DIETARY ENERGY DENSITY AND THE PERFORMANCE CHARACTERISTICS OF GROWING PIGS

by

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ABSTRACT

DIETARY ENERGY DENSITY AND THE PERFORMANCE CHARACTERISTICS OF GROWING PIGS

Optimal nutritional management of growing pigs is constrained by lack of quantitative information on the response of animals between 30 and 110 kg live weight to dietary energy content. Under "ideal" conditions modern genotypes appear to adjust feed intake to maintain a constant DE intake over a much wider range of dietary energy concentrations than previously thought (Mullan et al, 1998). However, under commercial pen conditions, voluntary feed intake is lower, pigs respond in terms of both growth rate and feed conversion to dietary DE density considerably above the levels currently thought to maximise biological and economic responses. The present study was designed to provide information on the response of growing pigs to dietary energy content under ideal and commercial housing conditions for two growth periods 30-60kg liveweight and 60-100kg liveweight.

The results of the pigs kept under individual (ideal) housed conditions were consistent with the literature in that they adjusted their voluntary feed intake with digestible energy density to maintain a constant energy intake. The results of the pigs kept in groups (commercial) housing conditions tended to increase their daily energy intake as the energy density of the feed increased. This increase in energy intake improved the growth rate of the pigs and increased the fat deposition of those pigs. Economic analysis of the experiments involving pigs in groups indicates that formulating diets to a least cost per megajoule of digestible energy is not the most profitable point to set the digestible energy density. Modelling programs need to be used to determine where the least cost per unit of growth of the pig occurs. This is the most economical digestible energy density to formulate too. This will have major impact on the cost of production of piggery operations as the cost of energy is the single most important parameter in the cost of producing a pig.

PREFACE

The studies presented in this thesis were completed by the author while a part-time, post-graduate student in the Faculty of Veterinary Science, University of Sydney, Camden, NSW, under the supervision of Professor Wayne Bryden. Sources of information are cited under the bibliography. The research is original and is not currently being submitted for any other degree.

The experimental protocols followed in this thesis were approved by the Bunge Meat Industries Animal Care and Ethics Committees and followed the guidelines of the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes.

ACKNOWLEDGMENTS

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Chapter 1

GENERAL INTRODUCTION

Optimal nutritional management of growing pigs is constrained by lack of quantitative information on the responses of animals between 30 and 110 kg live weight to dietary energy content using the newer genotypes housed under commercial conditions. Indeed, the dietary energy levels commonly recommended for pigs in Australia are based on the results of experiments with pigs housed in individual pens published in the late 1980's (Campbell and Taverner, 1986).

1.1 The importance of dietary energy in feed formulation

Feed accounts for 55-65% of the cost of producing a pig for market. The major limiting nutrient in feed is energy and thus it is the most important single factor in the cost of pigmeat production (Cole et al., 1971). Diet formulation is based on setting an energy density of the diet and then setting all other nutrients in relationship to the energy density. Therefore the major determinant of the cost of specific diets is energy density. The aim of diet formulation is to achieve the lowest diet cost that supports the maximal performance required to achieve desired carcass specifications.

1.2 The context of the research study.

The energy intake of the pig is determined by the concentration of available energy in the diet and the amount of that feed that is eaten. The concentration of available energy in the diet is a reflection of the chemical composition of the diet and the ability of the pig to extract that energy. The feed intake of the pig is affected by the requirement of the animal to maintain a balance of nutrients that is needed to maintain the pig and a certain level of performance within the environmental conditions (temperature, group size and disease status) in which the pigs are kept.

Under "ideal" conditions modern genotypes appear able to adjust feed intake to maintain a constant digestible energy (DE) intake over a much wider range of dietary energy concentrations than previously thought. However, under commercial conditions voluntary feed intake is lower and pigs respond in terms of both growth rate and feed:gain to dietary DE concentration considerably above the level(s) currently thought to maximize biological and economic responses.

The computer modeling program describing pig growth in response to nutrients "Auspig" described by Black et al.(1986), is not particularly accurate at predicting the responses of pigs to dietary energy concentration and there is a real possibility that current decisions on the most appropriate dietary energy contents for growing pigs are based on inappropriate information. Considerable potential appears to exist with modern genotypes to further exploit their obvious potential for lean tissue growth and greater carcass gains by using higher energy diets.

1.3 Development of proposed research program

The objective of the studies reported in this thesis was to examine the performance of pigs to dietary energy content. The determinants of the energy requirements of the pig, the factors that influence feed intake and the interaction between feed intake and the energy requirements are reviewed. The experiments examine the response of grower (30-60 kg liveweight) pigs to DE density under ideal (experiment 1) and commercial (experiment 2) housing conditions. Experiments 3 and 4 examine the same premise with older pigs ranging from 60-100 kg liveweight (finisher pigs). The results of the experiments were used to determine the economic implications of varying DE density in grower and finisher pigs diets, especially under commercial housing conditions.

Chapter 2

LITERATURE REVIEW

2.1 Definitions of energy metabolism

Definition of energy

The basic unit of energy metabolism is the Joule. A joule is 10^7 erg, where 1 erg is equivalent to the amount of energy required to accelerate a 1 gram mass by 1 metre per second.

Gross Energy (GE)

Gross energy is the energy released on combustion, determined by measuring the amount of heat released upon combustion of the feed. Generally measured with adiabiatic Bomb calorimeter, GE is the maximum amount of energy available to the animal. It is dependent on proportions of carbohydrate, fat, protein, minerals and water in the feed. As water and minerals contribute no energy to the diet, GE can be predicted from the energy content of carbohydrate, fat and protein.

Digestible Energy (DE)

Digestible energy is the energy in the feed remaining after removing the gross energy in the faeces. It can be determined with pigs housed in metabolism crates by measuring gross energy intake and subtracting faecal gross energy output over a 5-7 day collection period. The intention of this measurement is to estimate the energy that is absorbed by the pig.

