characteristics, the NE and HE diets are respectively best suited for the indoor and outdoor rearing of pigs.

Keywords: outdoor pigs, energy level, digestibility, growth performance, carcass characteristics, visceral organs

TABLE OF CONTENTS

List of Tables

List of figures

LIST OF ACRONYMS AND ABBREVIATIONS

ABBREVIATION	DESCRIPTION
%	percentage
ºC	Degree Celsius
ADF	Acid insoluble fibre
ADFI	Average daily feed intake
ADG	Average daily gain
API	Animal Production Institute
ADTFI	Average daily total feed intake
ART	Average retention time
BR	Brewer's grain
Ca	Calcium
CCW	Cold carcass weight
CF	Crude fibre
CL	Carcass length
CM	Corpa meal
CP	Crude protein
CR	Coarse rice bran
DE	Digestible energy
DM	Dry matter
EE	Ether extracts

LIST OF ACRONYMS AND ABBREVIATIONS

ABBREVIATION	DESCRIPTION
EMA	Eye muscle area
EMF	Eye muscle fat
F 1	First generation
FCR	Feed conversion ratio
g	gram
GIT	Gastro-intestinal tract
GLM	General linear model
HE	High energy
IW	Initial weights
kg	Kilogram
km	Kilo-metre
LR	Landrace
LW	Large White
LS	Least square
ME	Metabolisable energy
MJ	Mega joule
m	metre
max	maximum
min	minimum

LIST OF ACRONYMS AND ABBREVIATIONS

ABBREVIATION	DESCRIPTION
m^2	Square metre
NDF	Neutral detergent fibre
NE	Normal energy
NFE	Nitrogen free extracts
NRC	National Research Council
OMD	Organic matter digestibility
OMD_d	Diet organic matter digestibility
OMD_p	Pasture organic matter digestibility
P^2	Backfat
P	Phosphorus
R^2	r-squared
RS	Rearing system
SAPPO	South African Pork Producers Organisation
SE	Standard error
TF	Total fibre
TFIFCR	Total feed intake feed conversion ratio
TFI	Total feed intake
TR	Torfu residues
vs.	Versus

LIST OF ACRONYMS AND ABBREVIATIONS

ABBREVIATION	DESCRIPTION
WCW	Warm carcass weight
WGR	Whole ground rice

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CHAPTER 1: BACKGROUND AND OVERVIEW OF THE STUDY

1. BACKGROUND

1.1 GENERAL INTRODUCTION

The success of resource poor emerging farmers is limited by the high costs of equipment, housing and costs of feeds (Molekwa & Umesiobi, 2009). Due to welfare considerations, animal producers are also under pressure to utilize methods that promote the natural behavior of animals (Stern & Andreson, 2003). These concerns have led to research being conducted to find cheaper production alternatives that are animal friendly. One practice used in some European countries, which could help reduce these costs as well as promote an ideal environment is for the pigs to be raised outdoors or with outdoor access to pastures. Reasons for using this practice are the demand for organically produced meat, animal welfare considerations, low costs of establishment and the use of pastures as a cheaper source of nutrition (Edwards & Zanelle, 1996 cited from Rivera Ferre *et al*., 2001). Nevertheless, regardless of the advantages of raising pigs outdoors on pastures, the practice should be applied in a manner that will not have negative effects on growth performance and carcass characteristics. This can only be achieved by tackling the challenges that have negative effects on growth and carcass characteristics of outdoor pigs.

Free ranging pigs are more active than indoor-housed pigs, which is one of the factors that contribute to their increased energy requirements (Stern & Andreson 2003). Swedish farmers are as a result advised to supply outdoor pigs with 15-20% more energy than that required by indoor pigs (Alarik, 1998 cited from Gustafson & Stern, 2003). Gustafson and Stern (2003) indicated that increasing the energy level of diets is more effective in meeting the energy requirements of outdoor pigs under European conditions.

The amount of feed voluntarily consumed by growing pigs fed *ad-libitum* depends on the energy concentration of diets as pigs adjust their feed intake to satisfy their energy requirements (Chiba *et al.,* 1991 a). Feeding a diet that contains an energy level that is in excess of the requirements for production actually reduces average daily feed intake (Chiba *et al.*, 1991 a; De la Llata *et al.,* 2001). This effectively results in a low amino acid intake since the diet will be having a low amino acid to energy ratio, which reduces average daily gain. Chiba *et al.* (1991a, b) demonstrated poor performances of grower pigs and a high fat deposition when diets contained a high energy and low amino acid content while increases in the ratio of digestible lysine to metabolizable energy led to improved performance and protein digestibility (Urynek & Buraczewska, 2003).

In addition, adjusting the levels of essential amino acids of low-protein diets and maintaining a balance between energy and protein supply improves the utilization of nitrogen and reduces the negative effects that diets containing low amino acids and high energy have on weight gains and carcass characteristics (Le Bellego *et al*., 2001). Heat production from the deamination of excess amino acids is also reduced in such diets. A feeding strategy of using a diet with high energy density in pigs being raised outdoors may allow a high intake of metabolisable energy (ME) and pastures; but there is not much information, if any, of the effects of a diet containing high energy level on the utilization of nutrients by growing pigs under outdoor conditions in South Africa.

Pasture intake in pigs raised outdoors has been documented mainly in sows (Rivera Ferre *et al*., 2001;Santos Ricalde & Lean, 2002, 2006; Sehested *et al.,* 2004), but less so in growing pigs. The challenge has always been to determine the actual amount of pasture consumed by the pigs and to what extent this contributes to their nutrient needs. The methods used to determine intake of pastures include the classical sward cutting (herbage disappearance method) and marker methods (Piasentier *et al*., 1995; Rivera Ferre *et al*., 2001; Gustafson & Stern, 2003).

The methods that are used for the determination of herbage intake are inaccurate and therefore the determined herbage intakes are accepted as estimates (Macoon *et al*., 2003). Although these methods mainly show estimates, Moore (1996) and Nsahlai *et al*. (2005) suggested that the variations in intake of different pastures or between animals is well reflected by these measuring techniques. Pasture intake using the herbage disappearance method is calculated as the difference between herbage mass before and after grazing. Corrections should however be made for the re-growth of the pasture during the grazing period (Macoon *et al*., 2003). The herbage disappearance method is effective in estimating intake of group housed animals and is more suitable in grazing experiments of shorter periods. This method is not suitable for determining individual pasture intakes. The method requires hard labour but costs may be reduced, as the method does not involve a lot of the proximate nutritional analysis. The marker techniques are used to estimate the pasture intakes of individual animals, even though the rate of recoveries of markers dosed in animals is incomplete and therefore the pasture intakes may be overestimated in some cases (Malossini *et al*., 1996). In addition, marker methods are more expensive as they require expensive laboratory analysis.

One of the marker methods used is based on the ratio between faecal output, estimated with an external indigestible marker and herbage indigestibility that is either known or estimated *in vitro* (Piasentier *et al*., 1995). Chromium oxide is usually used for this purpose. An advantage of the chromium oxide method is that successful determinations of pasture intake can be made from small quantities of faeces sampled by grabbing them before they fall to the ground and thereby saving on time and labour costs. The other advantage of the method is that chromium oxide is largely unabsorbed by animals, which increases the precision with which the intake is quantified. The method can however be expensive because of the costs incurred in determining the chromium concentrations in the diet, in the faeces and the nutrient concentrations in the pastures prior to the estimation of pasture intake (Piasentier *et al*., 1995). One other disadvantage is that the flow of chromium oxide is diurnal and therefore the time of collection may need to be adhered to, which may not be practical.

The other marker method used is that of the combination of the naturally occurring odd chain alkanes (C29 & C33) found in the cuticles of plants and the even chain alkanes (C32) found in negligible quantities in plants but are available commercially (Smit *et al*., 2005). The odd and even chain alkanes are used as internal and external markers, respectively. An advantage of the alkane method of estimation is that intake determinations are independent of the diet digestibility. It should however be ensured that the animals are dosed with a known amount of even chain- alkanes on a daily basis.

Another aspect of pigs raised outdoors that is not often discussed is the effect of rooting and soil intake on feed intake and growth. The soil has a huge potential of supplying minerals that may be lacking in the pig's diet. It has been reported that the ash component of faeces from pigs raised outdoors is quite high indicating a significant intake of soil (Rivera Ferre *et al*., 2001). It has also been shown that it might not be necessary to supplement iron in pigs born outdoors (Brown *et al*., 1996; Kleinbeck *et al*., 1999). There were no differences between the growth performances of indoor pigs that received an iron supplement and outdoor pigs that had not received the supplement (Brown *et al*., 1996). Outdoor pigs were reported to have obtained iron from the soil. Outdoor pigs can also obtain some of their amino acid requirements from earthworms during the consumption of the soil (Edwards, 2003). The nutritional contribution of the soil may assist in lowering the high costs of feed.

The major objection raised against raising pigs outdoor is the possible impact of diseases. Outdoor-raised pigs are affected more by endo and ecto parasites than those raised indoors (Hovi *et al*., 2003). The average daily gain of Large White pigs exposed to *Ascaris suum,* an internal parasite of pigs, was lower (0.3 vs. 0.6 kg) compared to that of non-exposed pigs in the experiment of Zanga *et al*.

(2003). The most critical concern in outdoor pigs is the possible negative effects that they may pose towards the health of humans through the increased risk of zoonoses. Outdoor pigs are not well protected from disease causing vectors when compared to indoor pigs. The possibilities of transmitting zoonotic diseases may be high in outdoor compared to indoor pigs especially in circumstances where proper bio-security measures are not applied. Pigs are implicated as one of the most important contributors of food-borne infections in humans. Gebreyes *et al*. (2008) found a high prevalence of *Salmonella* and *Toxoplasma* in outdoor pigs compared to those raised indoors. *Toxoplasma gondii* is one of the bacterium that has a historical background in causing infections in humans especially in undercooked pork (Gamble *et al.,* 1999). The incidences of the bacterium in humans decrease when pig production becomes intensified and when bio-security measures are improved. There are concerns that the interest in outdoor production could see the re-emergence of *Toxoplasma* and other diseases that may affect the health of humans (Gebreyes *et al*., 2008). However, with better understanding of the epidemiology of these diseases coupled with improvements in biosecurity measures, the risk may be minimized compared to ten years ago.

Intensive systems are associated with welfare problems in pigs. Pigs in the wild spend most of their time rooting, chewing and exploring the environment (Olsen *et al*. 2001). Housing pigs indoors has not led to the relinquishment of this behavioural repertoire. Indoor-housed pigs have, as a result, been found to re-direct their behaviour towards their pen-mates and this leads to injuries (Olsen *et al*., 2001; Presto *et al*., 2008) and have a negative impact on the general turnover of the business by reducing growth performance, quality and, therefore, the value of the carcass.

The main challenge faced by outdoor systems is the inability to manipulate temperatures towards the pigs' requirements for effective production. It is evident from research findings that when feed and management are ideal, the environmental temperature is the main factor that influences the growth performance of pigs (Sather *et al*., 1997; Collin *et al.,* 2001; Quiniou *et al*., 2001; Gentry *et al*., 2002 a, b; Kerr *et al*., 2003). Different researchers (Sather et al., 1997; Gentry et al., 2002 a, b) have reported contrasting growth performance measures of pigs raised outdoors. In one study, daily weight gains were found to be lower for outdoor reared pigs both during the summer and winter periods compared to those raised indoors (Sather *et al.,* 1997); while in another study (Gentry *et al*., 2002 a) outdoor pigs were reported to have greater average daily gains during the summer and similar values in winter. Gentry *et al*. (2002 a) attributed the cause of the differences between the two studies to climatic conditions. The lower weight gains (0.750 kg vs. 0.897 kg) during the summer period reported by Sather *et al.* (1997) resulted from decreased feed intakes attributed to high temperatures (up-to 30 ºC). The lower weight gains and higher feed to gain ratio of outdoor pigs during the winter period could have been caused by the high energy requirements under cold conditions (temperatures dropping to as low as -45 ºC). This is because more feed is required for maintenance of growth rate and for the production of carcasses that are acceptable to consumers when temperatures are below the thermo-neutral zone of grower pigs (Quiniou *et al*., 2000).

In South Africa, outdoor pig production is practised on a small scale but may be getting more popular because of the advantages associated with welfare, lower starting up costs and possible opportunities of venturing into a niche market. The weather in South Africa is quite different from that in Europe and has longer periods where temperatures are higher than the thermo-neutral zone. There is however, a need to evaluate the performance of outdoor pigs and determine the method best suited to supplying essential nutrients under South African conditions enabling optimal productivity.

1.2 PROBLEM DESCRIPTION

The intensive indoor system of pig production has many challenges that include the high costs of establishing and maintaining infrastructure, acquiring equipment, feeding and disposing of slurry. These challenges are hampering efforts to increase pork production in South Africa by promoting non-traditional, previously disadvantaged groups of society to engage in pig production. The initiative is aimed at improving protein nutrition in the households, alleviating poverty and creating employment opportunities especially in the smallholder sector. One of the major challenges facing the government is financing the initiative and making it sustainable. Previously disadvantaged groups are challenged by the high initial capital costs and the difficulties of obtaining support from financial institutions. Raising pigs outdoors may provide a solution to some of these problems. South African emerging farmers can easily develop outdoor systems, since initial capital costs for establishing buildings are low. Infrastructure requirements in outdoor systems include only the shelters, feeders and the materials that will keep pigs within set boundaries. Movable huts or any form of material that is not used on the farm can serve as shelters. Wire or movable gates can be used for keeping pigs within set boundaries.

In South Africa, per capita pork production is low and this has seen the country importing pork from countries such as Brazil and France (Wright, 2006). It is envisaged that increasing per capita production of pigs at lower costs will offset the need to import pork resulting in the saving of foreign currency for the nation whilst creating employment. Cheaper pork will also lead to increased consumption of the meat protein thus, alleviating protein malnutrition especially in the rural areas.

Large quantities of maize have recently been used for the production of bio-fuels and since maize is one of the main ingredients used as an energy source in human and pig diets; it has resulted in high prices of pig feeds. Feed contributes about 70% of the operational costs in pig production. It has been shown that regardless of the feeding level, pigs having access to pastures will always consume a certain level of the pasture in their diet (Stern & Andreson, 2003; Gustafson & Stern, 2003). Outdoor pigs also have a substantial soil intake (Rivera Ferre *et al*., 2001). Soil can contribute to the micro-nutrient needs of pigs. In contrast to those raised indoors, outdoor piglets did not require an iron injection in the studies of Brown *et al*. (1996) and Kleinbeck *et al*. (1999). Edwards (2003) reported that outdoor pigs obtained on average 29.3 and 1.8 g protein and lysine, respectively, from the consumption of earthworms. The nutrients contributed from the pastures, soil and invertebrates may assist in reducing the costs of pig production.

Consumers are increasingly demanding accountability from producers in terms of the effects of rearing method on the welfare of pigs and the quality of meat produced (Barton Gade, 2002; Hoffman *et al*., 2003). Meat that is free from synthetic chemicals is preferred (Barton Gade, 2002). Pigs that are raised under environmentally enriched environments are less likely to injure one another (Beattie *et al*., 2000 & 2006), and, thus, require less synthetic chemicals in the form of medication especially under circumstances where good bio-security measures are applied. The outdoor system also can satisfy the welfare needs of pigs, which may reduce health problems brought about by abnormal behaviour of indoor rearing and, therefore, reducing the requirements for the administration of medication.

Pigs have been reported to have best growth performances at 22-23 ºC (Collin *et al*., 2001; Quiniou *et al*., 2001; Kerr *et al*., 2003), and temperatures on the South African Highveld in summer range from 17.5 to 28.2 ºC while in winter they range from 5.9 to 20.3 ºC. One of the major problems in outdoor systems is the inability to maintain the temperature at levels adequate for production. The climatic conditions in South Africa are not as extreme as those found in Europe, which bodes well for the South African situation. It should however be taken into account that there are measures available for offsetting the effects of the climatic conditions on the pigs. Shelter can be provided in the form of affordable material to protect the pigs from colds or high temperatures in the outdoor systems. Trees can be planted. The high energy demand of outdoor pigs can be met by increasing the energy density of the diet during periods of low temperatures (Gustafson & Stern, 2003) or by reducing the protein level of the diets while still maintaining the ratios of the essential amino acids to energy in the diets thus reducing heat production (Le Bellego *et al*., 2001).

Outdoor pigs have high energy requirements attributed to the large space allowances (Beattie *at al*., 2006; Stern & Andreson, 2003) and exposure to climatic conditions (Quiniou *et al*., 2000, 2001). Meeting the energy requirements of outdoor pigs may be difficult as the intake necessary to obtain the required quantity is limited by their stomach capacity (Chiba *et al.,* 1991 a). Possible ways of meeting the energy requirements include using fats and oils in diets to increase the energy density. Unlike in Europe and America, not much work has been done in South Africa to improve the performance of outdoor pigs.

The genotype used is one of the other factors that has an impact on performance and the genotypes used locally differ from those used in Europe and the Americas. This may have implications on the accuracy of predictions if one was to try to extrapolate performances in research held in Europe and America to South Africa. It would therefore be interesting to evaluate whether the welfare of pigs can be improved by outdoor rearing without affecting performance negatively.

1.3 PROJECT RATIONALE

One of the priorities in South Africa is making land available to societies that were previously disadvantaged. In ensuring food security in the country, it is essential that the land provided to these emerging farmers should be kept productive. Opportunities are available within the pork industry to increase pork production as per capita consumption of pork in the country is low and the country has had to import pork products. The need to find ways to increase pork consumption was one of the issues discussed during the SAPPO (South African Pork Producers Organization) conference held in May 2006 (Wright, 2006).

Raising pigs outdoors has a number of benefits associated with it, including low start-up costs, low infrastructure maintenance costs, flexibility in terms of land-use and animal welfare benefits. There are also challenges facing the system but a nutritional intervention can solve the predicament of the outdoor pigs needing energy for growth competing with that dissipated in moving around the larger space allowances and in thermoregulatory activities associated with outdoor systems. Oils and fats have traditionally been used to increase the energy density of diets without a concurrent increase in body temperature usually associated with fermentation that accompanies energy supplementation of energy by cereals and other fibrous materials. There is also a need to balance the energy supplementation with amino acid levels from the diet and to factor in possible benefits that may arise from the pasture itself. This study, therefore, aims at integrating these factors to improve the pasture system and make it more productive.

There is paucity of scientific data relating to the performance of outdoor pigs under the South African conditions. The objective of the study was to evaluate the effect of the energy concentration and rearing system on digestibility, growth performance and the carcass characteristics of indoor pigs and of outdoor pigs on pastures.

1.4 OBJECTIVES

1.4.1 Primary objectives

The primary objective of the current study was to evaluate dietary energy supplementation on performance of pigs reared outdoors or indoors..