Metabolisable Energy (ME)

Metabolisable energy is the digestible energy of the feed minus the gross energy of urinary and intestinal gaseous emissions. The gaseous emissions in the pig are often ignored, as they are small and not easily measured. The gross energy of the urine is usually considered relatively constant in balanced diets and is relative to the biological efficiency of feed intake relative to nitrogen retention. An excess of nitrogen in the feed, will increase urinary gross energy and thus the ratio of DE to ME will not remain constant. The Metabolisable Energy System of describing the energy in feeds is an estimate of the amount of energy that is available to the animal at a metabolic level.

Net Energy (NE)

Metabolisable Energy is divided into net energy and heat increment. Heat increment is the heat produced by the digestion and metabolism of nutrients and fermentation in the digestive tract (Ewan, 2001). The heat increment maybe used to maintain body temperature but is otherwise considered a loss of energy. The remaining net energy is used for maintenance (NE_m) and net energy for productive purposes such as tissue synthesis, foetal development or milk synthesis. Heat production is the sum of the heat increment and net energy for maintenance. The NE_m is affected by fasting heat production (FHP) of which up to 50% of the FHP is contributed by gut metabolism.

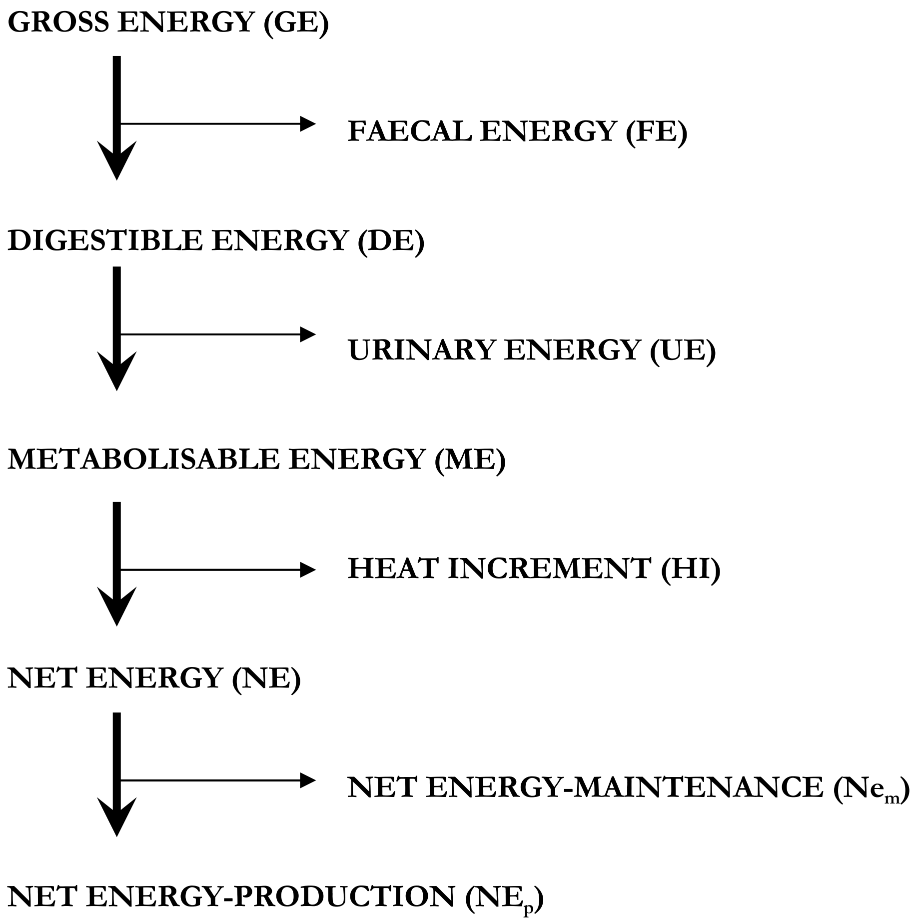


Figure 1. The partitioning of feed energy in the pig.

Methods of determining energy requirements of the animal have been by an empirical or a factorial approach. The empirical approach establishes requirements based on maximising performance in response to varying energy intake and is often used in experiments where growth measurements are used to assess the energy requirement of the animal. The factorial method is based on determining actual energy requirements for specific functions such as maintenance, growth and reproductive requirements. The factorial approach is conducive to the establishment of models of energy metabolism and is the most widely used approach to establishing the energy requirements of the animal

The ultimate aim of the study of energy metabolism is the partitioning of energy in the feed into the categories shown in Figure 1 and thus predicts the performance of the animal.

The utilisation of energy in growing animals can be shown schematically (Figure 2). The energy retention is plotted against intake of metabolisable energy. This relationship is accepted as linear under the assumption that it is corrected for metabolic body weight (BW*), where * was originally estimated as 0.75 (Kleiber, 1965) but has been adjusted by Noblet et al., (1993) to a value of 0.6 which better reflects today's improved genotypes. The rate of energy retention per unit of metabolisable energy is shown as "k". Under high physical activity the requirement of metabolisable energy is higher due to energy expenditure for activity that is not stored in the body.

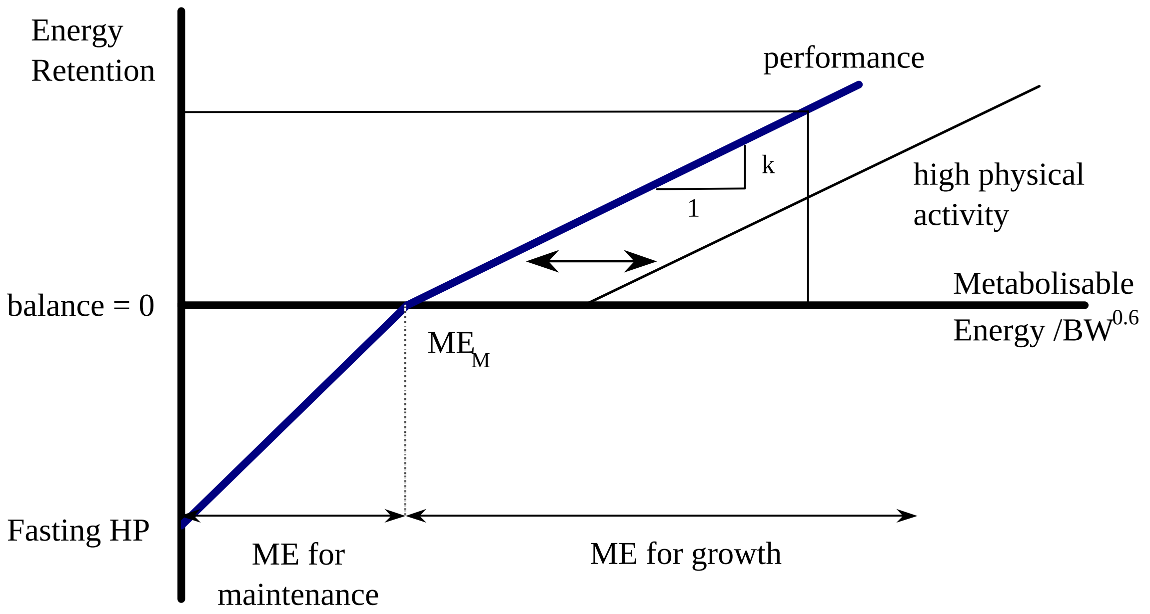


Figure 2. Energy retention in relation to the intake of metabolisable energy.

2.2 Energy for maintenance

Energy for maintenance is the energy required by the animal to maintain the body at a constant weight. It is measured by the fasting heat production in calorimetric studies. It is expressed as a proportion of body weight referred to as metabolic weight.

Maintenance energy requirements can account for approximately one third of the total energy requirements of a growing pig (Black and de Lange, 1995; NRC, 1998). The major energy demanding processes include blood flow, respiration, ion balance, tissue turnover, animal activity, feed ingestion, excretion and actual deposition of nutrients. (Black and de Lange, 1995).

The major determinant of maintenance energy is body weight; allometric functions have been used to describe the relationship (NRC, 1998). The effect of activity on maintenance energy is associated with eating as well as animal interactions and can account for 20% of the total maintenance requirement (Halter et al., 1980; Verstegen et al., 1987). The maintenance energy requirement is different for different genotypes due to differences in body composition in terms of fat, protein and visceral masses (Noblet et al., 1991). Due to the relatively inexpensive energy cost of maintaining fat and the higher cost of maintaining protein, Whittemore (1983, 1993) has suggested that maintenance energy requirements are better expressed relative to body protein mass. Yen (1997) noted that protein in visceral mass was metabolically more energy expensive than skeletal muscle thus suggesting that maintenance energy requirement can be further refined. There is some evidence that visceral size is different between genotypes (Koong et al., 1983; de Greef et al., 1994; Bikker et al., 1996a; Quiniou and Noblet, 1995; van Milgen et al., 1998), which may explain some of the variation between genotypes.

Maintenance energy requirements estimated from measurements of fasting heat production may vary from the heat production of the normal animal due to difference in activity levels, length of the fast and previous nutritional history.

Maintenance requirements can be broken down into its components of fasting heat production (FHP), activity heat production (AHP) and thermic effect of feed (TEF). Heat increment of feed is the addition of AHP and TEF. Total heat production and the relative proportions vary with genotype (Noblet et al., 1997). Fasting heat production ranges from 53 to 65% of total heat production with heat energy loss associated with activity contributing only 5% of total heat production in calorimetry trials. The remaining heat production was associated with TEF (Noblet et al., 1997). Heat production is measured in a respiratory chamber and may underestimate the heat production of activity although it is unlikely to account for any significant percentage of the total heat production under normal conditions (J.L. Black 2000 pers comm.).

Metabolisable energy requirements for maintenance can be estimated from fasting heat production. Estimates of ME_M =1.15 to 1.20 MJ/kg $BW^{0.60}$ (Noblet et al., 1997). FHP is higher for leaner genotypes than expected due to the higher ratio of lean to fat content (Tauson et al., 1997).

Increasing the ambient temperature above the thermoneutral zone for pigs increases the heat production significantly if feed intake is maintained; up to 56% in some breeds at 40°C (Tauson et al., 1997). However, feed intake will fall at temperatures above the thermoneutral zone and reduce overall heat production.

The effect of pleuropneumonia on maintenance energy was examined by Bray et al., (1997). The reduction of feed intake due to the pleuropneumonia was not associated with a reduction in oxygen consumption, indicating a reduction in energy utilization for weight gain. These changes suggest an increase in the maintenance requirement of the animal due to disease.

Maintenance energy is generally considered as a proportion of bodyweight and can be affected by the factors outlined above. To remove some of the genotype influences on calculation of maintenance energy van Milgen et al., (1997) suggested that this effect could be removed by expressing maintenance energy as a function of muscle, viscera and fat content of the body. They suggested the following equation:

$$\text{Maintenance Energy (KJ/d)} = 457(\text{muscle})^{0.81} + 1969(\text{viscera})^{0.81} - 644(\text{fat})^{0.81}.$$

For lean genotypes where fat content is a smaller component of the overall body composition they suggested the following equation.

$$\text{Maintenance Energy (KJ/d)} = 508(\text{muscle})^{066} + 2011(\text{viscera})^{0.66}$$

In the same experiments it was shown that the energetic cost of activity during fasting was allometrically associated with muscle mass rather than total body mass, thus removing the genetic component of this calculation.