1.4.2 Specific objectives

The specific objectives of the study were to determine the:

- Effects of energy level (14 vs. 16.1 MJ of DE per kilogram (kg)) on digestibility of nutrients, growth and carcass characteristics in growing pigs raised indoors or outdoors
- Effects of outdoor and indoor rearing systems on nutrient digestibility, growth performance and carcass characteristics of growing pigs

- The interaction of rearing system and energy level on digestibility of nutrients, growth and carcass characteristics in growing pigs raised indoors or outdoors

1.5 HYPOTHESES

This study hypothesized that:

- Dietary energy supplementation would improve the digestibility, growth performance and carcass characteristics of grower pigs reared either indoors or outdoors.
- Rearing system would have no effects on digestibility, growth and carcass characteristics of grower pigs.

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CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

One of the most important objectives of a pig farmer is to maximise profits. To ensure maximal profits, a pig farmer has to strive for best live weight gains while keeping the input costs as low as possible. Good live weights at low costs will be obtained only if the environment under which pigs are raised is manipulated to suit the needs for effective production. The efforts of striving for maximal growth have led to high initial capital cost investments in structures to ensure good animal performances once the pig unit is in production. Some emerging farmers do not have the luxury of building conventional piggery houses and that has led to interest in alternative cheaper production systems, which include the raising of pigs outdoors. Compared to indoor systems, the outdoor systems are cheaper to establish (Sehested *et al*., 2004) and this can benefit resource poor farmers. Another reason for the interest in outdoor production is the potential benefits from niche markets, which focus on consumers that prefer animals that are raised naturally or ethically (Hoffman *et al*., 2003). Not much can be done to manipulate the environmental climate under the outdoor production system and as a result, the performance of pigs may be affected. It is, therefore, important to evaluate production factors that may affect the performance of outdoor pigs. The objective of this review is to evaluate information on the factors of production that influence performance and evaluate their interactions with the outdoor system and the possible effects on the performance of pigs.

2.2 PIG PRODUCTION SYSTEMS

2.2.1 Intensive (Indoor) production systems

In intensive indoor production systems, pigs are raised indoors from birth until slaughter. The system emphasizes high levels of production and a high level of management proficiency is required to ensure best production at low costs. The intensive system of production is practised more than other production systems especially in the commercial sector. An estimated less than 30% of sows were reported to be kept outdoors in the United Kingdom while an even lower proportion were outdoors in some other European countries (Edwards, 2003). The intensive production system is preferred because; the environment under which pigs are raised can be better controlled (automatically or manually), the animals can be protected from predators, and it is much simpler to protect pigs from diseases vectors while cleaning is more effective in removing harmful micro-organisms.

The production system consists of sows being kept indoors in stalls for most of their gestation period and then being moved to the farrowing crates a week before farrowing. The sows are kept in the farrowing crates until weaning and then they are taken back to the stalls or boar house for breeding. After weaning, the piglets are moved to the weaner pens and then to the finisher pens where they are each given a space allowance of 0.3 to 0.4 m^2 and 1.0 to 1.3 m^2 during the weaner and grower-finisher phases, respectively (Knoesen, 1993). The intensive production system has come under criticism as it does not allow the pigs to behave naturally. The sow stalls and farrowing crates only allow the sow small spaces to move forward and backwards (Arey, 1999). The barren environments and the small space areas provided have led to behaviour that is deemed unnatural and the prevalence of ulcers and sores in thin sows (Davies *et al*., 1996).

2.2.2 Extensive (outdoor) production systems

Outdoor systems normally have one or a combination of the following characteristics; large space allowances, soil substrate or access to pastures and exposure to climatic conditions (Honeyman, 2005). In Africa, outdoor systems are mostly confined to the resource poor farmers as free-range systems without strict control systems. In the developed world, the breeding herd is kept outdoors in most of the systems while the weaners and slaughter pigs are raised indoors; whereas in the developing world, the pigs are born and raised outdoors.

The concerns of the consumers over the welfare of pigs produced indoors and the high capital costs of establishing conventional piggery houses have led to the growth in the number of producers raising pigs outdoors. The welfare of the pigs, the quality of meat produced and the wellbeing of the environment are emphasized in the outdoor system (Gustafson & Stern, 2003). While in indoor systems, weaning can take place at 3-5 weeks, the recommendation is that outdoor sows and piglets should be separated at 6 weeks of age (von Borell & Sørensen, 2004).

Movable gates or electrical fences are normally used in the production of outdoor pigs on pastures. Shelter can be provided by means of movable huts in the system (Rivera Ferre *et al*., 2001) and the pigs are provided with wallows to assist with cooling (Olsen *et al*., 2001b). Faeces and urine are left directly on the soil, which can be advantageous if good management is applied to prevent the localized excessive nutrient depositions at certain spots within the grazing camps. Robust breeds are normally used outdoors as sunburn can be a problem for light coloured breeds (Hovi *et al*., 2003). Although the outdoor systems are cheaper to establish compared to the conventional intensive indoor systems (Rivera Ferre *et al*., 2001), the main disadvantages of the outdoor production system is the fact that it is not easy to protect the animals from the environmental conditions. This usually leads to low growth performances especially in areas that have extremely low or high temperatures (Sather *et al*., 1997; Hoffman *et al*., 2003). The outdoor system requires good management to avoid localized deposition of nutrients. Another concern in outdoor systems is the fact that it is difficult to create a barrier between pigs and the other animals, which may serve as carriers of diseases that may be harmful to both pigs and humans (zoonotic diseases).

In both the indoor and outdoor production systems, the main aim of the producers is to come up with a product that is acceptable to the consumer at an affordable cost. This can only be attained by understanding and solving problems related to growth performance of the pigs, digestibility of the feeds given and the quality of the meat produced.

2.3 FACTORS AFFECTING GROWTH PERFORMANCE OF PIGS

There are numerous factors that affect the growth performance of pig. These include genotype, health, space, nutrition and temperature.

2.3.1 Genotype

There are variations in growth performance between pigs of different breeds. Improved European breeds that have been selected for lean meat production have superior performances compared to local or indigenous unimproved breeds of pigs (Loc *et al*., 1997; Ndindana *et al*., 2002; Kanengoni *et al*., 2004). The addition of genes of improved breeds through cross breeding has also been shown to improve the performance of unimproved breeds. Crossing the Large White (LW) pigs and Mukota pigs (an indigenous pig of Zimbabwe) led to improvements in the growth performances of the F1 progeny in the study of Kanengoni *et al*. (2004). That, however, did not lead to better performances of the F1 cross when compared to the LW.

The proportion and the combination of genes within pigs have an effect on performance. Blanchard *et al*. (1999) compared the performance of pigs containing proportions of 0, 0.25 and 0.50 Duroc genes. Although there were no differences in daily weight gains the feed efficiency decreased when the proportion of Duroc genes increased in the pigs. The growth performance of Danish Durocs was found to be superior to that of Pietrain X Large White pigs (Latorre *et al*. 2003). Fuller *et al*. (1995) obtained better performances from Duroc pigs compared to LW or Landrace (LR) crossbreeds. Superior daily gains of Durocs have been attributed to the high feed intakes in the breed (Latorre *et al*., 2003). Other researchers have however not found differences in performances between Duroc and Pietrain or Duroc and Large Whites (Kanis *et al*., 1990; Candek-Potokar *et al*., 1998).

The differences in performances obtained by different researchers comparing similar breed shows that variations are still found within breeds or from different sire lines. Most of the outdoor production systems in Europe consist of breeding sows while the growers are reared indoors (Guy *et al*., 2002 a). The large majority of outdoor breeding herds comprise of indigenous pigs or pigs that have 50% Duroc genes (Guy *et al*., 2002 a, b). Indigenous pigs and Durocs are normally used because of their robustness, their ability to better adapt to environmental conditions that are less favourable to production and their ability to produce milk with a high fat content (Sinclair *et al*., 1999). Interactions of growth performance between genotype and rearing systems have not been thoroughly investigated. Information that is available shows no interaction of rearing systems and genotype on growth performance of pigs. Guy *et al*. (2002 a) investigated the performance of three genotypes (LW X LR, Duroc crosses and Meisian crossbred pigs) in different housing systems. The LW X LR crosses had superior performances compared to the other breeds when housed either outdoors, in slatted floor pens or in the straw yard. Kelly *et al*. (2007) also did not find any interactions between genotype and housing system when a Duroc X (LW X LR), Saddleback and Duroc X Saddleback were compared. The Duroc X (LW X LR) cross performed better than the other two genotypes when housed either indoors or outdoors.

2.3.2 Health

The health status of a pig is one of the most important factors that affect growth performance. Various diseases also have different effects on performance. Live weight gains were respectively reduced by 2.8 and 7.7% in pigs containing antero-ventral pneumonia and atrophic rhinitis (Bernardo *et al*., 1990). One of the most important factors that can affect growth performance is stress. The immune response of pigs challenged with phytohemagglutinin was low in stressed compared to stress free pigs (Ekkel *et al*., 1995). Stress is caused by management factors such as weaning and poor management of the piglets after weaning, overcrowding, poor ventilation and poor feeding practices among other things.

In practice, piglets from different litters have to be mixed after weaning and the same procedure is repeated during the stage when the pigs are moved from the weaner to the grower house. The regrouping of pigs during these stages leads to fighting which was shown to elevate cortisol levels, increase the incidents of body injuries (scratches, lameness, tail and ear biting), high levels of coughing and diarrhoea in pigs that were stressed compared to those not stressed (Ekkel *et al*., 1995). The performance of pigs that had high stress levels (high cortisol), injuries, diarrhoea and coughing was significantly lower than the pigs that were not exposed to these challenges.

Indoor pigs have been shown to exhibit unnatural behaviours which show that they are stressed (Beattie *et al*., 1996). The immune system of indoor pigs is more likely to be affected by stress as aggression is high in indoor compared to outdoor raised pigs. Leg injuries are associated with aggression and the low performance of pigs with such injuries may be caused by low feed intakes attributed to the inability of the pig to stand for long periods to eat because of pain. Another factor which may cause low performances of pigs is the fact that the response to infections causes nutrients to be diverted from tissue growth and redirected to the support of the immune system.

Provided that sufficient shelter is available, outdoor pigs are less likely to suffer from health problems brought about by poor welfare or the harmful behaviour of pen mates towards one another as compared to indoor pigs. This is because the space allowance per pig in the outdoor production systems is normally larger and the environment is more enriched compared to that of indoor pigs. Endo and ecto-parasites are however a concern in outdoor systems (von Borell & Sørensen, 2004). Outdoor pigs are more likely to be exposed to *Ascaris suum* as compared to indoor pigs. *Ascaris suum* is an internal parasite that is found in the digestive tract of pigs. *Ascaris suum* can cause damage to the small intestine and in the process impair the digestion and absorption of nutrients. Urea levels in the blood of Large White pigs infected with *Ascaris suum* were low when compared to uninfected pigs (Zanga *et al*., 2003). The low urea level shows a reduction in the ability of infected pigs to utilize protein. This may explain the reduction in performance of Large White pigs infected with *Ascaris suum* in the experiment of Zanga *et al*. (2003). High prevalence rates of Salmonella and *Toxoplasma gondi* infections have been reported in antimicrobial free outdoor production systems of pigs (Gebreyes *et al*., 2008). Although clinical signs of *Salmonella* and *Toxoplasma gondi* may be seen in pigs, sometimes pigs become carriers without displaying symptoms. *Salmonella* and *Toxoplasma* weaken the pigs and affect growth performance. Both the diseases are zoonotic, meaning that they are infectious to vertebrate animals and human beings especially when infected animal products are consumed raw or when not well cooked. *Toxoplasma gondi* was estimated to have caused 100 000 cases of foodborne-related illnesses in human beings in the United States (Mead *et al*., 1999).

2.3.3 Space allowance

Space allowance is an important parameter that influences the growth performance of pigs. Research that has been conducted has shown varying effects of space allowance on growth performance (Beattie *et al.,* 1996, 2000; Brumm & Miller, 1996; Turner *et al.,* 2000; Wolter *et al.,* 2000; Street & Gonyou, 2008). Similar daily gains were obtained between pigs reared on low and high space allowances although feed utilization was more efficient for pigs provided with the smaller space allowance in the experiment of Turner *et al*. (2000). Beattie *et al.* (1996) obtained reduced daily gains in pigs when the space allowances were either below or above 1.1 m^2 per pig, although the feed utilization was more efficient for the pigs supplied with the space allowances that were below 1.1m^2/pig. Higher daily gains and more efficient feed utilization were obtained when pigs were allowed larger space allowances (Brumm & Miller, 1996; Beattie *et al.* 2000; Wolter *et al.* 2000; Street & Gonyou, 2008). Gentry *et al*. (2002a), however did not find any significant differences in any performance parameter when pigs were reared at small (0.90 m^2 /pig) and large (9.45m^2 /pig) space allowances.

One aspect that brings about differences between the performances of pigs reared in small and large space allowances is feed intake. Feed intake was low in pigs provided with small space allowances (Beattie *et al.,* 1996; Brumm & Miller, 1996). In contrast, feed intakes were similar between pigs raised in small and large space allowances (Turner *et al*., 2000). The differences in feed intake between the experiments of Beattie *et al*., (1996) and Turner *et al*. (2000) were reflected in the weight gains. Pigs supplied with small space allowances had low average daily gains compared to those supplied with the large space allowances in the experiment of Beattie *et al*. (1996) while differences were not found between pigs raised in small or in large space allowances in the experiment of Turner *et al*. (2000). The differences in weight gains between the experiments of Beattie *et al*. (1996) and Turner *et al.* (2000) were attributed to feed intake. Beattie *et al.* (1996) obtained low feed intakes (1011 vs. 1208 g) for pigs supplied with small compared to those supplied with large space allowances while there were no differences in feed intake between the different groups in the experiment of Turner *et al.* (2000).

Feed efficiency is expected to be higher for pigs raised in smaller space allowances compared to higher allowances as seen in the experiments of Beattie *et al.* (1996) and Turner *et al.* (2000), because pigs reared in large space allowances are highly active (Gustafson & Stern, 2003). The high activity leads to a high maintenance energy requirement and therefore the feed efficiency is negatively influenced. There are unfavourable feed efficiencies in pigs raised in small space allowances compared to those raised in larger space allowances (Brumm & Miller, 1996; Beattie *et al.* 2000; Wolter *et al.,* 2000; Street & Gonyou, 2008). The lower feed efficiencies of pigs raised in small space allowances (Brumm & Miller, 1996; Beattie *et al.* 2000; Wolter *et al.,* 2000; Street & Gonyou, 2008) may have resulted from stress. Pigs that are reared under crowded conditions engage more in harmful behaviours (fighting) towards one another compared to those provided with sufficient space (Beattie *et al.* 2000). The harmful behaviours lead to stress. According to Beattie *et al.* (2000), stress has a negative effect on feed conversion efficiency. The higher efficiency of feed utilisation in the experiments of Beattie *et al.* (1996) and Turner *et al.* (2000) compared to those of the experiments of Brumm and Miller, (1996), Beattie *et al.* (2000), Wolter *et al.* (2000) and Street and Gonyou (2008) could have been caused by the fact that the small space allowances in the experiments of the latter two researchers was not accompanied by harmful behaviours.

The stress impact of space allowances may be mitigated by enriching the environment. The effect of space allowance on performance was investigated under enriched environments in the experiments of Beattie *et al.* (1996) and Turner *et al.* (2000). The enriched environment may be the reason that the efficiency of feed utilization was improved despite the very small space allowance in the experiment of Beattie *et al*. (1996) as the pigs in the experiment were not harming one another. That might also be the reason that weight gains were similar between pigs raised on small and large space allowances in the experiment of Turner *et al*. (2000). Pigs reared in enriched environments have been shown to direct their explorative behaviours towards the resources that have been used for enrichment which is one of the factors that reduces fighting amongst the pigs, reduces stress associated with small space allowances and therefore maintaining proper performance. Outdoor systems are characterized by large space allowances. In general it may be said that though daily gains and feed efficiencies of outdoor pigs may be negatively affected compared to those of indoor pigs owing to the larger space allowances, if the space allowances of indoor pigs are below the minimum recommendations then pigs may become stressed which usually diminishes the benefits of small space allowances on feed efficiency. The experiment of Beattie *et al*. (1996) showed that the growth performance of pigs provided with a sufficient space allowance of 1.1 m^2 /per pig was higher than that of pigs allowed spaces of 2.3 m^2.

2.3.4 Temperature

One of the most important factors affecting the performance of outdoor pigs is the environmental temperature. Grower pigs have been reported to have best growth performances at between 22 to 23 ^{0}C (Collin *et al.,* 2001; Quiniou *et al.,* 2001; Kerr *et al*., 2003). The 22 to 23 ^{0}C temperature range is regarded as the thermo-neutral temperature zone of pigs. The thermo-neutral temperature zone is regarded as the temperature at which pigs do not have to engage in any behavioural and physiological activities in order to maintain homeostasis. Temperatures below or above thermo-neutrality lead to negative growth performances in pigs (Sather *et al*., 1997; Collin *et al.,* 2001; Quiniou *et al.,* 2001).

Daily weight gains were found to be lower for outdoor reared pigs compared to confinement reared pigs (750 vs 897g and 786 vs 935g during the summer and winter periods respectively) in a Canadian study (Sather *et. al.,* 1997). Minimum and maximum temperatures ranged from -45 to 20 ^{0}C during the different winter months (January–April) in Canada while the summer temperatures ranged from -4 to 28 ^{0}C (Enfalt *et al*. 1997). Hoffman *et al*. (2003) also obtained low growth performances of outdoor pigs raised from the late winter, through spring to the early summer month. The negative growth performance when temperatures are low is caused by the fact that the energy from feed is diverted from production to the process of maintaining body heat (Enfalt *et al.,* 1997; Sather *et al.,* 1997). Decreasing temperatures from 22 to 12 ^{0}C led to high metabolizable energy intakes of indoor pigs (Quiniou *et al*., 2001). The high metabolizable energy intake in the experiment of Quiniou *et al*. (2001) was accompanied by increased heat production which is an indication that the excess energy was used for heat increment.

Average daily gains (ADG) were significantly reduced when temperatures were increased from 22 to 29 ^{0}C in the experiment of Le Bellego *et al*. (2001). The low ADG's were caused by the reduction in feed intake (2.2 vs. 1.9 kg) when temperatures were increased. The reductions in feed intake led to low energy intakes which consequently led to the slow growth rates obtained (Le Bellego *et al*., 2001). It has been shown that the growth rate of grower pigs is dependent on the energy level of the diet and high energy intakes improve growth (Bikker & Vergesten, 1993). Other studies showed low growth performances when grower pigs were exposed to high temperatures (Kerr *et al*., 1995; Tuitoek *et al*., 1997).