2.3 Energy for growth and development

The energy required for growth and development is associated with the increase in body mass due to an accumulation of protein, fat and ash. Once the energy for maintenance is satisfied further increases in energy intake are used for protein and fat deposition in growing pigs. In terms of analysis one gram of protein contains 23.439 KJ of gross energy and one gram of fat contains 39.344 KJ of gross energy.

2.3.1 Energy for protein metabolism

The energy required to deposit 1g of protein, not including energy in the protein =54.0 KJ (Noblet et al., 1999). Protein turnover is the reason for the higher energy requirement for protein deposition than for fat deposition. Biochemically, deposition of protein creates a greater amount of heat that is subsequently lost (Millward et al., 1976).

Protein requires 23.439 + 54 = 77.439 KJ of energy from the diet to deposit one gram of protein. One gram of protein requires 4 g of water and results in 5 g of tissue, thus 77.429 * 0.2=15.48 KJ to deposit 1 g of protein tissue. The efficiency of energy deposition is different depending on what tissue is being deposited and the stage of life of the pig (Close et al., 1971).

Body protein deposition increases linearly with increased energy intake until maximum protein deposition is reached after which no further protein deposition occurs (Campbell and Taverner 1988; Bikker et al., 1995,1996a,1996b; Quiniou et al., 1995, 1996a, 1996b). Maximum body protein deposition is essentially a function of genotype and age although it can be modified significantly by environmental and dietary factors (Black et al., 1995; Moughan et al., 1995).

2.3.2 Energy for Fat metabolism

The energy required to deposit 1 g of fat, excluding energy of the fat =46.88 KJ (Noblet et al., 1999). One gram of fat requires 0.2 grams of water and results in 1.2 grams of tissue. Thus it requires 39.344+46.88 =86.224/1.2=71.85 KJ of energy to deposit one gram of fat tissue.

2.4 Voluntary feed intake

2.4.1 Classical theories of intake control.

The first theory involving the mechanisms controlling feed intake was proposed by Brobeck (1948), who suggested the thermostatic theory of intake; animals eat to keep warm and quit eating to prevent hyperthermia. The anterior hypothalamus is the most important temperature sensor in the body and heating or cooling of this area will affect heat loss or production and therefore control feed intake. Ingram (1968) noted a positive relationship between hypothalamic temperature and food intake in pigs but work in other species (Baile and Mayer, 1968; Dinius et al., 1970) showed that this was related to excitement rather than to ingestion and usually subsided before the end of the meal. Overeating increases heat production and heat loss mechanisms are activated to prevent hyperthermia rather than a reduction in intake. However, when there is no further mechanisms available to reduce heat loss the animal will reduce its voluntary feed intake to prevent an increase in core body temperature above 39.3°C. This is the basis of the upper evaporative limit to the thermoneutral zone of comfort for the pig (Giles and Black, 1991)

The first objective scientific study on mechanisms involved in controlling feed intake was carried out by Mayer (1953). He proposed the glucostatic theory of feed intake control which revolved around the animal attempting to maintain a constant level of glucose in the blood by a central nervous monitoring system. This mechanism and gut capacity are likely to exert short-term control of intake through manipulation of meal size and frequency.

Kennedy (1953) postulated that central nervous system monitoring of fat depots would control the intake of animals over an extended period: the lipostatic theory. The domestic pig may become grossly overweight and the feedback signals associated with the lipostatic theory appear to be significantly reduced in the pig, which is likely a response of genetic selection (Forbes, 1995).

Booth (1972) modified the glucostatic theory to say that the rate of glucose utilisation was the controlling factor on feed intake. Russek (1976) showed that the liver as well as the brain is sensitive to glucose. Shimizu et al. (1983) suggested that the liver was the metabolic sensor for the brain.

The CNS has a central role in the control of feed intake. Stephens (1980, 1985) showed that there are specific glucose receptors in the duodenum that are associated via a neural link to the central nervous system. Houpt (1983a, 1985) showed that osmotic and stretch receptors in the duodenum have CNS neural linkages.

The hormonal milieu involved in the regulation of intake has been extensively examined in many species and pigs are no exception. Exogenous insulin has been shown to increase intake in young pigs 6 hours after injection (Houpt and Houpt, 1977). This is certainly expected considering the role of insulin in the control of blood glucose concentration. Increased levels of growth hormone have been shown to decrease feed intake although this may be related to the better utilisation of nutrients in the body. Adrenaline has been shown to depress intake (Langhans et al., 1985) although this is related to abnormal behaviour, including termination of feeding (Hinton et al., 1987).

A variation on the lipostatic theory has been developed by Martin et al., (1989) who suggested that feed intake is regulated by the ability of blood metabolites to be incorporated into adipocytes. When adipose cells grow to a certain size they release fatty acids into the circulation, which is detected by the brain, and feed intake is decreased. Leptin is released from adipocytes and maybe associated with this theory (Houseknecht et al., 1998).

Cholecystokinin (CCK) is the most extensively studied of the hormones that are associated with feed intake. This hormone is secreted from the gut and secretion is increased during feeding. The effect of CCK in pigs is still not defined precisely as it is thought to reduce stomach emptying by constriction of the pylorus but Rayner et al (1991) showed that CCK caused feed depression via other mechanisms. It is postulated (Houpt, 1983b) that the site of action of CCK is the upper intestine although infusions of tryptophan increase plasma CCK but there was no effect on feed intake (Rayner and Gregory, 1985). Most of this early work involved the use of antagonists to CCK or artificially high levels of CCK that may have caused a general malaise in the pig (Baldwin et al., 1983). Recent work involving immunisation against CCK (Pekas and Trout, 1993) showed an increase in intake by 8.2% and growth by 10.6%. Thus CCK may play a role in controlling feed intake at normal physiological levels.

Other gut hormones that may exert some influence on feed intake include somatostatin, bombesin (Baile et al., 1983) and neuropeptide Y and peptide YY (Parrot et al., 1986). Opioid peptides may also influence feed intake (Baldwin et al., 1990) although this is likely a behavioural response rather than a physiological response. In addition the steroid hormones play a major role in feed intake as can be seen by differences in feed intake between males, females and castrated males (Jordon et al., 1965).

2.4.2 Sex of the animals

Estimations of the increased intake of castrates compared to male pigs range from 7 to 32% (Walstra, 1969; Houseman, 1973; Sparkes, 1982). Gilts tend to eat a similar amount to castrates and 7% greater than male pigs (Houseman, 1973; Sparkes, 1982). This suggests that the digestible energy intake of castrates is higher than gilts, which in turn is higher than males. This is in reverse to the protein deposition capacity of the different sexes which tends to refute the lipostatic mechanism of feed intake control as the fat deposition of castrates is higher than gilts and males.

2.4.3 Manipulation of carcass quality by control of feeding.

In general pigs fed *ad libitum* grow faster than pigs offered a restricted feed regime but have an increased feed:gain and carcass fat content (Cole et al., 1971). The increase in feed:gain refered to by Cole et al., (1971) occurred because energy intake exceeded that required for maximum protein deposition. Selection for increased growth and reduced fatness since 1971 has resulted in voluntary energy intake for pigs under 100kg liveweight below that required for maximum protein deposition (R.G. Campbell, unpublished). Feeding systems developed in the 1990's have all been aimed at *ad libitum* feeding due to the improvement in genetics and the desire to achieve maximum liveweight and protein gains.

2.4.4 Environmental constraints on feed intake

The temperature at which feed intake is depressed is dependent on the weight and relative insulation properties or fat proportion of the animal to maintain core body temperature. In practice a wide range of environmental factors including skin wetness, humidity, air quality and satiety of the animal affects the relationship between feed intake and ambient temperature. Close (1989) reviewed the literature and developed the equation relating body weight, environmental temperature and Metabolisable Energy intake.

$$MEI = 9.6 + 0.075ET+0.52BW-0.012ET \times BW$$

MEI = Metabolisable Energy Intake per day (MJ/day), ET is environmental temperature (°C) and BW is Body weight (kg).

The increase in feed intake seen under cold conditions does not overcome any significant growth retardation but they may increase growth rate above pigs kept at higher temperatures (Holme and Coey 1967). The increase in feed intake below lower critical temperature is greater in individually housed animals as pigs in groups tend to huddle and feeding bouts are reduced (Giles and Black, 1991).

Close et al., (1971) showed that there was a rise in water to dry matter intake ratio between 2.7 to 4.3 kg/kg DM with increasing ambient temperature. Barber et al., (1991) identified a component of water intake associated with feed intake with the water intake being 89% of the weight of the feed eaten with the rest of the water intake associated with water intake between feeding bouts.

Summer tends to reduce growth rates and is associated with reduced feed intakes and is dependent on housing conditions in terms of capacity to maintain lower temperatures (O'Doherty and McKeon, 2000). The seasonal effects tend to effect the carcass measurements rather than measured live performance as metabolism changes (O'Doherty and McKeon, 2000).

2.4.5 Group Size

Group size and stocking density have a significant impact on feed intake. Stocking rate can have the major effect on intake as shown by Kornegay and Notter (1984) where feed intake was reduced by 50g per day with each reduction of $0.1m^2$ in space allowance. Recommendations on space allowance for optimum feed intakes have been set by NRC (1987) and are $0.6\ m^2$ for pigs 25-60kg liveweight and 1.0 m^2 for pigs over 60 kg liveweight. As group size increased from three to twelve pigs feed intake decline by 10% despite the maintenance of space allowance (Heitman et al., 1961). Increase in pigs per feeder space from 13 to 16 with a concomitant increase in stocking density from 0.78 to 0.65 m^2 per pig reduced feed intake by 5% for pigs' 38 to 65 kg liveweight and 10% for pigs' 65 to 100kg liveweight (O'Doherty and McKeon, 2000). The difference in feed intake resulted in significant differences in daily energy intake and daily gain. The reduced intake was associated with an improved feed conversion. Petherick (1983) suggested an area of $0.047m^2/W^{0.67}$ is required for all pigs to lie on there side. Black (1995) reported that feed intake is depressed once floor space falls below 0.35 $m^2/W^{0.67}$ and declines in a linear manner from this point. Changing stocking density has been shown to significant effect growth rate of pigs primarily through reduction in feed intake (Jensen et al., 1973; Kornegay et al., 1993; Brumm and Miller, 1996).

Social interaction with another pig reduces feed intake regardless of stocking density. Increasing the number of pigs from 1 to 5 reduces feed intake by 8 to 10% (Chapple, 1993). It appears from the literature and commercial production that group sizes of pigs above 5 pigs/pen do not have a direct effect on feed intake when stocking density is kept constant at adequate levels (Petherick et al., 1989; Gonyou et al, 1992; de Haer and de Vries, 1993; Nielsen et al., 1995). Feeding pattern plays a major role in the difference in intake between individually housed pigs and group housed pigs. Pigs housed in individual pens spend more time eating than group housed pigs. However, in larger groups, pigs compensate for a lack of feeding time or space by eating fewer, larger meals (de Haer and de Vries, 1993).

2.4.6 Disease

The general response to disease and fever is a reduction in voluntary feed intake as the body strives to lower its core temperature. This is a generalised reaction in all mammals and is a protection mechanism. The level of feed reduction is very dependent on the type of disease that is being experienced and if it is a chronic or acute problem. An acute disease elicits an immune response and fever that results in an anorexic effect (Klasing and Johnson, 1991; Koutsos and Klasing, 2001). This reduction in intake can be total for short periods of time following a pneumonia challenge (Bray, 1996). A chronic disease situation appears to reduce feed intake via a mechanism associated with a decline in arterial oxygen supply (Bray, 1996).