One of the other factors worth noting is that high temperatures have a more pronounced negative effect on growth rates compared to low temperatures. Sather *et al*. (1997) conducted an experiment in which pigs were grown from 25-105 kg both during the winter and summer periods. Pigs raised during the summer period took 9 more days to reach 105 kg compared to those that were raised during the winter period. It has also been shown that the negative effects of high temperature are more pronounced on finisher pigs compared to grower pigs (Le Bellego *et al*., 2001). Reductions in average daily feed intakes (ADFI) and ADG' s were 12 and 10% and 17 and 16% during the grower and finishing period respectively in the experiment of Le Bellego *et al*. (2001). Lower feed intakes of outdoor pigs were also associated with high air temperatures in the experiment of Andreson and Redbo. (1999). Lower feed intakes of pigs raised under lower temperature conditions in the experiment of Andreson and Redbo (1999) led to unfavourable growth rates.

2.3.5 Nutrition

Protein, energy, minerals and fibre are all influential on the growth performance of pigs.

2.3.5.1 Protein and Energy

The quantity of essential amino acids, the ratio of lysine to megajoule of digestible energy (DE), the quantity of energy concentration per kilogram of feed and under certain circumstances the interaction between the quantity of lysine to megajoule of energy and energy density are some of the most important factors that affect the growth performance of pigs (Chiba *et al*. 1991a; Szabo *et al.* 2001; Urynek & Buraczewska 2003). Increasing the ratio of lysine to megajoule of digestible energy from 1.5 to 3.2 grams in diets containing an energy level of 12.6 MJ of DE /kg improved daily weight gains by 218 grams in the experiment of Chiba *et al*. (1991a). Similarly there was an improvement in daily gains when the ratio of lysine to energy was increased in other studies (Nam & Aherne, 1994; Van Lunen & Cole, 1998; Szabo *et al.,* 2001; Urynek & Buraczewska, 2003).

Pigs eat to meet their energy requirements (Chiba *et al*. 1991a) and therefore the amount of feed consumed is determined by the energy concentration in diets. Lysine is the first limiting amino acid for growth in pigs and therefore its high concentration in diets leads to high intakes and therefore better performances. Lysine intake in diets containing low and high levels of lysine (1.5 and 3.2 g lysine /kg MJ of DE) in the experiment of Chiba *et al.* (1991a) was about 11 and 20 g/day, respectively and this was reflected in weight gains as pigs with the higher lysine intakes had better weight gains. Pigs fed diets with low lysine levels did not adjust feed intake in order to compensate for the low intake of the nutrient. Lysine level in other studies (Nam & Aherne, 1994; Szabo *et al*., 2001) did not affect feed intake of pigs.

The ratio of lysine: DE has also been found to have varying effects on the feed efficiency of pigs at different growth stages. Gain to feed ratio was increased by 0.287 when the ratio of lysine: DE of a diet containing 12.6 MJ of DE /kg was increased from 1.5 to 3.2 in pigs fed from 20 to 50 kg in the experiment of Chiba *et al*. (1991a). There were also improvements in feed efficiency when the ratio of lysine: DE was increased in other studies (Nam & Aherne, 1994; Szabo *et al.,* 2001). Szabo *et al*. (2001) evaluated the performance of both grower (20-60kg) and finisher pigs (60-105kg) fed three levels of dietary lysine: DE ratio containing a low, medium and high ratio of lysine: DE; and obtained no differences in growth performance between pigs fed the high and medium lysine levels in finisher pigs while pigs fed the low lysine: DE level had a significantly lower ratio of gain to feed.

Increasing the energy concentration in diets of pigs, irrespective of the lysine level and maintaining the ratio of amino acids: DE was found to improve growth performance (Chiba *et a*l., 1991a; Nam & Aherne, 1994; Smith *et al*., 1999; De la Llata *et al*., 2001; Szabo *et al*., 2001; Kerr *et al*., 2003; Urynek & Buraczewska, 2003). It was however shown that there is an interaction between the energy density and lysine: DE levels (Chiba *et al.,* 1991a; Urynek & Buraczewska, 2003) in daily weight gains of pigs. Increasing energy levels from 12.6 to 15.7 MJ of DE /kg in diets containing a lysine: DE level of 1.5g/ MJ improved daily weight gains of pigs by 22g per day, while a further increase of energy to 16.7 MJ of DE/ kg reduced daily weight gains by 4g (Chiba *et al.,* 1991a). The best weight gains for pigs fed a diet containing a lysine: DE ratios of 2.35 and 3.20 g/ MJ were respectively obtained at energy levels of 16.7 and 15.7 MJ of DE per kilogram.

The positive effects of increasing energy density have been shown to be different on variables of growth performance and the effects are dependent on the growth phase of pigs (Smith *et al*., 1999; De la Llata *et al*., 2001; Kerr *et al*., 2003). While differences were obtained in daily weight gains and feed efficiency between diets containing low and high energy levels in pigs grown from 25 to 41 kg; there were no such differences between the growth performances of pigs fed the low, medium and high energy level in pigs grown from 41 to 59 and 82 to 110 kg (Kerr *et al*., 2003). Feed efficiency was however different in pigs grown from 59 to 83 kg fed either a low or a medium energy level. Results similar to those of Kerr *et al*. (2003) were obtained by De la Llata *et al*. (2001) when grower pigs (36 to 59 kg) were fed diets containing a high energy level. Weight gains were not affected in pigs grown from 59 to 93 and 93 to 120 kg while feed efficiency was improved and feed intake was reduced (De la Llata *et al*., 2001).

Research results therefore indicate that introducing pigs to high energy diets at advanced stages may only lead to improvements in feed efficiency but not daily gains and one of the studies that clearly demonstrates the pattern is that of Smith *et al.,.* (1999). Smith *et al.* (1999) conducted a study that compared the effects of energy density and lysine: energy on performance of pigs. The study consisted of two experiments. Pigs used in the first experiment were grown from 44.5 to 73 kg while those of the second experiment were grown from 29.2 to 72.6 kg.

Increasing energy density for pigs in the first experiment only led to improvements of feed efficiency while the same treatments in pigs of the second experiment led to improvements in both daily gains and feed efficiency. Bikker and Vergesten (1993) showed that young pigs grown from 20 to 45 kg depended more on energy for growth compared to heavier pigs, which may explain the difference in response of high energy between light and heavy pigs.

It is important that care should always be taken to ensure that amino acids are adjusted whenever the energy level of feed is increased. It has been shown that the weight gains of pigs are negatively influenced when the energy level of diets is increased without adjustments in amino acids (Chiba *et al.,* 1991a). Daily weight gains decreased from 645 to 494 grams per day when the energy level of a diet containing a constant lysine level of 0.45% was increased from 12.6 to 16.7 MJ/ kg in the experiment of Chiba *et al*. (1991a). The reduction in weight gains was caused by the low feed intake (1.7 vs. 2.4 kg) when the energy level was increased. Even though the reduction in feed intake did not affect energy intake, the lysine intake was significantly reduced in the high compared to the low energy diet (7.35 vs. 10.8 g/ day).

2.3.5.2 Minerals

Minerals are an important nutritional component of feed. Plants absorb minerals from the soil which are then made available to animals during the consumption of the plants or ingredients made from plants. The levels of minerals supplied in feed should be in line with those required by pigs at different stages of growth. Both low and high levels of minerals can have negative effects on growth performance.

Feeding diets containing inadequate levels of calcium (0.3% per kilogram) reduced the growth performance of pigs (Hall *et al.,* 1991). Increasing levels of calcium from 0.3 to 0.6% per kg led to improved growth performances while feeding excessive levels (0.9%) led to a decline in performance (Hall *et al.,* 1991). Reducing the phosphorus quantity from the recommended NRC (1998) levels of 0.56 to 0.40 % per kilogram improved daily gains of grower-finisher pigs from 834 to 873 g (Mavromichalis *et al.,* 1999). The improvement in performance might have been brought about by the fact that grower-finisher pigs required lower levels of phosphorus compared to young pigs. O'Quinn *et al.* (1997) reported that grower-finisher pigs required less than 0.42 % phosphorus. However, a high omission of inorganic phosphorus also reduces growth performance. The work of Mavromichalis *et al.* (1999) showed a high decline of growth performances when inorganic phosphorus was totally removed from the diets of grower-finisher pigs. A reduction in the mineral content of diets has been shown to reduce feed intake (Spurlock *et al.,* 1998; Mavromichalis *et al.,* 1999).

Certain minerals have an impact on the utilisation of one another and an imbalance can lead to a negative influence on performance. One of the interesting interactions between minerals is that of the ratio between calcium and phosphorus (Ca:P). Research showed that increasing the ratio of calcium: phosphorus reduced the growth performance in pigs (Qian *et al.,* 1996; Hanni *et al.,* 2005). Hanni *et al.* (2005) conducted an experiment in which pigs fed from 38.6 to 113 kg were allocated diets containing either a Ca: P ratio of 1.0: 1, 1.25:1, 1.5:1 or 2.0: 1. The negative impact of a high Ca:P level was high when the ratio was increased from 1.5:1 to 2.0:1.

Pigs that are not supplemented with iron after birth have low daily gains (Kleinbeck *et al.,* 1999). The benefits obtained by outdoor reared pigs from the minerals in the soil were shown in the experiments of Brown *et al.* (1996) and Kleinbeck *et al.* (1999). Brown *et al.* (1996) showed that it was not necessary to supplement outdoor born and raised pigs with iron as there were no differences in the growth performance of piglets that either received or did not receive an iron supplement. According to Kleinbeck *et al.* (1999), pigs reared outdoors can receive iron through the soil, bedding, plants, sow feed or faeces. Soils are basically formed by minerals. Outdoor reared pigs have been shown to have substantial levels of soil intake (Rivera Ferre *et al.,* 2001) and may therefore benefit from the minerals in soils.

2.3.5.3 Fibre

A reduction in daily weight gains when fibre was added to diets was obtained by some researchers (Ndindana *et al*., 2002; Kanengoni *et al*., 2004). Feed intake has however been observed to either increase or remain similar between diets consisting of high or standard fibre levels. The increase in feed intake when the fibre level of diets increases is an effort to maintain energy intake (Sterne & Andreson, 2003) as pigs eat to satisfy their energy requirements (Chiba *et al*., 1991a).

Partanen *et al*. (2002) obtained contrasting results when they found no differences in growth performance of pigs when growing-finishing pigs were fed diets containing medium and high fibre diets. The differences in response to the medium and the high fibre diets compared to other experiments containing high fibre could have been caused by the relatively lower NDF level in the diets as compared to that contained in the experiments of other researchers (Laswai *et al*., 1997; Ndindana *et al*., 2002; Kanengoni *et al*., 2004). The highest fibre diets during the grower stage in the experiment of Partanen *et al*. (2002) only contained an NDF level of 284 g/kg which was comparatively low when compared to the NDF levels at fibre inclusion rates of 200-300 g/kg in the experiments of Laswai *et a*l. (1997) and 276.4-523.5 g/kg in the experiments of Ndindana *et al*. (2002) and Kanengoni *et al*. (2004). Increasing the inclusion level of ground maize cobs from 0-300 g/kg in the study of Kanengoni *et al*. (2002) increased the levels of neutral detergent fibre (NDF) from 276.4 to 523.5 g/kg. It has been shown that there is a negative correlation between NDF and digestibility of nutrients (Kanengoni *et al*., 2002). The low NDF level in the experiment of Partanen *et al*. (2002) could not have had significant negative effects on the utilisation of nutrients by the experimental animals. Wenk (2001) also pointed out that the effect of fibre on performance is not only affected by the fibre level, but by the chemical composition of fibre.

Though fibre has negative effects on growth of pigs, it has been shown that the extent of the effects vary between breeds. Indigenous pigs have been shown to utilise fibre more effectively compared to exotic breeds (Ndindana *et al*., 2002; Kanengoni *et al*., 2002; Len *et al*., 2009). The better utilisation of fibre by indigenous pigs is attributed to the large digestive tract relative to size of animal which increases the fermentation and transit time of digesta. The study of Thacker and Haq (2008) also showed that the negative effects of fibre are reduced as the animal weights increase. Including lucerne leaf meal at levels of 75 g/kg reduced live weight gains of growers in the experiment of Thacker and Haq (2008) while the inclusion of the leaf meal at 150 g/kg during the finisher phase increased the growth performance of the pigs. This indicates that the negative effects of fibre are higher in younger animals compared to mature or older animals.

2.4 FACTORS AFFECTING DIGESTIBILITY IN PIGS

There is a positive correlation between digestibility and performance in pigs. The rate of passage through the digestive tract, fibre level and ash are some of the important factors that can affect digestion in mono-gastric animals.

2.4.1 Rate of passage

The rate of passage of feed is the speed with which digesta moves through the digestive tract. The rate of passage is measured by calculating the period from initial intake of a diet to the period when the diet is excreted. Better digestibility coefficients of nutrients are obtained when the movement of feed through the digestive tract is slow compared to when the movement is faster. Digestibility coefficients of 0.738, 0.637 and 0.578 were obtained for organic matter (OM), while 0.707, 0.624 and 0.565 were obtained for energy when the average retention times (ART) of digesta in the digestive tract of pigs were 81, 37 and 33 hours respectively (Le Goff *et al*., 2002). Better digestibility coefficients of dietary components were obtained in rats (Hansen *et al.,* 1992) and pigs (Dung *et al.,* 2002; Kim *et al.,* 2007) when the movement of digesta through the digestive tract was slow. An improved digestibility associated with the slow movement of feed through the digestive tract may be caused by the high ART which allows the digestive enzymes sufficient time to break down complex feeds into simpler ones. The high ART also allows more time for absorption of digested nutrients to take place. One factor that has been shown to affect the rate of passage in pigs is the level of feeding. The high ART of digesta in the experiment of Le Goff *et al*. (2002) was partly attributed to restricted feeding level.

2.4.2 Fibre

Dietary fibre (non starch polysaccharides) is defined as plant polysaccharides and lignin that are resistant to digestive enzymes (Bach Knudsen, 2001). Starch components that are resistant to digestive enzymes are also regarded as dietary fibre. Both the level and source of fibre have an effect on digestibility in pigs (Wenk, 2001).

2.4.2.1 The effect of inclusion level of fibre on digestibility

Increases in fibre level of diets in the experiment of Anderson and Lindberg (1997) led to reduced digestion of organic matter (OM), crude protein (CP), ether extracts (EE), nitrogen free extracts (NFE), total fibre (TF) and energy. Increasing the fibre level from 0-100 g/kg through the addition of maize cobs reduced CP apparent digestibility by 4%, and an increase of maize cobs to 200 and 300 g/kg led to further decreases of 25 and 32 % in CP digestibility respectively (Ndindana *et al*., 2002). Reductions in digestibility of other nutrients were obtained when the levels of maize cob were increased. Other studies also reported similar reduced digestibility coefficients of dietary components when the fibre level of diets increased (Anderson & Lindberg, 1997; Laswai *et al*., 1997; Lizardo *et al*., 1997; Kanengoni *et al*., 2002; Thacker & Haq, 2008; Len *et al*., 2009).

High fibre increases the peristaltic movement in the digestive tract, reduces the ART of digesta (Hansen *et al.,* 1992) and therefore limits the time for microbial digestion and the ability of dietary components to be absorbed. Jørgensen *et al*. (1996 cited by Wenk, 2001) reported a five to six fold increase in the flow of digesta through the terminal ileum of pigs fed high dietary fibre cited from Wenk (2001). High fibre in feeds may also trap nutrients, protect them from the action of digestive enzymes and therefore adversely affect absorption in the small intestine.

The extent of the negative effect of fibre level on digestibility is dependent on the breed and the growth stage of the pigs being fed the fibre diets (Noblet & Knudsen, 1991; Anderson & Lindberg, 1997; Laswai *et al*., 1997; Kanengoni *et al*., 2002; Len *et al*., 2009). Len *et al*. (2009) when comparing the indigenous Vietnamese Mong Cai piglets to the Landrace X Yorkshire crosses showed that there was no difference in ileal digestibility between the indigenous Mong Cai and Landrace X Yorkshire crosses. Differences in digestibility between the breeds were found when the total tract digestibility was determined and that was an indication that the indigenous Vietnamese pig had a better capacity to ferment dietary fibre in the colon. Both the Mukota and Mong Cai are kept by smallholder producers where they are fed by-products containing high fibre in their respective countries (Ndindana *et al*., 2002; Len *et al*., 2009). Pigs that have thrived on high fibre diets have been observed to have undergone anatomical changes which make them better utilizers of fibre. The Mukota pig was observed to have proportionally longer small and large intestines compared to the Large White (Dzikiti & Marowa, 1997 cited from Ndindana *et al*., 2002). The longer large intestine of indigenous pigs could increase the ART of digesta and result in a higher fermentative capacity and therefore a better utilization of diets containing high fibre levels.

2.4.2.2 Effect of fibre source on digestibility

Various fibre sources have different effects on digestibility in pigs. Research has shown that fibre source is more important than the level of fibre inclusion when evaluating the effects of fibre on digestibility (Dung *et al*., 2002). The most important factor that brings about the variations in the digestibility of different sources is the physiological characteristics (solubility, viscosity, water holding capacity and physical structure) and chemical content of the fibre. Sources containing soluble fibre are more digestible compared to those having insoluble fibres (Latymer *et al*., 1990 cited from Le Goff, 2002). This was shown in the experiment of Le Goff *et al*. (2002) whereby a diet containing sugar beet pulp fibre had better digestibility of dietary components compared to diets based on maize and wheat bran fibre sources. Sugar beet pulp was reported to contain significant proportions of soluble fibre (Le Goff *et al*., 2002).

Dung *et al*. (2002) conducted an experiment that compared the digestibility of a basal diet to six fibre sources (Brewer's grain (BR), copra meal (CM), cassava residues (CR), whole ground rice (WGR), coarse rice bran (RB), and tofu residues (TR)). The digestibility coefficients of OM and CP were lower in WGR and RB than in the basal diet. Crude protein digestibility of TR was also lower than that of the basal diet. The lower digestibility coefficients of OM and CP in WGR and RB were caused by the high silica and lignin contained in the diets. Coarse rise bran contained the highest level of lignin compared to the other fibre sources (100 g/kg vs. a range of 36-61 g/kg of the other fibre sources) while TR contained the lowest ratio of hemicellulose/cellulose. The ratio of hemicelluloses/cellulose varied from 0.09 to 9.26 with TR consisting of the lowest and CR the highest ratio. The high cellulose concentration in TR may explain the low crude protein digestibility in TR. Lignin and cellulose are indigestible while hemicelluloses are partly digested by the gastric juices. Digestibility coefficients of hemicellulose and cellulose in the experiment of Dung *et al*. (2002) were 83 and 58 % respectively. Fibre has the effect of protecting dietary components from the enzymatic digestion and thereby increasing the viscosity of the digesta which results in high rate of passage and negative effects on digestion. This effect of fibre may explain the low coefficients of digestibility especially in diets containing fibre components that are indigestible.

2.5 CARCASS CHARACTERISTICS

The rearing method and the type of feed used have a bearing on specific carcass traits which in turn affect the quality of the meat produced. In order for the producer to satisfy the consumers with regard to the quality of the final product then they must raise their pigs taking into consideration the impact of the various factors on specific carcass traits such as; the lean meat percentage, the dressing percentage and the meat quality traits such as drip loss and pH.

2.5.1 Dressing percentage

The dressing percentage of the pig is the weight of the carcass after the removal of the viscera or the intestines, heart, lungs and trachea. The dressing percentage is calculated as the cold carcass weight as a percentage of live weight. The dressing percentage is an important component that influences turnover in pigs. Pigs with high dressing percentages are of high value. The experiment of Gustafson and Stern (2003) showed that the dressing percentage of the pigs should be evaluated if proper conclusions are to be made about the performances of pigs. Gustafson and Stern (2003) obtained similar growth and final weights between outdoor pigs fed on a normal and a high energy level, but the dressing percentages of pigs fed the high energy level were higher than those fed on the normal energy level. Pigs fed on the normal energy level were found to be more feed efficient when the FCR was calculated based on the dressing percentage in the experiment of Gustafson and Stern (2003). The results of Gustafson and Stern (2003) showed that some of the live weight in pigs fed on the normal energy level resulted from the heavier viscera.

2.5.2 Lean meat percentage

The lean meat percentage of pork is one of the most important factors that influence meat acceptability by consumers (Barton Gade, 2002). The lean meat percentage is the measure of the ratio between muscle and fat in the carcass. Consumers prefer meat with a high percentage of lean (Sather *et al*., 1997). The lean meat percentage of pork is determined from the eye muscle area of meat. The eye muscle area and the fat depth are determined and then the following formula is used to determine the percentage lean of meat:

$$\% \text{ lean} = 72,5114 - 0,4618V + 0.0547S$$

Where V is the fat thickness (mm) and S is the muscle depth (mm) (Bruwer, 1990).

The fat thickness and the muscle depth have been measured using the vernier calipers (Kanengoni *et al.*, 2004) and the intrascope (Hoffman *et al*., 2003).

2.5.3 Carcass length

The carcass length is an important factor that determines the number of back bacon rashers that may be obtained from pigs. The carcass length of exotic improved breeds is usually higher than those of indigenous unimproved breeds. The carcass length is measured from the first rib to the pubic bone using a measuring tape.

2.5.4 Back-fat thickness

The back-fat content of pigs is measured to determine the amount of fat in pork. Back-fat measurements are done with an ultrasound in live animals and an intrascope or vernier calipers are used to measure back-fat in carcasses (Hoffman *et al*. 2003; Kanengoni *et al.* 2004). The back-fat is usually measured between the 2nd and 3rd rib on the left hand side in pigs (Gentry *et al*. 2002a, b). Normally, pigs with higher back-fat contents have lower lean meat percentages (Kanengoni *et al*., 2004; Len *et al*., 2009).

2.5.5 Carcass quality

Apart from the carcass characteristics of meat, the other important aspect that influences meat acceptability is the quality of the carcass. Some of the important quality characteristics of pork that have been investigated include the drip loss, meat tenderness and the pH of meat (Sather *et al*., 1997; Hoffman *et al*., 2003; Otto *et al*., 2004).

Drip loss affects both profitability and consumer acceptance of pork. A high drip loss in meat reduces the quantity of meat produced and also limits the extent of processing which leads to negative financial implications. Meat with a high drip loss also has an unattractive appearance which has a negative influence on the consumer acceptance of meat (Otto *et al.,* 2004). Otto *et al.* (2004) have shown that the pH in meat is negatively correlated to drip loss. Meat with low pH has a high drip loss and tends to become pale, soft and exudative (Hofmann *et al*., 2003) while meat with a very high pH tends to have a dark colour and has a short shelf life. Another important meat quality characteristic is meat tenderness. Tender meat is preferred by consumers and since meat tenderness is affected by the growth rate of animals, it is essential to select pigs for high growth rates and ensure that the environment encourages the fast growth of the animals. The low growth rates of outdoor pigs (Enflat *et al*., 1997; Sather *et al*., 1997) may have a negative influence on meat tenderness.

2.6 FACTORS AFFECTING CARCASS TRAITS

The composition of meat is one of the most important factors that determine acceptability by consumers. The carcass composition is mainly influenced by nutrition, genotype, and the interactions between the nutrients and the age and genotype of the animals.

2.6.1 Nutrition

2.6.1.1 Energy and protein level

The levels of energy and crude protein and the ratio of amino acids to energy have an effect on the carcass characteristics of pigs. It has been recommended that grower pigs should be supplied with diets that contain 14 MJ of DE per kilogram (NRC, 1998). Increasing the energy level of the diet without an accompanying increase in the levels of crude protein or essential amino acids will result in carcasses that contain high levels of fat and low percentages of lean (Chiba *et al*., 1991b). The back-fat content of carcasses was increased from 14.7 to 20.7 mm when the energy level of a diet containing 7.38 % crude protein was increased from 12.5 to 16.7 MJ of DE per kilogram (Chiba *et al.,* 1991b). Increasing the crude protein content from 7.38 to 15.75 % in diets containing energy level of 16.7 MJ of DE /kg reduced the back-fat content from 20.7 to 16 mm (Chiba *et al.,* 1991b). Similar results were obtained when the energy level of a diet was increased without adjusting the crude protein content (Szabo *et al.,* 2001). Chiba *et al.* (1991b) showed that the levels of fat deposition are high in diets that have a combination of a high energy level and a low protein level.

It has further been shown that the negative effects of a diet containing low levels of crude protein can be removed by adjusting the levels of essential amino acids (Kerr *et al.,* 2003). Kerr *et al.* (2003) did not find any significant differences in lean gain and the lean fat ratio in carcasses of pigs fed diets containing low and high protein levels when the quantities of essential amino acids were increased in the diets that contained low quantities of crude protein. Low protein diets in the experiments of Kerr *et al.* (2003) contained 17, 14 and 12 % crude protein during the early grower (25.3 to 41 kg), late grower (41 to 58 kg) and early finisher stage (41 to 58 kg). High protein diets contained 21, 17 and 15 % crude protein during the early grower, late grower and the early finisher stage, while the levels of amino acids were kept similar between the diets. In general, results showed that increasing the energy level improved the lean meat percentages of carcasses but this was only achieved when the ratio between amino acids and energy was kept constant (Chiba *et al.,* 1991b; Kerr *et al.,* 2003). The length of period that pigs are fed diets containing high energy levels also has an effect on the carcass characteristics of pigs. Pigs fed diets containing high energy levels from 25 to 115 kg had high back-fat and low lean percentages compared to those fed high energy levels from 25 to 90 kg in the experiment of De la Llata *et al.* (2001).

2.6.1.2 Fibre

High fibre levels have been found to reduce the dressing percentage in pigs (Kanengoni *et al.,* 2004; Len *et al.,* 2009). The dressing percentage of pigs receiving the low and the high fibre diets in the experiment of Len *et al.* (2008) were 71.5 and 69.3 % respectively, while Kanengoni *et al*. (2004) obtained dressing percentages of 53.3 and 42.7% for the pigs receiving the control diet (276.4 g NDF/ kg) and the high fibre diet (523.5 g NDF/kg) respectively. The low dressing percentages are mainly caused by the increases in the weights of visceral organs and the digestive tract which was apparent in other experiments when pigs were fed high fibre diets (Jorgensen *et al.,* 1996). Most work that has been done shows no differences between the back-fat content of pigs fed on diets containing different fibre levels (Fevrier *et al.,* 1992; Partanen *et al.,* 2002; Len *at al.,* 2009). However while fibre had no effect on the back-fat content of the Large White pigs in the study of Kanengoni *et al.* (2004), increasing fibre levels led to reductions on the back-fat content of the indigenous Zimbabwean Mukota pigs.

2.6.2 Genotype

The genetic make-up of the individual is one of the factors that have an influence on the carcass characteristics of pigs. Huge differences are especially found between indigenous pigs that have not been selected for maximum growth and the exotic pigs normally used for commercial farming. The back-fat content and the dressing percentage of the indigenous Zimbabwean Mukota pigs were respectively found to be high and low compared to the exotic Large White (Kanengoni *et al.,* 2004). Len *et al.* (2009) obtained similar results when the indigenous Vietnamese Mong Cai was compared to a crossbreed of a Landrace X Yorkshire. In addition, the lean meat percentage was found to be high in the Landrace X Yorkshire cross in the experiment of the latter researchers. The inclusion of the exotic pig's genes in indigenous genotypes through crossbreeding reduces the back-fat content and improves the dressing percentages (Guy *et al.,* 2002c; Kanengoni *et al.,* 2004; Len *et al.,* 2009).

It seems as though the main differences between the carcass characteristics are brought about by the degree that selection for decreased back-fat thickness and improved feed utilization have taken place (Friesen *et al.,* 1994). Exotic pigs in the experiment of Friesen *et al.* (1994) were found to have different carcass lengths and loin muscle area. Friesen *et al.* (1994) had differentiated pigs according to genotype based on their potential for lean meat deposition. Pigs that had the potential for high lean meat deposition were found to have longer carcass lengths and high *Longissimus* muscle area. In another experiment, Enfalt *et al.* (1996) obtained leaner carcasses in Yorkshire compared to Duroc sired sows. Danish Duroc sired progeny had lower dressing percentages and more lean meat compared to a Pietrain X Large White cross (Lattorre *et al.* 2003).

2.7 RELATIONSHIP OF PRODUCTION SYSTEM WITH THE BEHAVIOUR OF PIGS

The production output of a pig is directly related to its behaviour (Mcglone, 1999). Animal welfare considerations also stipulate that animals should have the freedom to express their normal behaviour if they are to be deemed to be ethically raised. The rearing environment has an effect on the animal behavior. It is therefore essential to evaluate the behavior of pigs raised indoors and outdoors since they are inquisitive and intelligent animals with a wide repertoire of behaviours.

2.7.1 Rooting

The rooting behaviour that pigs spend most of their time engaged in, when in their natural environment or when in the wild has been reported for decades (Olsen, 2001a). To root, pigs normally use their snout to remove plants from the soil or to turn the soil upside down in attempts to find feed or in exploring the environment. The level of rooting in pigs is influenced by the diversity of the environment under which the pig is being reared, the availability of a suitable substrate for rooting and by the amount of nutrients available in the feed of the animal (Jensen *et al.*, 1993; Olsen, 2001a; Stern & Andreson, 2003).

The straw material which is normally used as bedding especially in pigs reared in deep litter systems has been reported to be a good environmental enrichment source as it provides rooting material (Beattie *et al.,* 1996). It has however been shown that adding roughage to the environment of pigs supplied with the straw material has even a more beneficial effect as this encourages pigs to focus more time on their environment (straw and roughage) instead of towards the other pigs (Olsen, 2001a). Rooting in straw material was found to be high in pigs supplied with insufficient protein levels (Jensen *et al.,* 1993). Restricting feed intake to 80% of the indoor recommendations increased the rooting behaviour by 32 % in the experiment of Stern and Andreson (2003). The rooting behavior was also found to be more in outdoor pigs raised on a clover/grass pasture when the stocking densities was high compared to when it was low (5 pigs on 50 m^2 vs 5 pigs on $100m^2$) (Andreson & Redbo, 1999). Andreson and Redbo (1999) suggested that the high rooting activity of pigs at high stocking densities might have been caused by the low herbage available in that group as compared to the herbage available in the low stocking density group.

Housing pigs indoors does not abolish their repertoire behavior of rooting, even when sufficient feed is provided (Beattie *et al.,* 1996; Beattie *et al.,* 2000; Turner *et al.,* 2000; Olsen, 2001; Presto *et al.,* 2004). One of the main concerns of pigs reared indoors is the fact that the rooting behavior is mostly directed towards the concrete floor, the pen hardware and of major importance towards pen-mates (Olsen, 2001a; Høtzel *et al.,* 2004). The behaviours directed towards pen-mates have been shown to result in health problems in pigs and that causes a negative effect on performance (Beattie *et al.,* 2000; Olsen, 2001; Høtzel *et al.,* 2004). The rooting behavior in outdoor pigs is mainly directed towards the pasture which may have a negative impact on the upkeep of the pasture. The negative effect of rooting on pasture can however be abolished through proper management.

2.7.2 Activity

Outdoor pigs spend most of their time walking and exploring the environment compared to indoor housed pigs. Outdoor pigs were observed to spend 4.96 and 11.20 % of their time walking and exploring the environment respectively (Høtzel *et al.,* 2004). Similar results of high locomotion and exploratory behaviours were reported by Johnson *et al.* (2001) and Presto *et al.* (2004). Exploratory behaviours have been defined as activities involving "increased overall alertness, sensory focusing, making nasal contact, with parts or objects of the pen or paddock and locomotion accompanied by investigation" (Høtzel *et al.,* 2004). Johnson *et al.* (2001) further reported more playful activities in outdoor piglets aged between 35-50 days when compared to indoor reared piglets. Differences in activities such as standing, lying and sitting were not found between outdoor and indoor pigs in the experiments of Johnson *et al.* (2001) and Høtzel *et al.* (2004).

Activities such as walking, exploration of the environment and playing seem to be alternated for behaviours such as fighting, biting, sucking and nosing pen-mates in indoor rearing systems. Indoor and outdoor pigs were reported to spend 46 % and 0 % of their time respectively engaging in oral-nasal behaviours (biting, sucking and nosing body parts) towards their pen-mates (Høtzel *et al.,* 2004). Indoor pigs further spent more time (0.20 vs. 0.03) threatening, attacking and fighting (Agonistic behaviours). Similarly, Presto *et al*. (2004) found that nosing, riding; aggression and ear manipulation were respectively 80, 91, 68 and 98.5 % higher in indoor compared to outdoor pigs. The same researchers also found high levels of tail manipulation and inactivity in indoor pigs.

2.7.3 Wallowing

Wallows are normally provided in outdoor systems for cooling during periods when the environmental temperatures are high. Pigs were observed to spend a longer period of time in the wallow when temperatures increased from below zero to 15 ^{0}C in the experiment of Olsen *et al.* (2001b). Similar results of increased periods of time spent in the wallow when temperatures increased were obtained in the experiment of Andreson and Redbo (1999). However, in contrast to the experiment of Olsen *et al.* (2001b) the pigs in the experiment of Andreson and Redbo (1999) had a high need for using the wallow at temperatures of 20 ^{0}C. Pigs are unable to sweat and wallowing helps to wet the skin and that assists in losing heat through evaporation. Olsen *et al.* (2001b) also reported that when temperatures dropped to below 14 ^{0}C, the frequency and time spent wallowing decreased. The pigs in the experiments of Anderson and Redbo (1999) and Olsen *et al.* (2001b) used the wallow even when temperature were below 0 ^{0}C, but the time spent wallowing was reduced when temperatures were low.

2.8 THE EFFECT OF PIG PRODUCTION SYSTEM ON HUMAN HEALTH

2.8.1 Factors impacting on human health

Apart from the impact that management and production systems have on the health and growth performance of pigs, one of the most important factors is the impact of the production system on the health of human beings. Outdoor pigs usually have access to pastures. The meat of animals raised on pastures has high levels of unsaturated fatty acids compared to the meat of animals raised without pasture access (Hoffman *et al*., 2003). Unsaturated fatty acids reduce the chances of coronary heart diseases in human beings. The consumption of meat from outdoor pigs could as a result have health benefits on human beings.

The air quality in the indoor production system may be negatively affected especially when the environment, under which pigs are thriving, is not clean and when the ventilation is not sufficient and therefore the health of human beings may be affected. On the other hand, the nature of the outdoor production system makes it difficult to protect the pigs from the outside environment. Outdoor pigs have access to the soil and will also in some cases come into contact with vectors that may expose them to a variety of diseases. Some of the diseases carried by these vectors, particularly the wild animals are zoonotic diseases.

Zoonotic diseases are the diseases and infections that can be transmitted between vertebrate animals and human beings (Eddi *et al*., 2003). Some of the most important zoonotic organisms that can be transmitted from pigs to human beings are *Salmonella, Toxoplasma gondii* and *Taenai solium* (Sarti & Rajshekhar, 2003; Gebreyes *et al*., 2008). *Salmonella* is a bacterium that can affect a wide range of mammals, birds and reptiles. This bacterium causes salmonellosis in human beings. The bacterium is found in the environment and reproduces in the gut or the skin of the animals (Adak *et al*., 2005). The transmission of *Salmonella* between animals takes place through direct contact between the animals or when the animals come into contact with contaminated faeces. Human beings can also contract salmonellosis through contact with animals or by eating animal products that are not well cooked.

Toxoplasma gondii and *Taenai solium* are parasites. *Toxoplasma gondii* is found worldwide and affects all warm-blooded animals. Cats are the main hosts of *Toxoplasma gondii* and the reproduction cycle takes place in them. The other cycle of the parasite takes place in various mammals and birds (Tenter *et al*., 2000). During the reproduction cycle of *Toxoplasma gondii*, oocytes that are resistant to the environmental conditions are produced and are transmitted between mammals orally via the ingestion of animal products or water that is infected. Unborn human babies may also be infected via the placenta from their mothers (Poljak, 2009). Unborn foetuses that are infected in pregnant women exhibit asymptomatic infections, while death or acute disabilities in children may occur (Gagne, 2001).

Taenia solium is a parasite that indirectly transmits taeniosis between human beings. Exclusively, taeniosis is a human disease (Sarti *et al*., 2003). Pigs are exposed to the eggs of *Taenia solium* when they come into contact with contaminated human faeces (Sarti *et al*., 2003) or through eating feed or pastures that have been contaminated by the eggs of this parasite. The ingested eggs hatch in the gut of the pig and the resulting parasite (*Taenia solium*) makes its way to the muscles of the pig and form measles. The disease taenosis is then transmitted to humans by the ingestion of the infected meat.

2.8.2 Control of *Toxoplasma gondii*, *Salmonella* and *Taenia solium* in pigs

The fact that it is difficult to create a barrier between pigs and the environment is the main drawback in outdoor production systems. Measures of protecting pigs from harmful organisms have been suggested by some researchers (Sarti *et al*., 2003; Leirs *et al*., 2004; Mikkelson *et al*., 2004). An important strategy would be to prevent pigs from being infected. One of the strategies would be to make the environment unattractive for animals that are carriers of infections (e.g. rodents).