Disease is a potent manipulator of feed intake with the direct mechanism associated with immune stimulation and oxygen supply and the interaction with energy density is as yet untested in the scientific literature.

2.4.7 Appetitie of individuals versus grouped pens.

Experiments examining feeding behaviour of pigs in groups versus those in individual housing by De Haer and Merks (1992) showed that there was longer feeding times of larger meals with pigs in groups. This behaviour was modified when pigs were kept in the same environment for longer periods to that closer to individuals. This meal effect in group-housed pigs may lead to an asynchrony of nutrient availability to the animal.

2.4.8 Appetite as a consequence of gut capacity

The physical limit to the capacity of the pig gut has not been explored in any direct experiments but indirect experiments on diet dilution has shown that baby pigs do have a limit in which they can compensate for this diet dilution (Wangsness and Soroka, 1978; Pekas 1983). A confounding factor involved in determining the gut capacity is the rate of passage of the feed from the stomach into the intestine and then expelled as faeces. Gregory et al., (1987) showed that infusion of fat or glucose into the stomach did not reduce feed intake and they concluded that the rate of gastric emptying influenced the meal size. Unpublished work by King et al., (2000) showed that the inclusion of lupins into the diet reduced gastric emptying and had a major impact on the measurement of DE and NE.

2.5 Integrative theories of feed intake control.

The development of more integrative theories to describe feed intake was recognised by Balch and Campling in 1962. They looked at hypotheses that had been established and noted that they did not predict how feed intake is controlled under all circumstances. From this integrative models were developed which involved all the factors identified as affecting feed intake. Most single factor models agree that feed intake is related to energy requirement of the animal. As yet there is no evidence that energy is measured directly within the body and thus intake is adjusted to maintain an energy status in the body. The body does partition the nutrients that are absorbed and excess energy is deposited as fat stores in the body. Le Magnen (1976) has shown that energy supply to some tissues is monitored and used to control feed intake and Booth (1979) indicated that the rate of use or supply of energy by cells is critical. It appears that meal size is dictated by more peripheral mechanisms of stomach and intestinal distension, delivery of nutrients to the liver with central nervous system control and thus a faster acting mechanism (Le Magnen and Devos 1984). The frequency of feeding may be more under the control of post absorptive or metabolic factors such as continued delivery of energy and other nutrients to the liver resulting in changes of the hormonal milieu (Stricker and McCann 1985). Forbes (1995) suggests that many of the mechanisms that have been looked at are additive in nature rather than exclusive and as such may involve extending some mechanisms such as the intestinal distension when other mechanisms such as protein nutrition are at an optimum. The interaction of the all the factors involved in feed intake will only be handled by very complex modeling systems that need to be developed to answer some of the questions relating to the interactions.

2.6 Manipulation of energy density

The manipulation of the energy density of the diet and its effect on subsequent performance of the pig has received little attention due to the belief that pigs could compensate for a change in energy density of the diet by adjusting feed intake to compensate and thus maintain a constant digestible energy intake per day. Cole et al., (1967) was the first to examine the effects of increasing energy density of the diet on pig performance. This experiment used castrated pigs in individual pens allowed *ad libitum* access to pelleted diets ranging from 12.4 MJ DE/kg to 16.37 MJ DE/kg over a liveweight range of 38 to 105 kilograms. The results of the trial showed that the pigs adjusted their voluntary feed intake to maintain a constant level of daily digestible energy intake. Thus there was no physical limitation on the pigs ability to adjust food intake to maintain daily energy intake. Cole et al., (1967) also noted that when the pigs were kept in metabolism crates there daily energy intake was significantly less than when the animals were kept in individual holding pens. The reduction in energy intake was constant across treatments and as such is likely to be a reduction in the energy required by the pigs via a lower maintenance requirement with the reduced activity although they also grew significantly slower. In a subsequent experiment (Cole et al., 1969) a diet of very low energy density (11.1 MJ DE/kg) was compared to a standard diet of 14.2 MJ DE/kg there was a reduction in energy intake per day from 44.3 to 41.9 MJ DE per day. There was a resultant reduction in growth rate and fat deposition. From these experiments Cole et al., (1971) concluded that pigs ate for a constant intake of digestible energy intake per day except where physical limitations effect feed intake. Low energy diets will limit total intake due to the maximum physical capacity or an under filled stomach in very high-density diets can allow higher levels of digestible energy per day to be consumed.

Owen and Ridgman (1967) used a lower range of digestible energy densities from 10.3 to 14.1 MJ DE/kg and showed that there was only a slight increase in feed intake with increasing nutrient density for pigs less than 50 kilograms but was significantly greater for pigs greater than 50 kilograms. Therefore bodyweight and gut capacity play a large role in the ability of the pig to adjust to energy density of the diet with pig less than 50kg less likely to adjust intake in response to changes in nutrient density. They also showed in later work (Owen and Ridgman 1968) that a two week compensatory period was required to demonstrate changes in feed intake to the differences in nutrient density of the feed.

McCracken et al., (1997), showed that there was no significant effect of dietary energy density on the ME intake or Empty body gain for male and female crossbred pigs from 22 to 46 kg when housed in individual pens. The energy density range was 12.4 - 15.4 MJ of DE/kg. In association with the increase in energy density, total body dry matter, fat and energy percent increased. Protein gain was constant (152 g per day) across treatments with fat gain significantly increasing from 96 to 126 g per day. Dry matter and energy digestibility of the diets significantly increased as the energy density of the diet increased. As energy density increased there was a non-significant ($p<0.07$) decline in heat production, which accounts for the extra energy retention. Water retention declined as the fat deposition increased.