Rodents are carriers of various pathogens that are harmful to both humans and pigs. *Toxoplasma* and *Salmonella* are some of the pathogens carried by rats (Leirs *et al*., 2004). The limiting of rats within a pig unit may also discourage the prevalence of cats. Cats are the final hosts of *Toxoplasma gondii* (Leirs *et al*., 2004) and shed the oocysts of the parasite. Danish farmers interviewed by Leirs *et al*. (2004) reported that strategies used to control rodents involved the frequent replacement of litter as rats lived in the litter, the frequent moving of the huts, storing feed in containers that rats could not access and avoiding feed spills.

Toxoplasma can survive in the soil. Rings can therefore be put in the noses of pigs to prevent them from rooting especially in the areas where *Toxoplasma* is prevalent. Encouraging pigs to eat roughage is one of the strategies that can assist fight against *Salmonella* (Mikkelsen *et al*., 2004). Roughages stimulate the production of anaerobic bacteria, lower the pH in the digestive tract and have been indicated to reduce the number of *Salmonella* in the animal (Mikkelsen *et al*., 2004). It should also be ensured that the conditions under which the pigs are thriving minimizes stress as much as possible. It has been shown that stress makes pigs susceptible to infections (Ekkel *et al*., 1995). Moreover, the shedding of *Salmonella* increases in pigs that are stressed and that can therefore increase transmission between the pigs. Pigs that show clinical signs of *Salmonella* like diarrhoea should be isolated to prevent them from affecting other pigs and humans.

The main strategy of protecting pigs from the infection of *Taenia solium* is to restrict them from coming into contact with human faeces. Communities should be made aware of the dangers of *taeinosis* and of the factors leading to the prevalence of the condition. People should be encouraged to thoroughly cook pork and where the condition is endemic; carcasses should be evaluated before they are made available for consumption. Infected people should be regularly dewormed.

2.9 PASTURE INTAKE OF OUTDOOR PIGS

Concentrates make up most of the diet of free range pigs on pastures. Growing pigs fed *ad libitum* in an indoor study of Carlson *et al.* (1999) were shown to ingest 19% of their daily DM intake from the clover/grass herbage. On the same type of herbage in an outdoor study, pasture intake provided 5% of DM intake in the experiments of Stern and Anderson (2003). Mowat *et al*. (2001) measured pasture intakes of 0.10 kg in growing pigs offered a sward mixture of ryegrass white clover and concentrates on an *ad-libitum* basis. Average daily dry matter pasture intakes of lucerne were 0.15 kg in the experiment of Riart (2002).

2.9.1 Factors affecting pasture intake

The level of pasture intake seems to be dependent on the fibre content, quantity of energy as well as the capacity of pigs to consume more feeds. Pasture intake of grazing sows was shown to be high in summer compared to spring in the study of Rivera Ferre *et al*. (2001). In this experiment, the summer period coincided with the period when NDF was most high.

The increase in intake when the fibre level of feeds is high has been shown elsewhere (Hakansson *et al*., 2000) and is an attempt to maintain digestible energy intake. Stern and Andreson (2003) studied the grazing behavior and weight gain of pigs on pastures offered 100 or 80% allowance of concentrates. Pigs offered the 80% allowance had 3.6% more pasture intake than the 100% allowance. Gustafson and Stern (2003) conducted an experiment in which pigs on pastures were offered 15% extra metabolic energy above indoor recommendations. This was done by increasing the energy concentration (through the addition of fat) or volume of a standard diet. In their study the pigs feeding on the high energy concentration managed to consume more pastures than those feeding on the high volume diet. Both the concentrate and volume groups were unable to consume all the concentrates on offer; however the concentrate group was able to consume more pastures. The authors concluded that the volume group was limited by capacity. It should also however be noted that pasture intake is also determined by individuals in pigs. Individual variation in pasture intake was 0.07 to 0.16kg in the experiment of Mowat *et al*. (2001)

2.9.2 Estimating pasture intake in pigs

It is essential to quantify pasture intake in order to determine the nutritional contribution of pastures to animals. It is however challenging to quantify the intake of pastures in animals grazing in the field. Methods that have been used for the purpose of quantifying pasture intake include the methods based on the use of internal or external markers, the feeding behaviour of the animal, the grass disappearance method, the prediction from the forage characteristics and the method based on the performance of the animal (Moore, 1996). According to Moore (1996), all the methods used to determine pasture intake are considered to be estimates and are associated with a certain degree of error; but they are reliable for indicating pasture intakes in animals fed on different diets.

Most of the methods specified by Moore (1996) and also a lot of work done on determining pasture intake have been done on ruminants. The main methods that have been used to quantify pasture intake in pigs have been the methods based on the herbage disappearance method (Gustafson & Stern, 2003; Stern & Andreson, 2003) and those based on the use of markers (Rivera Ferre *et al*., 2001). It is essential to evaluate the different methods of quantifying pasture intake in pigs so that the best option can be chosen for determining pasture intake.

2.9.2.1 Grass disappearance

The grass disappearance method is the classical method of determining pasture intake. The grass disappearance method has been suggested to be suitable for determining intake of animals grazing in groups (Smit *et al*., 2005). The grass disappearance method works better when animals are grazed a portion of land for a shorter period of time and when most of the grasses offered are consumed (Smit *et al*., 2005).

The following steps are usually followed when the grass disappearance method is used. Firstly a certain portion of the grass within the camp that the animals are to graze is harvested and the mass of the harvest is determined. The harvested portion is then protected so that the animals cannot have access to it. When the animals leave the camp, the pasture is harvested to determine the residual pastures. The portion of the camp that was first used to determine the quantity of pastures offered is also harvested and the mass from the portion is determined separately. This is done to determine the re-growth of the pastures during the grazing period. The difference between the mass of the pasture just before the animals were allowed access and just after the animals stopped grazing, is considered to be the pasture intake. However, corrections have to be made for the re-growth.

2.9.2.2 Use of markers

Markers are indicator substances that are not digested in the digestive tract of the animals. Markers are divided into external and internal markers. External markers are those that occur naturally in plants while the internal markers are fed daily to the animal. Internal markers include the insoluble parts of the diet such as the acid insoluble ash, acid detergent lignin, the acid insoluble fibre and the odd-chain n-alkanes found in the cuticle of plants (Khan *et al.,* 2003; Sims *et al.,* 2007). One of the external markers that are extensively used is chromium oxide (Piasentier *et al*., 1995; Patterson *et al*., 2001).

A good marker must be non-absorbable, must not influence or be influenced by the digestive tract and should have similar physical properties to the diet (Khan *et al.,* 2003). The techniques based on determining pasture intake using markers rely on the information about the digestibility of the pasture and faecal output. If the digestibility of the diet is already known, the calculations of pasture intake can be made using the following formula:

$$\text{Pasture intake} = \frac{\text{faecal output X 100}}{\text{\% indigestibility of the diet}}$$

Faecal output in grazing animals can be calculated by dividing the marker that is consumed per day by the marker concentration in the faeces (Lippke, 2002). To determine pasture intake in animals that are supplemented with concentrates, the following formula may be used (Piasentier *et al*., 1995):

$$HI_{CR}=[D_{jj}/F_{jj}-Is\ (1-OMD_{s})]/\ (1-OMD_{h})$$

Where HI = herbage intake, D_{jj}= the concentration of marker in the diet, F_{jj} is the concentration of the marker in the faeces, is = the intake of the supplement, OMD_s is the organic matter digestibility of the supplement and OMD_h is the organic matter digestibility of the herbage.

2.10 CONCLUSION

The intake of sufficient quantities of nutrients from a balanced diet is the main factor influencing the growth performance and the carcass characteristics of pigs. One important factor in ensuring the intake of the required quantities and the efficient utilization of nutrients by animals is providing a diet well balanced in nutrients for the different classes of pigs and genotypes. It should however be taken into account that the growth performance of pigs will be negatively influenced when pigs are not healthy. Management factors such as the bio-security in a pig farm and space allowance are important factors that have an influence on the health of pigs and therefore affect growth performance. It should also be ensured that pigs thrive in their thermo-neutral temperature zones. High temperatures lead to the reduction of feed intake and therefore low growth rates while low temperatures result in high feed intakes and reduced feed efficiencies. Outdoor pigs are more likely to be affected by the negative effects of extreme temperature and by diseases transmitted by the environmental fauna. This poses a big problem as some of the diseases transmitted to pigs may affect human beings unless certain measures are employed to reduce these diseases. The growth performance of indoor pigs is more likely to be affected by the stress and injuries that are brought by the lack of enrichment which is characteristic in modern pig units. It is difficult to meet the energy needs when pigs are not thriving in their thermo-neutral temperature zone unless strategies such as increasing the energy density of the diets are used. The outdoor system may however be a cheaper alternative for emerging farmers. The broad objective of the current study was to determine the effect of dietary energy supplementation and rearing system on digestibility of nutrients, growth and carcass characteristics of grower pigs.

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CHAPTER 3: THE EFFECTS OF ENERGY LEVEL ON THE DIGESTIBILITY OF DIETARY COMPONENTS IN PIGS RAISED IN TWO REARING SYSTEMS

3.1 INTRODUCTION

The outdoor system has been reported to encourage the natural behavior of pigs. Compared to indoor rearing, the major disadvantage of the outdoor system is that it is difficult to protect pigs from the weather conditions. Characteristically, outdoor rearing systems have large space allowances (Sather *et al*., 1997; Gentry *et al*., 2002; Guy *et al*., 2002; Hoffman *et al*., 2003). The large space allowance and the inability to control the climate especially during cold seasons may increase the energy requirements of outdoor pigs. The extra energy demand in the outdoor system is attributed to the high activity of the outdoor pigs as well as the need to maintain homeostasis (Sather *et al*., 1997; Gustafson & Stern, 2003).

Pigs eat to meet their energy requirements. It has however been shown that it might be difficult for pigs consuming diets containing low energy levels or being raised under conditions that impose high energy demands to consume sufficient feed to meet the requirements for maintenance and production (Hakansson *et al*., 2000). This is because feed intake is limited by the capacity of the stomach (Chiba *et al*., 1991). The energy in feed is essential for the digestion and absorption of dietary nutrients. The high energy demand which may not be met may result in a shortage of the amount of energy available for the digestion of dietary components. Outdoor systems may also consist of soil or grass substrates.

While grasses can contribute to some nutritional requirements of pigs (Stern & Andreson, 2003), they can have a negative effect on diet digestibility especially when they have a high fibre level (Andreson & Lindberg, 1997). This can accentuate the assumed negative effects of the outdoor system on digestion. Increasing the energy density of diets is effective in attaining the high daily recommended energy intake in outdoor pigs (Gustafson & Stern, 2003). Digestibility is also improved in diets containing high energy densities (Chiba *et* *al*., 1991; Kerr *et al*., 2003; Urynek & Buraczewska, 2003). It is possible that increasing the energy density of diets may reduce the expected negative digestion in pigs raised outdoors on pastures. Not much work has been done on the digestibility of nutrients in pigs reared outdoors on pastures. The objective of this study was, therefore, to evaluate the digestibility of nutrients in pigs reared either indoors or outdoors fed on diets containing different energy levels. The hypotheses tested were that the digestibility of dietary components would be reduced by rearing pigs outdoor while increasing the energy level of the diets would reduce the negative effects of the rearing system on digestibility.

3.2 MATERIALS AND METHODS

3.2.1 Experimental site

The study was carried out at the Agricultural Research Council (ARC) - Irene at the Pig Nutrition Section. Irene is situated about 15km South of Pretoria on the Old Olifantsfontein road and lies at an altitude of 1526m. The average daily outdoor and indoor temperatures for the 5 day collection period were 13.4^{0}C and 22^{0}C respectively. Before commencement of the trial, the protocol of the current experiment was evaluated and approved by the Animal Ethics Committee of the ARC Animal Production Institute (API).

3.2.2 Diets

Two diets formulated to contain the normal (NE) and the high energy (HE) levels (14 vs. 16.1 MJ of DE per kilogram (kg)) were used in the experiment and are given in Table 3.1. Sunflower oil was used to increase the energy level of the HE diet. The two diets were formulated to contain 180 g of crude protein per kilogram and the ratios of the essential amino acids to energy were adjusted to be similar between the two diets. The lysine: metabolisable energy ratio of the diets was 0.82 and the levels of methionine, threonine and tryptophan were adjusted to 50, 60, and 18% in proportion to the lysine content (NRC, 1998). Outdoor reared pigs had access to pastures predominantly consisting of Kikuyu (*Pennissetum clandestinum*) while the indoor pigs had no access to pasture. The indoor and outdoor raised pigs had free access to water through drinking nipples and water buckets respectively.

Table 3.1 Ingredients and chemical composition of the experimental diet and pasture

Ingredients (kg/ton)	Conventional Energy	High Energy
Maize	600	550
Wheat bran	30	1
Soya oil cake meal	182	122
Full fat soya	100	200
Limestone	7	6
Salt	4	5
Lysine HCL	13	14
Methionine	0.4	
Monocalcium-Phosphate	16	18
[1]Crude Glycerol	43.6	-
Sunflower Oil	-	80
[2]Pig supplement	4	4
Chemical analysis (%)		
Crude Protein	19	18
Ether Extract	9	14
Crude Fibre	3	3
Neutral Detergent Fibre	17	19
Acid Detergent Fibre	4	6
Digestible Energy (MJ/kg)	15	17

[1] The crude glycerol was obtained from Biotech biodiesel plant in Bainsvlei and contained the following: Glycerol 442.85 (g/kg); Fatty acids 557.14 (g/kg); [1]GE 15.29 MJ/kg (DM); Potassium 344.66 mg/kg; Sodium 144.58 mg/kg; Calcium 55.22 mg/kg; Magnesium 16.89 mg/kg; Copper 4.71 mg/kg; Zinc 2.55 mg/kg; Phosphorus 21.59 mg/kg; Sulphur 80.27 mg/kg; Lead 0.85 mg/kg.

[2]The pig supplement contained vitamin A 6500000 iu; D3 1200000 iu; E 40000 iu; K3 2 g; B1 1.5 g; B2 4.5 g; B12 0.03 g; B6 2.5 g; Niacin 25 g; Calcium pantothenate12 g; Choline 190.5 g; Folic acid 0.6 g; Biotin 0.05 mg; Manganese 40 g; Zinc 100 g; Copper 125 g; Iodine 1 g; Ferrous 100g and Selenium 0.3 g.

3.2.3 Pigs and Housing

A total of 48 LW X LR (Large White X Landrace) male crosses that had initially been randomly selected at average weights of 27 ± 4.6 kg for assessing the growth performance of indoor and outdoor raised pigs fed on diets containing either the normal or the high energy level were used in the digestibility study. Faecal collection took place at average weights of 68 ± 1.7 kg. Pigs were housed in pairs and each indoor and outdoor pig had a space allowance of 0.51 and 13.5 m^2 respectively. Indoor pigs were housed in flat decks in a house consisting of a concrete floor while outdoor pigs were in camps containing a pasture that predominantly consisted of Kikuyu grass. Camps for the outdoor pigs were constructed from movable gates, each having a height and length of 1.2 and 3 m respectively. Empty feed bags were used to construct shelter for outdoor pigs as shown in Figure 3.1. To satisfy the wallowing requirements of outdoor pigs, a wallow was dug in the middle of each camp and watered daily.

3.2.4 Experimental design and procedures

The 48 LW X LR crosses were divided into two groups and allocated to the two rearing systems and the 24 crosses in each rearing system were fed on either the NE or HE level in a 2 X 2 factorial design. Each rearing system had 12 pigs fed on each experimental diet. The 12 pigs on each diet were divided and housed in groups of two and that resulted in 6 pairs of pigs per treatment.

Chromium oxide was used as a marker to estimate digestibility. Faecal collection took place while the growth performance of the pigs was being evaluated. The pigs were adapted to a diet containing chromium oxide for a period of 14 days before the collection of faeces took place. Faeces were collected for a period of 5 days. Grab sampling was used to collect faeces. During the collection period, indoor pigs were individually allowed to exit their pens and walk around the house while the person collecting the faeces walked behind the pig with a clean sample collecting bottle. This motivated the pigs to defecate and the faeces were caught with the sample bottle before they could drop on the ground. Faeces of pigs from the same pen were combined for the day and frozen immediately after collection. When the faeces were ready to be analysed, the faeces were thawed at room temperature overnight and then dried for a period of 24 hours at 60 ^{0}C. The 5 day faeces for the same pen were combined and mixed after the drying period and taken to the laboratory for proximate analysis.

Figure 3.1 Photo of outdoor pigs showing the movable gates and feedbags used as shelter

3.2.5 Laboratory analyses

The diets were analysed at the ARC-Irene laboratory that holds a SANAS accreditation. A representative sample that had been ground through a 1mm sieve was used in the analyses. Dry matter (DM), crude protein (CP) and crude fibre (CF) were determined according to the procedures of the Association of Official Analytical Chemists (AOAC, 1995). Dry matter was analysed by drying a 2 g sample at 105^0C for 5 hours. The weight of the sample after drying was divided by 2g and then multiplied by hundred to determine the dry matter percentage. To determine CF, a 2 g sample was chemically digested and solubilised with dilute sulphuric acid and sodium hydroxide. The remaining fibre was then corrected for ash. The Kjeldahl method was used to determine the nitrogen content in samples and then the nitrogen content was multiplied by 6.25 for conversion into CP. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analysed by the methods of van Soest (1963). Neutral detergent fibre was determined by extracting a 1 g sample in a neutral detergent solution and alpha amylase. Acid detergent fibre was determined after incubating a 1 g sample with pepsin under an acidic environment for 24 hours and then extracting the sample with an acidic solution, the remaining residue was then dried and ashed (van Soest, 1963).

3.2.6 Digestibility determination

To avoid the errors that could have been brought by soil intake, digestibility was determined on the basis of organic matter in the samples. Digestibility was calculated using the following formula:

$$\text{Digestibility coefficient} = 100 - \left(100 \times \frac{\%\ \text{Indicator feed}}{\%\ \text{Indicator } faeces} \times \frac{\%\ \text{Nutrient } faeces}{\%\ \text{Nutrients } feeds}\right)$$

3.2.7 Statistical analysis

The effects of rearing system, energy level and interactions between the diet and rearing system on the digestibility coefficients of CP, OM, EE, DE, CF, ADF and NDF were evaluated using the generalized linear model (GLM) procedures of the Statistical Analysis Systems Institute SAS (2002). Pairwise separation of means was done using the Bonferroni test. Differences were significant when $P<0.05$. The model used was

$$Y_{ijk}= \mu+t_i+r_j+(tr)_{ij}+\varepsilon_{jk}$$

Where:

Y_{ijk} = The individual observations of the ith diet, the jth rearing system and the kth replicate

μ = The digestibility coefficients of CP, DE, EE, CF, ADF, NDF and OM

t_i = The effect of the diet

r_j = The effect of the rearing system

$i_{(tr)}$ = The interaction between t and r

ε_{ijk} = The random variation or experimental error

The relationships of CP, OM, EE, DE, CF, ADF and NDF to herbage intake and energy level were investigated using the CORR procedures of SAS (2002).

3.3 RESULTS

Table 3.2 shows the effects of diet, the rearing systems and their interaction on the apparent digestibility of crude protein (CP), ether extract (EE), digestible energy (DE), crude fibre (CF), acid detergent fibre (ADF), neutral detergent fibre (NDF) and organic matter (OM).

The digestibility coefficients of all dietary components were affected by the rearing system except for EE. The digestibility coefficients of CP, DE, CF, NDF, ADF and OM were lower ($P < 0.05$) in pigs raised outdoors than those raised indoors. There was, however, a tendency ($P=0.061$) for EE digestibility of outdoor raised pigs to be lower than of those raised indoors.

The supplementation of energy did affect ($P > 0.05$) the digestibility of CP. Although CF digestibility was not significantly affected ($P>0.05$) by the energy level, the HE diet tended ($P=0.073$) towards a higher digestibility. The digestibility coefficients of DE, EE, NDF, ADF and OM were higher ($P < 0.05$) in the HE diet than in the NE diet. Increasing the DE level improved the digestibility of DE, CF, NDF, ADF and OM by 4.27, 11.56, 11.47, 20.26 and 1.82 %, respectively. There were no diet X rearing system interactions ($P > 0.05$) for the digestibility of DE, CF, NDF, ADF and OM.

Table 3.3 shows the correlation coefficients of digestibility coefficients of CP, EE, CF, NDF, ADF, Energy and OM with herbage and energy intake. The digestibility coefficients of all the dietary components were negatively ($P < 0.05$) correlated to herbage intake. All the dietary nutrients evaluated were positively ($P < 0.05$) correlated to the level of energy.

Table 3.2 Apparent digestibility coefficients (LS means) of dietary components in indoor and outdoor reared pigs fed either a normal or high energy level

		Nutrient						
Rearing system	Diet	Crude Protein	Energy	Ether Extract	Crude Fibre	Neutral Detergent Fibre	Acid Detergent Fibre	Organic Matter
Indoor	NE	0.79	0.85	0.77	0.48	0.69	0.54	00.89
	HE	0.83	0.89	0.90	0.62	0.82	0.75	0.92
Outdoor[x]	NE	0.68	0.79	0.73	0.22	0.55	0.25	0.8708
	HE	0.69	0.83	0.86	0.31	0.65	0.45	0.88
	SE	6.82	4.72	4.72	14.2	8.33	13.73	0.69
	R^2	0.52	0.61	0.73	0.59	0.62	0.67	0.53
Mean indoor		0.81	0.87	0.84	0.55	0.75	0.64	0.90
Mean outdoor		0.68	0.80	0.80	0.27	0.60	0.35	0.88[b]
Mean NE		0.73	0.82	0.75	0.35	0.62	0.40	0.88
Mean HE		0.76	0.86	0.88	0.47	0.73	0.60	0.90
P-values								
Rearing system		0.0004	0.0002	0.0614	0.0001	0.0003	0.0001	0.0023
Diet		0.3802	0.0058	0.0001	0.0737	0.0048	0.0029	0.011
RS X Diet		0.6685	0.8781	0.7861	0.7217	0.6354	0.9521	0.85

NE=normal energy, HE=high energy
[x]Outdoor pigs consumed on average 15% of kikuyu pasture which had 11 %CP, 1.27 % EE, 26.79 %CF, 75.81 %NDF, 37.03 %ADF and 14. 7 % DE

Table 3.3 Simple correlation coefficients between Digestibility coefficients of Crude Protein, Ether Extract, Crude Fibre, Neutral Detergent Fibre, Acid Detergent Fibre, Gross Energy and Organic Matter with herbage intake and energy intake

Dependent variable	**Herbage intake**	**Energy intake**
Crude Protein	- 0.91***	0.99***
Ether extracts	-0.89***	0.90***
Crude Fibre	-0.78***	0.94***
Neutral Detergent Fibre	-0.90***	0.89***
Acid Detergent Fibre	-0.83***	0.93***
Energy	-0.91***	-
Organic Matter	-0.71***	0.77***

Pearson's correlation coefficients
*p<0.05 ;**p<0.01; ***p<0.001

3.4 DISCUSSION

The digestibility coefficients of all the nutrients evaluated were negatively affected by rearing pigs outdoor. This can be attributed to the fact that the outdoor pigs in the current study had access to pastures and were estimated to consume on average 0.2 ± 0.120 kg of pasture per day and were also observed to root thus consuming soil in the process. The faecal ash content of the indoor and outdoor pigs were 20.0 ± 0.95 % and 37.5 ± 9.47 % respectively which clearly indicates that outdoor pigs consumed the soil. Rivera Ferre *et al*. (2001) obtained high soil (ash) intake in grazing sows compared to sows housed indoors in a concrete floor house. Pastures contain different levels of fibre depending on the specie and stage of maturity and this tends to lower the digestibility of nutrients. The negative correlation between herbage intake and the digestibility of all the dietary components evaluated in the current experiment further reinforces this view.

The NDF level of the pasture in the current experiment was 75.8 g/kg and at an average daily herbage intake of 0.2 kg, outdoor pigs had a daily NDF intake of 15.16 g/kg above indoor intake per day. A negative correlation between NDF intake and nutrients digestibility was also shown by Kanengoni *et al*. (2002). Rivera Ferre *et al*. (2001) obtained low digestibilities in sows consuming pastures.

Fibre is one of the main factors that have a negative influence on digestibility. The digestibility of dietary components were found to decrease when fibre was added to diets (Laswai *et al*., 1997; Lizardo *et al*., 1997; Wenk, 2001; Kanengoni *et al*., 2002; Ndindana *et al*., 2002; Thacker & Haq, 2008; Len *et al*., 2009). Fibre increases the peristaltic movement and reduces the digesta transit time through the gastro-intestinal tract (Dung *et al*., 2002; Kim *et al*., 2007). The reduced transit time of diets containing high fibre may limit the period for the digestive activities of enzymes and micro-organisms on the digesta (Wenk, 2001). The time available for absorption in the small intestine is also reduced when the transit time is shortened.

Another factor that may have affected the digestibility of outdoor pigs is the higher ash intake compared to that of indoor pigs. Ash does not contain energy and can therefore reduce the energy value of feeds through dilution which can in turn have a negative effect on digestion. The digestion of protein was low in diets containing ash in the experiment of Ogunji *et al*. (2008).

Outdoor pigs have a large space allowance and the environment is normally enriched, this leads to high explorative behaviours (Johnson *et al*., 2001; Hötzel *et al.,* 2004) which are characterized by many activities. In addition, it is difficult if not impossible to protect outdoor pigs from the exposures of the environmental climate. The thermo-neutral temperature zone of grower pigs is 23 ^{0}C (Quiniou *et al.,* 2001; Kerr *et al*., 2003). The average temperature during the experimental week was 13.4 ^{0}C. Pigs have been shown to use more energy for the production of body heat when raised under conditions of low temperatures (Quiniou *et al*., 2001). The high activity together with the high energy demand for the maintenance of body heat in the current experiment could have also resulted in less energy being available for digestion.

The apparent digestibility of DE, EE, ADF, NDF and OM were improved by increasing the energy level of the diet while the digestibility of CF tended to follow the same trend. The results further indicated the potential of energy on improving digestibility and on reducing the excretion of nutrients into the environment. Increasing the energy level of the diet however, did not affect the digestibility of CP. The increase in digestibility coefficients of all other nutrients, except for CP, as dietary energy level is increased obtained in the current experiment are similar to those obtained in other studies (Chiba *et al*., 1991; Lawrence *et al*., 1994; Urynek & Buraczewska, 2003). It is not clear why the CP digestibility was not affected by energy level in this study, unlike in the cited studies, but the explanation could be related to the weights of the animals. While Lawrence *et al*. (1994) and Urynek and Buraczewska (2003) used pigs weighing 13 to 25 kg and 21 kg respectively, the pigs used in the current experiment weighed on average 68 kg. It could be that the CP requirements of the pigs were lower at the weight that the experiment was conducted. The absolute level of energy also appears to affect digestibility of nutrients. Increasing the energy level from 14 to 15 MJ of DE/ kg only led to significant increases in the digestibility of crude fat, while the digestibility of other dietary components were not affected in pigs weighing approximately 62.4 kg in the experiment of Cho *et al*. (2008). Variations in response to digestibility between the current experiment and that of Cho *et al*. (2008) might have been brought about by the differences in the energy levels used between the two experiments. The diets containing the high energy levels in the current experiment and that of Cho *et al*. (2008) were 17.6 and 15 MJ of DE/ kg respectively.

Increasing energy density has been shown to affect growth performance and feed conversion efficiency depending on the growth phase of pigs (Smith *et al*., 1999; De la Llata *et al*., 2001; Kerr *et al*., 2003). Weight gains were not affected in pigs grown from 59 to 93 and 93 to 120 kg while feed efficiency was improved and feed intake was reduced (De la Llata *et al*., 2001). Improvements in feed efficiency result from better digestion and absorption of nutrients in addition to better utilization. Digestion is clearly demonstrated to be improved when energy level is increased in this study.

There was no interaction between energy level and rearing system on the digestibility of nutrients in the current experiment. This is an indication that increasing the energy level improves digestibility regardless of the rearing system in pigs. The fact that Swedish farmers are advised to supply outdoor pigs with 15-20% more energy than that required by indoor pigs (Alarik, 1998 cited from Gustafson & Stern, 2003) does not mean that indoor pigs do not benefit from higher energy levels as well.

3.5 CONCLUSION

Rearing pigs outdoors reduces digestibility while increasing the energy level of the diet leads to improvements in the digestibility of the dietary components evaluated except for that of crude protein. The results from the current experiment imply that increasing the energy level of diets is a strategy that can be used to improve nutrient utilization and reduce the excretion of nutrients in pigs which may benefit the environment and improve profitability.

3.6 RECOMMENDATIONS

Increasing the energy level in pig diets improves digestion of nutrients whether they are being raised indoors or outdoors. Improved digestion lead to reduction in nutrients excreted to the environment which has positive implications on reduction of environmental pollution. In the current study only one higher level of energy was used. More experiments to evaluate the best energy level in order to exploit fully the advantages associated with increasing the energy level of diets may need to be explored. It may also be necessary to conduct more experiments that investigate the digestibility of nutrients in pigs reared under the conditions of the current experiment at different stages of growth, in order to evaluate and determine the correct stages at which pigs, (especially those raised outdoors- since they have a direct effect on the environment) should be supplemented with energy.

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CHAPTER 4: THE INFLUENCE OF ENERGY LEVEL ON THE GROWTH PERFORMANCE OF PIGS REARED EITHER INDOORS OR OUTDOORS

4.1 INTRODUCTION

The growth performance potential of a pig under the environment in which it is raised, is primarily determined by the intake of sufficient nutrients. The energy level of a diet is the most important factor that dictates the intake of other nutrients (Chiba *et al*., 1991) and therefore the importance of energy intake on growth performance and its relations with other nutrients cannot be overlooked. It has as a result been emphasized that the proportions of other nutrients in diets should be adjusted in accordance to the energy levels. Increasing the energy level and adjusting the amino acids in proportions to energy improves the growth performance in pigs (Chiba *et al*., 1991; Smith *et al*., 1999; Kerr *et al*., 2003). The outdoor rearing of pigs is becoming popular (Gentry *et al*., 2002a, b) mainly because of the advantages associated with the system and the positive manner in which consumers perceive the system (Barton Gade, 2002).

Researchers have reported different results on the growth performance of outdoor reared pigs (Enfalt *et al*., 1997; Sather *et al*., 1997; Gentry *et al*., 2002 a,b; Hofmann *et al*., 2003). The differences in growth performances of outdoor pigs have been attributed to the variations in the climatic conditions in various locations (Gentry *et al*., 2002a) and the variations in space allowance provided to pigs (Stern & Andreson, 2003). Low growth performances of outdoor pigs have been reported in areas that have extremes of temperatures (Enflat *et al.*, 1997; Sather *et al*., 1997) while performances that are similar or superior to those of indoor pigs have been reported in areas with climatic temperatures that are less extreme (Gentry *et al*., 2002 a, b). The low growth performances during the cold seasons have been attributed to the high quantities of energy required for the production of body heat. This was evident in the experiment of Sather *et al*. (1997) when feed intake and utilization for growth increased and decreased respectively during the winter period whereas feed intake decreased during the high temperature season (Sather *et al*., 1997). The low feed intake in summer is a behavioral response by the animal to minimize the production of body heat. Low feed intakes are associated with low daily gains in pigs (Sather *et al*., 1997; Le Bellego *et al*., 2001).

Since the consumption of feed to satisfy the high energy requirements especially during the cold winter months may be limited by the stomach capacity (Gustafson & Stern, 2003) and the production of heat during the hot summer months, meeting the high energy demand for maintenance and production may be challenging in outdoor pigs. Increasing the energy level of diets through the addition of fat can assist in meeting the high energy needs of outdoor pigs (Gustafson & Stern, 2003). Normally, the ground substrates of outdoor systems consist of either the soil or a combination of both the soil and the grass. It has been shown that both the soil and the grass can contribute to certain nutritional needs of pigs (Brown *et al*. 1996; Kleinbeck *et al.* 1999; Gustafson & Stern, 2003) and this aspect makes it more interesting to evaluate whether the outdoor system cannot be utilized in trying to reduce the feed costs in pig production. Outdoor pigs are also less likely to stress one another through fighting and that has a positive impact on growth performance (Beattie *et al*., 2000).

Not much work has been done to evaluate the growth performance of outdoor pigs in South Africa. The objective of this experiment was therefore to evaluate the growth performance of outdoor pigs in the Gauteng province of South Africa. The other objective was to evaluate the best method for supplementing the energy needs of outdoor pigs in the Gauteng province of South Africa. The growth performance of the outdoor pigs was evaluated through comparing indoor and outdoor reared pigs fed on either a normal or high energy level. The hypotheses tested were that increasing the energy level of a grower diet would improve the growth performance of indoor and outdoor raised pigs and that the rearing system would not have an influence on the growth performance of grower pigs in the Gauteng province of South Africa.

4.2 MATERIALS AND METHODS

The study was carried out at the Animal Production Institute (API) of the Agricultural Research Council (ARC) - Irene at the Pig Nutrition Section. The location of the API of the ARC has been described in paragraph 3.2.1. The average environmental temperature, humidity and sunshine hour of the experimental area during the study period are presented in Table 4.1 and averaged 14.7 °C, 42.7 % and 8.61 h, respectively. Indoor pigs were kept in a house with temperatures ranging between 21 to 23 °C. During the trial period, the experimental site predominantly consisted of kikuyu pastures. Information on the climatic environmental conditions of the experimental site was obtained from the weather station situated at the ARC of Irene about 800 m from the experimental site. The protocol of the experiment was evaluated and approved by the Animal Ethics Committee of the ARC-API before the experiment could be initiated.

Table 4.1 Average temperature, humidity and sunshine hour of the experimental area during the study period

	Average min.	Average	Average max.
Temperature (°C)	7.4	14.7	20.3
Humidity (%)	24.3	42.7	72.3
Sunshine hour		8.61	

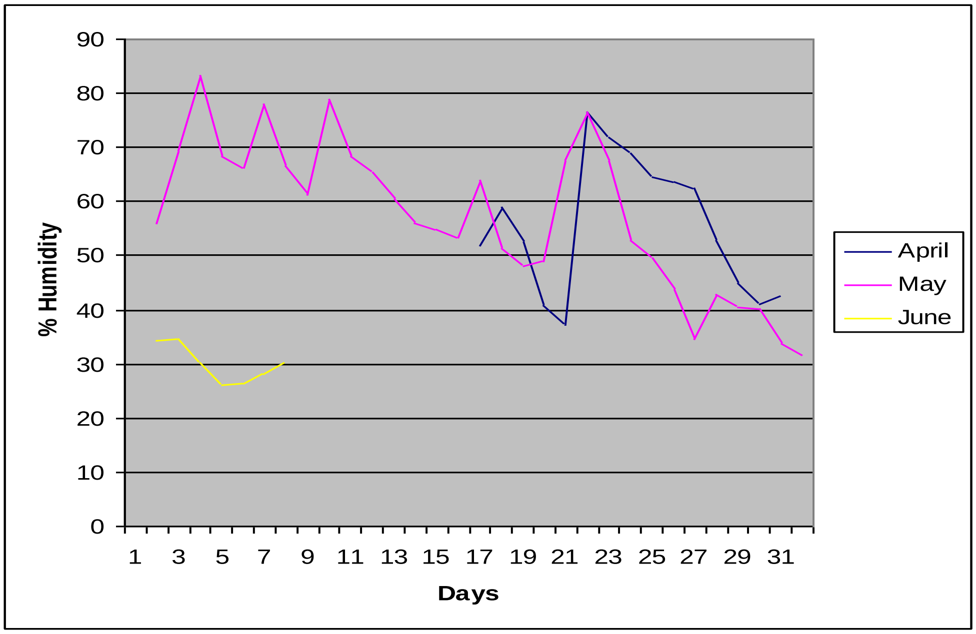

Figure 4.1 Average humidity of the experimental site during the April, May and June months

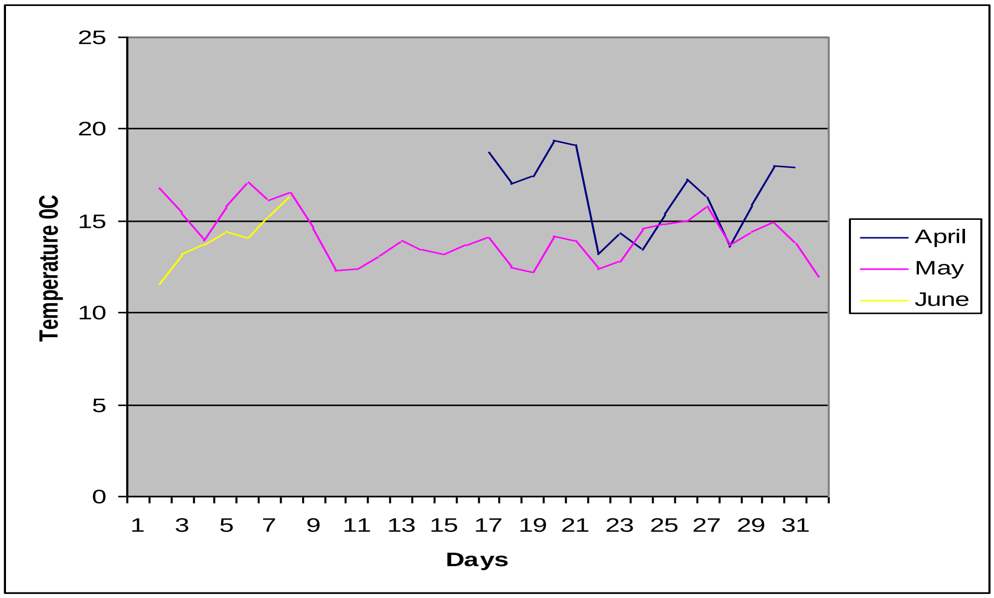

Figure 4.2 The average temperature of the experimental site during the April, May and June months

4.2.1 Pigs and Experimental Design

Forty eight Large White x Landrace male grower pigs were randomly selected at an average age of 9 weeks and at a weight of 27± 4.6 kg and were allocated to two different diets formulated to contain different energy densities (14 MJ DE/kg vs. 16.1 MJ DE/kg) and to either indoor or outdoor rearing in a 2 x 2 factorial design. The pigs were divided into two groups and 24 were allocated to each rearing system. Indoor pigs were reared in a naturally ventilated house that consisted of a concrete floor pen while outdoor pigs were kept on pastures. The 24 pigs from each rearing system were further divided into two groups and fed on one of the two energy levels. Each treatment consisted of 12 pigs. Each experimental unit consisted of 2 pigs and was repeated 6 times. Each outdoor experimental unit was provided with four camps. The camps were constructed from movable gates and feed bags were used to provide shelter from the climatic elements for the outdoor pigs. The outdoor pigs were allowed a 7-day grazing period in each of four camps, on a rotational basis throughout the experimental period of 8 weeks. Each camp had a space area of 27 m^2 (3 x 9m). A wallow was dug in the centre of each camp and watered regularly. The experiment continued for a period of 8 weeks and 5 days from the 16^{th} of April to the 9^{th} of June 2009.