In modifying the digestible energy density of pig diets the fat and crude fibre components of the feed are the components often manipulated. As the ratio of fat to crude fibre increases the digestible energy density of the diet increases. The use of fats in pig diets was extensively reviewed by Wiseman (1994). In general the digestibility of fats is affected by the composition of the fat in terms of the fatty acid chain length and degree of saturation. The level of free fatty acids can influence the energy content of the fat as well. Crude fibre is an imprecise nutritional term and is more a reflection of analytical procedures rather than any discrete nutrient. The concept of crude fibre reducing the energy density of the diet is due to the relative indigestibility of fibre and thus the monogastric animal cannot extract much energy from this portion of the feed.

Forbes (1995) concluded that in the pig adjustment of feed intake to dietary energy density may not be complete, resulting in increased daily DE intake.

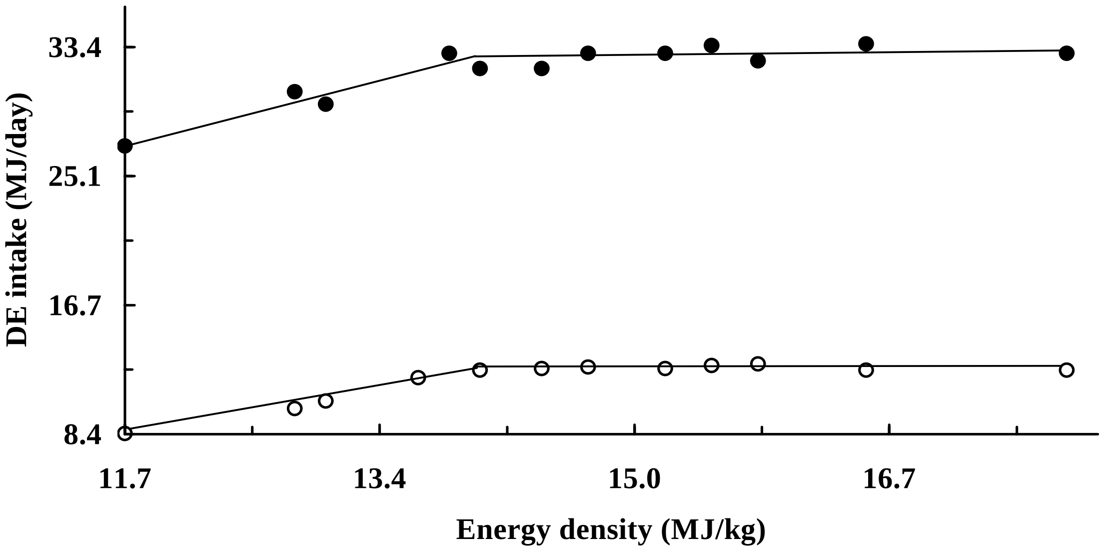


Figure 3. Summary of the effects of the energy density of food on the voluntary intake by pigs from 5 to 30kg (○) and from 30 to 100 kg (●) (NRC 1987, Forbes 1995)

Figure 3 shows a summary of trials compiled by the NRC (1987) showing the relationship between energy density of the feed and digestible energy intake for growing pigs. There is a positive relationship up to 14 MJ DE/kg and constant for energy densities greater than 14MJ DE/kg. This positive relationship is related to the physical limitations of the digestive tract especially at very low-density diets (Cole et al., 1971). Cole et al., (1971) also suggested that with very high energy density diets (above those in figure 3) a physical response is also seen in that there is an inadequate gut fill that results in a stimulus to increase feed intake, a minimum gut fill signal. This would result in an increase in daily digestible energy intake. These physical limitations and their affects are schematically represented in Figure 4.

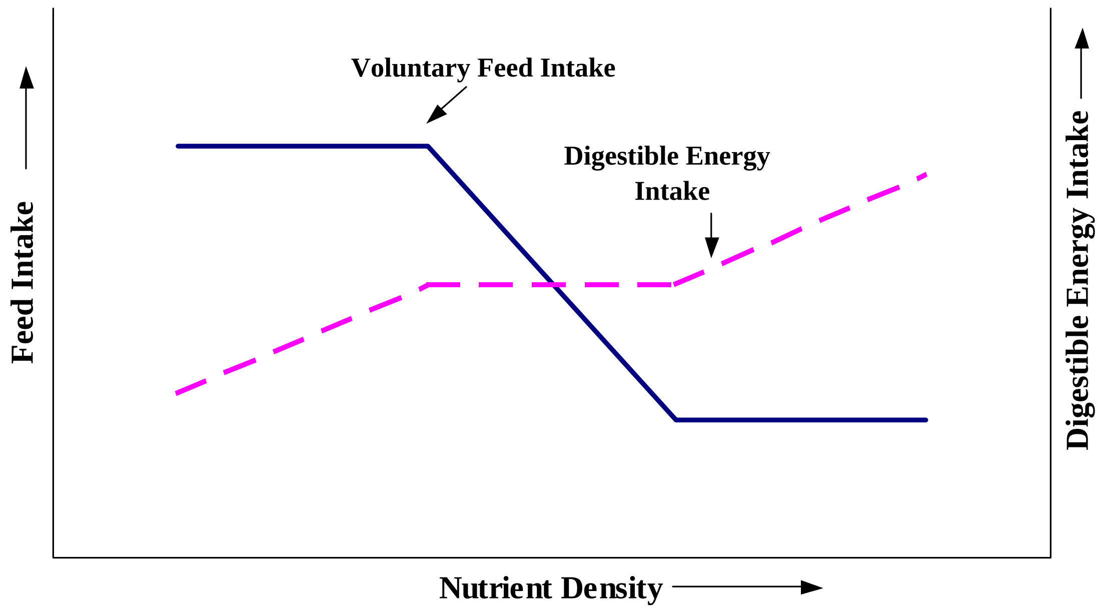


Figure 4. Schematic representation of the effect of nutrient density on feed and energy intake. (Adapted from Cole et al., 1971).