4.2.2 Dietary Treatments

Pigs were fed *ad-libitum* in feed troughs and indoor pigs had free access to water through low pressure drinking nipples, whereas water for the outdoor pigs was supplied in drinking buckets. Outdoor pigs were supplied with clean drinking water each morning throughout the experiment. The water for the outdoor pigs was refilled in the afternoon. In order to estimate feed wastages, empty feed bags were placed underneath each feed trough to collect wastage which was subtracted from feed offered. The treatments consisted of two diets, namely: (a) a normal energy diet (NE) that had been formulated to contain 14 MJ DE/kg and (b) the high energy density diet (HE) that had been formulated to contain 16.1 MJ of DE/kg compared to the normal energy diet. The dietary compositions of the diets are presented in Table 3.1 in Chapter 3. Diets were formulated and mixed by experienced personnel at the ARC-API of Irene. The NE and HE diets contained 19.4 and 17.7 g of protein per kg and a lysine: digestible energy ratio of 0.82 %. The levels of methionine, threonine and tryptophan were adjusted to 50, 60, and 18% in proportion to the lysine content (NRC, 1998). The confined pigs were fed a similar diet as that of the pigs having outdoor access with the difference being that the former were not allowed access to kikuyu pastures.

4.2.3 Growth Performance measurements

Individual animals were weighed during selection and on a weekly basis after the onset of the trial. The average daily gains (ADG) were calculated by subtracting the initial weight from the final weight to obtain the total weight gain for the entire experimental period. The total weight gain was then divided by the number of the experimental days to determine the ADG.

Feed was supplied *ad-libitum* and feed intake was recorded every three days. The amount of feed supplied to the pigs was weighed and recorded. To calculate feed intake, the amount of feed inside the feed trough after every three days was subtracted from the total feed supplied for the three days. Average daily feed intakes (ADFI) were then calculated by adding feed intakes for the entire experimental period and then dividing the total feed intake (concentrates) by the number of the experimental days.

The feed conversion ratio (FCR) was determined per pen (experimental unit). To determine the FCR of each experimental unit, the total feed intake of the experimental unit was divided by the total weight gain per pen.

Pasture intake was determined during Week 7 of the experiment and therefore the calculations of the total feed intake (concentrates and pasture intake) were based on week 7 of the experiment. Chromium oxide was used to estimate pasture intake as was done in sheep in the experiment of Piasentier *et al*. (1995). The organic matter digestibility coefficients of the pasture were estimated in another experiment that evaluated different methods of determining pasture intakes in pigs. Pasture intake (PI) was estimated as PI= $[D/F\text{-}Is\ (1\text{-}OMD_d)]/\ (1\text{-}OMD_p]$ where D is the external marker in diet, F is the marker in faeces, *Is* is the quantity of the supplement fed, OMD_d is the organic matter digestibility of the diet and ODM_p is the organic matter digestibility of the pasture.

4.2.4 Statistical analyses

The effects of rearing system, diet and interactions between the diet and rearing system on final body weight (FW), average daily gains (ADG), average daily feed intake (ADFI), feed conversion ratio (FCR), average daily total feed intake (ADTFI) and for the total feed intake feed conversion ratio (TFIFCR) were evaluated by means of ANOVA using the GLM procedures of the Statistical Analytical Systems Institute (SAS, 2002). Initial body weight was used as a co-variate for all variables evaluated. The model used was:

$$Y_{ijk} = \mu + t_i + r_j + (tr)_{ij} + \varepsilon_{jk}$$

Where:

Y_{ijk} = The individual observations of the ith diet, the jth rearing and the kth replicate

μ = The mean body weight and feed intake

t_i = The effect of the diet (HE, NE)

r_j = The effect of the rearing system (Outdoor, indoor)

$i_{(ts)}$ = The interaction between t and r

ε_{ijk} = The random variation or experimental error

4.3 RESULTS

Table 4.2 shows the growth performances between pigs raised either indoors or outdoors throughout the entire experimental period. Rearing system had no effect ($P>0.05$) on the final weight (FW) and on the average daily gain (ADG) of pigs. The rearing system had a significant effect on the average daily feed intake (ADFI) and on the average daily total feed intake (ADTFI). Outdoor reared pigs had a higher ADFI and ADTFI ($P<0.001$). The efficiency of feed utilisation was lower ($P < 0.05$) in outdoor reared pigs compared to the indoor reared pigs both during the entire experimental period and during the seventh week of the experiment when the total feed intake feed conversion ratio (TFIFCR) was measured.

Table 4.2 The growth performance (LS Means) of indoors and outdoors reared pigs fed on either a normal or high energy level

Rearing System	Diet	IW (kg)	FW (kg)	ADG (kg)	ADFI (kg)	FCR (kg)	ADTFI	TFIFCR
Indoor	NE	25.97	70.71	0.81	2.98	1.84	3.02	1.83
	NE	28.06	70.97	0.78	2.76	1.75	2.69	1.77
Outdoor	NE	26.13	70.55	0.84	3.17	1.91	3.43	2.13
	HE	27.78	71.51	0.82	3.16	1.91	3.29	2.05
	SE	1.345	2.403	0.027	0.109	0.053	0.166	0.053
	R^2	0.206	0.046	0.224	0.845	0.339	0.835	0.339
Main Effects								
Indoor		27.02	70.84	0.8	2.86	1.8	2.87	1.8
Outdoor		26.1	71.03	0.83	3.16	1.91	3.36	2.09
NE		26.05	70.63	0.8	3.11	1.87	3.23	1.98
HE		26.1	71.24	0.83	2.91	1.83	2.99	1.91
P-values								
RS		0.968	0.939	0.22	0.001	0.045	0.001	0.028
Diet		0.182	0.806	0.41	0.001	0.425	0.166	0.661
RS X Diet		0.873	0.888	0.718	0.046	0.365	0.196	0.994

Feeding the HE diet had no effect (P>0.05) on the FW, the ADG, ADTFI and TFIFCR. Significant (P > 0.05) differences were found between the ADFI of the pigs fed on the NE and HE diets. There were no differences (P>0.05) in the herbage intake of pigs consuming either the CE or HE diets.

Significant interactions between rearing system and diet in the current experiment were only found for ADFI. Increasing the energy level of the diet significantly (P=0.001) reduced the ADFI in indoor pigs while the ADFI's of outdoor pigs consuming either the NE or the HE diets were similar. Even though the indoor pigs consuming the HE diet had a reduced feed intake, that did not affect the feed efficiency across the treatments as there were no significant (P

>0.05) differences between the FCR and the TFIFCR of the pigs consuming either the NE or HE diets.

4.4 DISCUSSION

The average daily gains (ADG) of the indoor and outdoor reared pigs were similar. This finding between indoor and outdoor pigs is in accord with the results obtained by Gentry *et al*. (2002a). In contrast, the ADG was lower in outdoor compared to indoor reared pigs in the experiments of Enflat *et al*. (1997), Sather *et al*. (1997) and Hoffman *et al.* (2003). The differences with reference to ADG's in the current experiment and those obtained in Europe (Enflat *et al.*, 1997; Sather *et al*., 1997) and in the Western Cape of South Africa (Hoffman *et al*., 2003) could have been brought about by the variations in the environmental temperatures. The ranges of temperature in the experiment of Sather *et al*. (1997) were between -45 to 22 ^{0}C and 0-28 ^{0}C during the winter and summer periods respectively while the temperatures ranged between 14-28 ^{0}C in the experiments of Hoffman *et al*. (2003). The temperature in the current experiment ranged between 7.4 to 20.3 °C. On average, the temperature in the current experiment was 14.7 °C.

Feed intakes of outdoor reared pigs were lower compared to those of indoor reared pigs in the experiments of Sather *et al*. (1997) and Hoffman *et al*. (2003) during the summer period. This explains the accompanying low ADG in outdoor reared pigs in the experiments of Sather *et al*. (1997) and Hoffman *et al*. (2003) and in general when compared to the current experiment. It has been shown that the growth performance of pigs is optimized at 23°C (Collin *et al*., 2001; Quinion *et al*., 2001; Kerr *et al*., 2003). The ADG were high during the winter compared to the summer period in the experiment of Sather *et al*. (1997). This therefore shows that high temperatures have a more negative effect on ADG's compared to low temperatures. This can be explained by the fact that pigs do not have sweat glands and therefore the reduction in feed intake which is normally accompanied by low ADG is one of the strategies used for thermoregulation.

Even though differences were not found between the ADG's of the pigs reared in the different systems in the current experiment, outdoor pigs had higher feed intakes as compared to the indoor pigs. It could therefore be extrapolated that the low temperatures during this experiment were not too extreme as the outdoor pigs were able to consume sufficient feed for the maintenance of the ADG's. The high feed intakes however led to unfavourable feed efficiencies in outdoor compared to the indoor reared pigs. The high feed intakes and the unfavourable feed conversion in outdoor pigs could have resulted from the combination of the low temperature, high activity and the pasture intake. Temperatures below 23^0C results in the energy from the consumed feed being used for the production of body heat instead of growth. The high activity of the outdoor pigs associated with the large space allowances and the enriched environment may have contributed to the feed being less efficiently utilised. It has been shown that outdoor reared pigs are more active than the indoor reared (Hötzel *et al*., 2004).

Outdoor pigs in the current experiment had access to pastures. Pastures contain variable quantities of fibre depending on the stage of the maturity and the specie (Minson, 1990 cited from Rivera Ferre *et al*., 2001). It has been shown that the intake of fibre has a negative impact on the growth performances of pigs (Ndindana *et al*., 2002; Kanengoni *et al*., 2004; Thacker & Haq 2008; Len *et al*., 2009). This is caused by the negative effect that fibre has on the value of a diet and is another aspect of the outdoor system that may have resulted in high ADFI and FCR. The energy value of feed is reduced by high fibre levels (Noblet & Le Goff, 2001). Table 3.5 showed that there were negative correlations between herbage intake and the digestibility of dietary components.

The growth performances of the pigs both during week 7 and throughout the experimental period were surprisingly not improved by feeding the HE diet. The ADFI was reduced; this was however not reflected in the FCR and is in contrast to earlier work done with grower pigs (Chiba *et al*., 1991; Szabo *et al*., 2001; Kerr *et al*., 2003). Gustafson and Stern (2003) obtained similar growth rates between outdoor reared pigs fed on either a normal (14.6 MJ ME/ kg) or a high energy level (16.6 MJ ME/ kg). However, the latter researchers obtained heavier carcasses (carcasses with high dressing percentages) in pigs fed on the high energy level which according to them was an indication that pigs fed on high energy levels had better growth performances. It is therefore difficult to properly state the effects that the energy level had on performance without evaluating the carcass characteristics.

Access to pastures did not reduce the concentrate intakes in outdoor pigs both throughout the experimental period and during week 7 when the ADTFI was determined. Pasture intakes were similar between pigs fed on the diets with the different energy levels. The voluntary pasture intakes of 0.2 ± 0.12 kg in the current experiment were similar to those obtained in other studies that evaluated the performances of grower pigs on pastures (Mowat *et al*., 2001; Riart, 2002). These results confirm the findings that outdoor pigs will voluntarily consume pastures even when fed a concentrate diet *ad-libitum* (Edwards, 2003).

The live weight gains of the pigs, the feed intakes both during week 7 when pasture intake was measured and throughout the experimental period were similar between indoor and outdoor pigs fed diets containing different energy levels. The utilization of feed (feed conversion ratio both during week 7 and throughout the entire experimental period) between indoor and outdoor pigs fed on the two energy levels was also similar between pigs throughout the experimental period. Indoor pigs fed on the diet containing high energy levels had lower average daily feed intakes while the average daily feed intakes of the indoor pigs fed on the normal energy levels and the average daily feed intakes of outdoor pigs were similar. The reduction in the feed intakes of pigs consuming high energy levels is similar to results obtained by Chiba *et al*. (1991), Szabo *et al*. (2001) and Kerr *et al*. (2003) in pigs raised indoors. Pigs eat to satisfy their energy needs and it would therefore be expected that the energy requirements of pigs feeding on high energy levels would be met at low feed intakes. The fact that the average daily feed intakes of the outdoor pigs fed on the diets containing the normal and the high energy levels were similar may indicate that the energy needs of outdoor pigs were not met, especially for the pigs fed on the diet containing the normal energy level. The high energy intake in the outdoor pigs was not reflected in the growth performance. Gustafson and Stern (2003) obtained similar feed intakes between outdoor pigs fed on different energy levels. Daily weight gains of the pigs were similar, the carcass weights of the pigs fed on the high energy levels were however higher than those of the pigs fed on the normal energy levels. It is therefore possible that the high energy intake may lead to interactive effects on the carcass characteristics of the outdoor pigs.

4.5 CONCLUSION

It can be concluded that daily live weight gains of indoor and outdoor raised pigs were similar; the efficiency of feed utilisation tends to drop when pigs are raised outdoors. Feed efficiency is improved when indoor pigs are fed diets containing high energy levels. Taking into account the results of the current experiment, it appears unnecessary to increase the energy levels of the diets when rearing pigs outdoors in the Gauteng province of South Africa. It cannot however be concluded that indoor and outdoor pigs can respectively be raised on diets containing high and normal energy levels without evaluating and comparing the carcass characteristics and therefore, the results are to a certain extent inconclusive.

4.6 RECOMMENDATIONS

The effects of energy level on the carcass characteristics of pigs should be evaluated to give complete information on the effects of energy level on performance. The economic benefits of raising indoor pigs on high energy diets should also be carried out to evaluate whether the reduced intake of feeds is financially rewarding. High temperatures have a more negative influence on the growth performance of pigs. It may therefore be essential to evaluate the growth performance of outdoor pigs in the Gauteng province during the summer period. Studies should be done on outdoor pigs on different pastures to evaluate the effects of stages of growth of pastures and the effects of different pastures on the growth performances of outdoor pigs.

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CHAPTER 5: CHARACTERISTICS OF CARCASS AND VISCERAL ORGANS OF PIGS REARED EITHER INDOORS OR OUTDOORS ON DIETS CONTAINING DIFFERENT ENERGY LEVELS

5.1 INTRODUCTION

There are important factors that should be taken into consideration in pig production besides good live-weight performances and these include the quality and the yields of the carcasses produced. The physical quality of the carcass affects meat acceptability by consumers, while the carcass yield may determine profitability and food security.

Nutrition, rearing system, genotype and the age of the animal are important factors that have been found to influence the carcass characteristics and yields in pigs (Chiba *et al*., 1991 a, b; Sather *et al*., 1997; Partanen *et al*., 2002; Kerr *et al.*, 2003; Kanengoni *et al*., 2004; Len *et al*., 2008). Outdoor pigs have mostly been reported to have lower carcass weights, which are indirectly influenced by the environmental temperatures (Lee *et al*., 1995; Sather *et al*., 1997; Guy *et al.*, 2002; Hoffmann *et al*., 2003; Strudholm & Hermansen, 2005). A study has however reported similar carcass weights between indoor and outdoor pigs (Gentry *et al*., 2002 b). It has been shown that pastures can supply some of the nutritional needs of outdoor pigs (Edwards, 2003) and therefore pigs should be given the opportunity to graze in some outdoor systems (Gustafson & Stern, 2003; Stern & Andreson, 2003). Pasture contains variable amounts of fibre and high intakes of fibre can reduce the dressing percentages in pigs (Kanengoni *et al*., 2004). The low dressing percentage is caused by the effect that fibre has on the visceral organs of pigs. Fibre stimulates the enlargement of the visceral organs of pigs, especially the digestive tract (Wenk, 2001). Both the low carcass weights and dressing percentages may impact negatively on profit.

The proportions of muscle and fat in a carcass are some of the important characteristics that influence the extent of meat acceptability by consumers. Outdoor pigs have been reported to have high percentages of lean and a low back-fat content (Lee *et al*., 1995; Sather *et al*., 1997). It has been shown that increasing the energy density of feed increases protein and fat depositions (Chiba *et al*., 1991b; Renaudeau *et al*., 2006). The increases in the depositions of protein and fat can result in heavier carcasses. It should however be taken into consideration that the ratio between fat and muscle in the carcasses of pigs consuming high energy levels may be negatively influenced especially if the energy and protein levels of the diet are not balanced. Although pastures have the potential to supply some of the nutritional needs of pigs, too much pasture intake can reduce the dressing percentage. Gustafson and Stern (2003) showed that increasing the energy density of the diet can reduce the envisaged negative effects of fibre on the dressing percentage of pigs. Both the increase in dressing percentage and carcass weights can improve returns from pork production.

The temperature conditions in the Gauteng province of South Africa are not too extreme and therefore good carcass weights may be obtained from the outdoor production of pigs. However, since not much information is available on the carcass characteristics of outdoor pigs in South Africa, the objective of this study was to compare carcass characteristics of outdoor and indoor pigs fed on diets with different energy densities. The other objective was to evaluate the effects of energy density and rearing system on the internal organs of pigs. The hypotheses tested are as follows; pigs reared outdoors on pastures have a low back-fat content, carcass weights, dressing percentage and heavy internal organs and that increasing the energy level diminishes the differences in the carcass characteristics and internal organs of pigs reared either indoors or outdoors.

5.2 MATERIALS AND METHODS

5.2.1 Pigs

A total of 48 Large White (LW) X Landrace (LR) male crosses were slaughtered at average weights of 70.9 ± 1.74 kg. The pigs had been raised either indoors or outdoors and allocated to either the normal or the high energy diets as reported in Chapter 4. The compositions of the diets that were used are shown in Table 3.1. The pigs were slaughtered at the abattoir of the Agricultural Research Council (ARC) at Irene. The slaughtering methods were approved by the Ethics Committee of the ARC. The pigs were transported from the experimental site to the ARC-Irene abattoir which is situated just under a kilo-meter from the experimental site. Upon arrival at the abattoir, the pigs were placed in the waiting pens for an hour before being slaughtered.

5.2.2 Slaughtering Procedure and Measurements

A movable weighing scale was placed at the exit of the waiting pen and the weight of each pig was recorded en route to the slaughtering room. The normal slaughtering procedures of the abattoir were followed during slaughtering. The pigs were electrically stunned for about 7-10 seconds, hoisted by the left hind leg, exsanguinated, immersed in hot water and then the hair was removed. After dehairing the carcasses were opened and the viscera removed. The digestive tract was separated from the other visceral organs such as the liver, heart and the lungs which were weighed individually while the digestive tracts were cleaned. The digestive tracts and the internal organs that were of interest were then individually weighed.

Carcasses were weighed soon after slaughter to get the warm carcass weights and then 24 hours after being chilled at 2 °C to obtain the cold carcass weight. Drip loss was calculated as the warm carcass weight less the cold carcass weight after the 24 hour chilling period. Dressing percentage calculations were determined as the cold carcass weight as a percentage of live weight. The head, kidneys and tail were then removed from the carcass. The carcass was split into half along the median plane from the last remaining sacral vertebra to the first cervical vertebra. The back-fat and the loin muscle area measurements were then taken from the left-hand side of the carcass. Back-fat thickness and muscle depth were determined using venier calipers. Back-fat measurements were made between the 2nd and 3rd rib. To have access to the loin for the measurements of the eye muscle length, eye muscle width and eye muscle-fat, the left hand side carcass was cut at the 6th rib. The lean meat percentage was calculated using the formula proposed by Bruwer (1990) presented below:

% lean = 72, 5114 – 0,4618V + 0.0547S where V is the fat thickness (mm) and S is the muscle depth (mm).

The carcass length was measured from the first rib to the pubic bone using a measuring tape.

5.3.3 Statistical analyses

The effects of rearing system, diet and the interactions between diet and rearing system on carcass and visceral organ data were evaluated by means of ANOVA using the GLM procedure of the Statistical Analysis System (2002). A significance level of 5% was used to evaluate the effect of rearing system and energy level on the carcass characteristics and the visceral organs. The model used for analysis was:

$$Y_{ij}= \mu+t_i+r_j+(tr)_{ij}+\varepsilon_{jk}$$

Where:

Y_{ijk} = The individual observations of the ith diet, the jth rearing and the kth replicate

μ = The mean carcass traits and viscera

t_i = The effect of the diet (HE, NE)

r_j = The effect of the rearing system (outdoor, indoor)

$i^{(ts)}$ = The interaction between t and r

ε_{ijk} = The random variation or experimental error

5.4 RESULTS

The effects of diet and rearing system on the carcass characteristics of pigs are presented in Table 5.1. while the effects on the visceral organ characteristics are presented in Table 5.2. The system of rearing did not lead to differences

(P>0.05) in the warm carcass weight (WCW), cold carcass weight (CCW) drip loss, dressing percentage, back-fat (P2), carcass length (CL), eye muscle area (EMA), eye muscle area fat (EMF) and the lean meat percentage (Lean %). The GIT and the livers of the outdoor raised pigs were heavier (P < 0.05) compared to those of the indoor pigs. The rearing system did not have an effect (P>0.05) on the weights of the lungs and the heart.

The WCW and CCW were improved (P<0.05) by feeding a diet containing the high energy level. This was reflected in the high dressing percentage (P<0.05) for the pigs consuming the HE diet. The HE diet had a tendency towards shorter (P=0.07) CL and higher (P= 0.08) EMF. There were no differences (P>0.05) between the drip loss, P2, EMA and the lean % of pigs fed on the different diets. The liver weights of the NE fed pigs were heavier (P<0.05) than those of the HE fed. Diet did not have an influence (P>0.05) on the weights of the GIT, heart and lungs.

There were RS X Diet interactions (P<0.05) for the EMA and the Lean %. The EMA of the NE fed pigs was larger (P<0.05) than that of the HE fed pigs in the indoor rearing system, while the opposite was obtained in the outdoor system. The Lean % was higher (P<0.05) for the carcasses of the NE fed pigs in the indoor rearing system while the same variable was higher for the carcasses of the HE fed pigs in the outdoor rearing system. There was no RS X Diet interaction (P > 0.05) for WCW, CCW, drip loss, dressing %, P2, CL and EMF. Rearing system X Diet interaction (P>0.05) for the weights of the visceral organs were not found.

Table 5.1 The measurements (LS Means) of carcass traits of pigs raised either indoors or outdoors on two energy levels

Rearing System	Diet	WCW (kg)	CCW (kg)	Drip loss	Dressing %	P2 (mm)	CL (cm)	EM (mm)	EMF (mm)	LeanP
Indoor	NE	56.14	54.75	1.39	79.05	11.86	71.66	46.83	0.743	74.73
	HE	57.23	55.94	1.3	80.72	11.91	71.27	44.12	0.828	74.54
Outdoor	NE	55.8	54.11	1.69	78.59	10.11	72.42	43.43	0.736	74.55
	HE	57.81	55.44	1.37	80.05	11	71.5	45.94	0.8	74.66
	SE	2.05	2.03	0.05	0.38	0.53	0.76	1.39	0.04	0.1
	R^2	0.977	0.968	0.069	0.3206	0.175	0.793	0.654	0.252	0.571
Mean Indoor		56.68	55.35	1.34	79.89	11.89	71.47	45.48	0.785	74.64
Mean Outdoor		56.31	54.78	1.53	79.32	10.55	71.96	44.68	0.766	74.6
Mean NE		55.97	54.43	1.33	78.82	10.99	72.04	45.13	0.74	74.64
Mean HE		57.02	55.69	1.54	80.39	11.45	71.38	45.03	0.81	74.6
P-values										
Rearing System		0.239	0.13	0.366	0.232	0.14	0.175	0.492	0.626	0.612
Diet		0.002	0.002	0.3389	0.602	0.605	0.07	0.932	0.08	0.571
RS X Diet		0.89	0.86	0.607	0.82	0.643	0.46	0.028	0.754	0.032

NE=normal energy, HE= high energy diet, CCW=cold carcass weights, P2=back-fat content, CL=carcass length, EM=eye muscle area, Lean %=lean meat percentage

Table 5.2 GIT, heart, liver and lungs (LS Means) of indoor and outdoor reared pigs fed two energy levels

Rearing System	Diet	GIT (kg)	Heart (kg)	Liver (kg)	Lungs (kg)
Indoor	NE	6.97	0.58	2.4	2.3
	HE	6.46	0.45	2.06	2.1
Outdoor	NE	7.59	0.56	2.63	2.29
	HE	7.32	0.6	2.47	2.21
	SE	0.23	0.02	0.1	0.12
	R^2	0.419	0.098	0.328	0.06
Mean indoor		6.72	0.52	2.32	2.2
Mean Outdoor		7.46	0.58	2.55	2.25
Mean NE		7.28	0.57	2.52	2.29
Mean HE		6.89	0.52	2.27	2.15
P-values					
Rearing System		0.005	0.253	0.0002	0.725
Diet		0.123	0.425	0.015	0.271
RS X Diet		0.635	0.118	0.374	0.618

GIT= gastro intestitonal tract

5.5 DISCUSSION

The carcass measurements of the indoor and outdoor raised pigs were similar in the current experiment. The experiment of Sather *et al*. (1997) which was conducted during the winter period reported trends for the WCW and CCW results similar to those obtained in the present experiment. In contrast, Sather *et al*. (1997) obtained lower carcass weights for the outdoor reared pigs during the summer period. Warm and cold carcass weights were found to be low for the outdoor compared to indoor raised pigs in an experiment conducted in South Africa (Hoffmann *et al*., 2003). Gentry *et al*. (2002 b) obtained heavier carcass weights for pigs born and reared outdoors compared to the indoor reared pigs. The variations obtained in the weights of the carcasses between the current experiment and the experiments of the other researchers (Sather *et al*., 1997; Gentry *et al.*, 2002 a, b; Hoffmann *et al*., 2003) could be attributed to the fact that the final live-weights of the indoor and outdoor pigs in the current experiment were similar while the final weights were different in the experiments of the other researchers.

There were no differences in drip loss between the indoor and outdoor reared pigs during the 24 hour cooling period in the present experiment which is similar to the findings of Hoffmann *et al*. (2003) and Lebret *et al*. (2006). The carcass lengths of the indoor and outdoor pigs were similar; which is in accordance to the findings of Enflat *et al*. (1997). In agreement with Gentry *et al*. (2002 b) the EMA and the EMF of the indoor and outdoor pigs were similar. Overall, the back-fat depth (P2) and the lean % of the indoor and outdoor pigs were similar in the current experiment in agreement with Gentry *et al*. (2002b). However, other workers reported lower levels of back-fat and greater percentages of lean for outdoor pigs compared to the indoor pigs (Lee *et al*., 1995; Sather *et al.,* 1997; Gentry *et al.*, 2002 a; Guy *et al.*, 2002; Hoffman *et al*., 2003; Strudholm & Hermansen, 2005). These variations in percentage lean and back-fat content between indoor and outdoor pigs in the current experiment and the experiments of the other workers (Sather *et al.,* 1997; Gentry *et al.*, 2002 a; Guy *et al.*, 2002; Hoffman *et al*., 2003; Strudholm & Hermansen, 2005) are attributed to differences in carcass weights. Carcass weights between indoor and outdoor pigs were similar in the present experiment, while outdoor pigs had lower carcass weights in the experiments of the other researchers. It has been shown that body weight can influence the levels of back-fat in pigs (Hoffmann *et al*. 1991).

Surprisingly, the dressing percentages of the indoor and outdoor pigs were similar. Outdoor pigs were consuming pastures and had an ADFI that was significantly higher than that of the indoor pigs. Depending on the specie and stage of growth, pastures contain different levels of fibre. Low dressing percentages have been reported for pigs fed on high fibre (Kanengoni *et al*., 2004; Len *et al*., 2008) and for pigs having a high feed intake (Lebret *et al*., 2006). The anatomical adaptation of high fibre consumption in pigs is the increase in the size of the digestive tract and visceral organs. This results in pigs consuming high fibre levels having a larger portion of their live-weight as internal organs compared to pigs consuming the recommended levels of fibre (Wenk, 2001). It was therefore not surprising that the GIT and the livers of the outdoor pigs in the current experiment were heavier than those of the indoor pigs. The heart and the lungs were not affected by the rearing system.

The WCW and CCW were improved by feeding the HE diet. It has been shown that the deposition of protein and fat are enhanced by supplying pigs with increased energy levels (Chiba *et al*., 1991b; Renaudeau *et al*., 2006). The high protein and fat depositions which are normal in pigs consuming high amounts of energy or fed on diets containing a high energy density may explain the heavier WCW and CCW for pigs consuming the HE diet. The dressing % of pigs consuming a diet with the high energy level was greater than those of pigs fed on the normal energy level in agreement with Gustafson and Stern (2003). This could have resulted from the high carcass weights obtained from the pigs consuming the HE diet.

The drip loss was not affected by the energy level. Adding energy had a tendency of reducing the carcass lengths. This has a negative effect on the number of rashers that can be obtained from pigs. The HE diet did not affect the EMA, there was however a tendency for high fat content on the EMA of the pigs fed the HE diet. The P2 and the lean % were similar between pigs fed on the two experimental diets. The similar P2 and lean % obtained between pigs fed on the NE and HE diets is a reflection that the ratio of energy and protein allowed for the same levels of fat and protein depositions in both diets. Kerr *et al*. (2003) did not find any significant differences between the lean meat percentages of pigs fed on diets containing low to high energy levels when the ratio between the essential amino acids and energy was balanced.

The dressing percentages of the pigs fed on the high energy levels were improved. This finding is in accordance with the results obtained by Gustafson and Stern (2003) when outdoor pigs were fed on diets containing either the normal or the high energy levels. Outdoor pigs have high energy needs (Stern & Andreson, 2003) and the improvements in dressing percentage when the energy level of the diet was increased may imply that the NE diet could not support the maximal weight gains of the carcasses in both the indoor and outdoor pigs.

The liver was the only internal organ that was affected by the energy level of the diet. Pigs fed on the NE diet had higher liver weights. The main reason for this effect is not known. One of the nutritional factors that may affect the weight of the liver is the protein level of the diet. The liver plays a crucial role in the metabolism of protein and therefore the level of protein of a diet can affect its weight. Pigs fed on diets containing high protein levels were found to have livers that had higher weights compared to those fed on low protein diets (Chiba *et al*., 1994; Szabo *et al*., 2001). The chemical analysis of the feed in the present experiment (Chapter 3: Table 3.1) showed a protein level that was slightly higher for the diet containing the normal energy level compared to the diet containing the high energy level. The current experiment was not designed to evaluate the effect of protein on liver weight. It is therefore not clear whether the slight differences in the levels of protein could have led to the variations in the weights of the liver.

An interesting interaction was found between the diet and the rearing system for the EMA. Although not significantly different, indoor pigs fed on the NE diet had a bigger EMA than those fed on the HE diet while a contrasting effect was obtained in the outdoor rearing system. Similar to the EMA, an interaction between the diet and the rearing system for lean % was obtained. The pattern of interaction for the lean % corresponded with that of the EMA in that the lean % was high for the indoor and outdoor pigs consuming the NE and HE diet respectively. The bigger EMA obtained for the indoor pigs fed on the NE diet and for the outdoor pigs fed on the HE diet could have contributed to the high lean % in the respective groups. These findings could imply that as far as lean % is concerned the NE and the HE diets were respectively more effective for maximal protein depositions in the indoor and outdoor rearing systems. Increasing the energy level improves the deposition of protein (Chiba *et al*. 1991b; Renaudeau *et al*., 2006). It has however been shown that the response in protein deposition to the increase of energy reaches a plateau which is a representation of the maximal protein deposition (Chiba *et al*. 1991 b; Renaudeau *et al*., 2006). The maximal protein deposition is influenced by factors such as genotype (Quiniou *et al*., 1996), the stage of growth (Mohn & De Lange, 1998) and the temperature (Le Bellego *et al*., 2001). A higher energy than required could reduce the protein deposition (Chiba *et al*., 1991 b). It could be that the high energy level in the HE diet was too high and had a reducing effect on the deposition of protein resulting in a slight reduction of lean % for the indoor reared pigs. Outdoor pigs are active and were in the current experiment exposed to temperatures below thermo-neutrality. The NE diet was perhaps not supplying sufficient energy for maximal protein deposition and hence the response to the HE diet for EMA and lean %. The surprising similar feed intakes (Chapter 4) between outdoor pigs consuming the normal and the high energy levels strongly supports the theory that the NE diet did not supply sufficient energy for maximal protein deposition and could also be an indication that the feed intake of the outdoor pigs was limited by the stomach capacity. The results in the current study also presents a suggestion that as far as lean percentage was concerned, the NE diet was more suitable for the indoor rearing system while the HE diet improved the lean % of the outdoor pigs.

5.6 CONCLUSION

Pigs can be raised successfully outdoors without any negative effects on the carcass measurements. Increasing the energy level while maintaining a balance between the levels of the essential amino acids and energy, improves the carcass weights as well as the dressing percentages in both indoor and outdoor raised pigs. Considering the fact that the lean meat percentage is one of the most important characteristic in the pork industry, the results of the current study indicates that indoor pigs should be fed on diets containing normal energy levels, while outdoor pigs should be fed on diets containing high energy levels. The financial benefits from the two feeding regimes should however influence the choice of the diet.

5.7 RECOMMENDATIONS

It is recommended that the financial benefits of raising pigs outdoors should be calculated before a decision is made on whether pigs should be raised on diets containing the normal or the high energy levels.

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CHAPTER 6: OVERALL CONCLUSION

Raising pigs outdoors reduces the digestibility of nutrients owing to the consumption of fibre and soil. Research has shown that fibre and soil reduces retention time in the gut and therefore that has a negative influence on digestibility. Increasing the energy level of a diet improves digestibility and is one strategy that can be used to improve performance of pigs raised outdoors and it also reduces nutrient excretion into the environment. The growth rates of the indoor and outdoor raised pigs were similar when pigs were grown during the cooler part of the year in the Gauteng area. Outdoor pigs required more feed for maintenance and production and therefore the efficiency of feed utilisation was reduced. Higher energy levels reduced feed intake in pigs raised indoors, the effect is however not obtained in outdoor pigs. The high energy level used in the current study may not have satisfied the energy needs of the outdoor pigs as feed intakes were similar between outdoor pigs that consumed the normal and the high energy levels. Pastures did not reduce the feed intakes of the outdoor pigs fed *ad-libitum* and contributed to the less efficient feed utilisation as reflected by the high feed intakes and the negative correlations between pasture intake and digestibility. The carcass yields and characteristics of the indoor and outdoor pigs were similar. Increasing the energy levels of the diets while still maintaining the correct ratio between energy and the essential amino acids improves carcass yields and the dressing percentage. Lean meat production is high in indoor and outdoor raised pigs fed on diets containing the normal and high energy levels respectively. The high energy level seems best suited for production in grower pigs as it improves digestibility which is also beneficial for the environment, reduces feed intake and improves the carcass yields. The financial benefits of raising pigs outdoors have to be evaluated.

CHAPTER 7: OVERALL RECOMMENDATIONS

The current experiment only evaluated the effects of energy level on performance of pigs raised outdoors; therefore it is recommended that experiments that combine aspects of the energy level and the manipulation of other nutrients should be conducted to further reduce the negative impact that pigs may have on the environment. The experiments should be done to also improve performance and reduce feed costs. It is recommended that the growth performances of outdoor pigs should be evaluated for the different seasons. The effects of different increasing levels of energy on digestibility, growth performances, carcass characteristics and financial turnover should be conducted to determine the energy level that can be used to exploit fully the advantages associated with increasing energy levels in diets of pigs especially for the outdoor raised pigs since they have a more direct impact on the environment. Different types of pastures, as well as their management to preserve their quality should be evaluated to reduce the impact of fibre in pastures on digestibility and therefore performance and to ensure that pigs will fully benefit from the nutritional contributions of pastures.