The results of some recent work from the USA (Stein and Easter, 1996) on finisher pigs fed *ad libitum* in a commercial group penned environment concluded that it is possible to modify the daily energy intake of the pig and the resultant growth composition (Table 1). Feeding lower energy diets reduced daily energy intake and also fat deposition more than protein deposition.

Table 1. The responses of finisher pigs housed in group pens to dietary energy density between 54 and 112 kg liveweight (Stein and Easter, 1996).

	ME Density (MJ/kg)				
	11.3	12.1	12.9	13.8	14.7
Daily gain (g/d)	872	931	1006	1038	1017
Feed Intake (kg/d)	2.91	3.28	3.36	3.23	3.31
Feed:Gain	3.84	3.44	3.33	3.12	2.81
ME intake (MJ/d)	32.9	39.7	43.3	44.6	48.7
Dressing Percentage	73.51	73.96	74.56	74.9	75.97
Carcass P2 fat depth	17.5	17.8	19.8	21.8	21.6

There was a curvi-linear increase in daily ME intake from 32.9 to 48.7 MJ with an increase in dietary ME density from 11.3 to 14.7 MJ/Kg. This suggests that there may be a group size by dietary energy density interaction with ME intake as this relationship is not seen in pigs housed in individual pens.

2.7 Summary

This review has shown that the general theory of how a pig responds to the energy density of the diet is based on the pig manipulating its voluntary intake to maintain a constant daily digestible energy intake. There is variation, however, at the extremes of dietary energy density due to either high fibre levels at the lower energy density or high fat levels at higher energy densities. This theory has been based on observations of pigs generally housed in individual pens. The impact of housing pigs in groups is a reduction in voluntary feed intake. Despite this difference in voluntary feed intake between group and individual housed pigs the concept of constant daily energy intake is considered valid, but has not been tested experimentally.

Chapter 3

EFFECT OF ENERGY DENSITY ON THE PERFORMANCE CHARACTERISTICS OF GROWER PIGS

3.1 INTRODUCTION

The growing trend towards development of greater efficiency in all phases of pig production is vital to the continued profitability of the industry. The nutrition of the pig is no exception to this philosophy and is in a process of continual refinement of dietary specifications to produce the most cost effective result in terms of pig response to intake of nutrients. The most important single nutrient in the diet is the energy level of the diet as this is the major determinant of the cost of the diet and thus the profitability of pig production. The housing of pigs in modern pig production is predominantly in groups ranging from 10 to 1000 pigs per pen. The setting of the optimum energy density of the diet has been related to the least cost per megajoule of digestible energy which is a result of the theory that the pig will adjust intake to ensure a constant daily energy intake. Recent findings by Stein and Easter (1996) suggest that this relationship is not consistent when pigs are housed in group situations. The following experiments were conducted to test the hypothesis that energy intake is associated with an interaction between pigs housed under ideal and commercial (group-housed) conditions and different dietary energy densities.

3.2 METHODS

The investigation of energy density for growing pigs was undertaken in two experiments. The first experiment was undertaken in individual pens. The second experiment was undertaken in group pens under commercial conditions.

3.2.1 Experiment 1 – Individually housed grower pigs

The experiment was designed as a two by six factorial with the factors being sex (male and female) and six dietary energy density (12.5, 13, 13.5, 14.0, 14.5, 15.0 MJ DE/kg) treatments. Eight male and eight female pigs, 9 weeks of age and 30kg±2kg were randomly assigned to each dietary energy treatment. The pigs were a synthetic commercial crossbred genotype and were housed in individual pens measuring 1.5m by 1 m. The composition and calculated analysis of the formulated diets is shown in Table 2. Diets were formulated to the same available lysine to digestible energy ration of 0.69g/MJ. All other amino acids were maintained at a ratio to lysine based on commercial ratios employed by Bunge Meat Industries. Auspig computer modeling was used to confirm diets were adequate in all amino acids for pigs of 30 kg liveweight. All diets were pelleted at a commercial feedmill. The experiment was conducted over a six-week period during August to October at Bunge Meat Industries Ltd research and development facility, Corowa. Each pig was individually weighed at the beginning and the end of the experiment. Feed intake was recorded on a weekly basis but reported on a sectional basis. A real time ultrasound fat depth measurement at the P2 site (located 6 cm from the mid line of the back of the pig adjacent to the last rib) was taken at the start of the experiment and again at the end of the experiment (6 weeks). The pigs were then slaughtered as per normal commercial practices at the Bunge Meat Industries abattoir. Carcass weight was recorded as head on hot standard carcass weights. Fat depth measurements at the P2 site of the carcass were recorded by a Hennesy Chong probe.

3.2.2 Statistical Analysis

The effect of energy density and sex on growth rate, feed conversion efficiency and feed intake for each experimental period was determined using the General Linear Model Univariate procedure of SPSS for windows version 10. Linear and Quadratic effects of energy density on growth rate, feed conversion efficiency and feed intake for each experimental period was determined using the Curve Estimation procedure from SPSS for windows version 10.

Table 2. Composition of the diets A to F in Experiment 1.

RAW MATERIAL		A	B	C	D	E	F
WHEAT	%	5.000	10.000	23.500	30.000	46.067	55.750
BARLEY	%	60.7667	50.650	31.100	22.000	5.000	5.000
LUPIN KERNELS	%	8.000	17.350	25.000	25.000	25.000	25.000
MILLMIX	%	10.000	5.000	5.000	5.000	5.000	
CANOLA MEAL	%	8.000	8.000	8.000	8.000	8.000	
MEATMEAL	%	1.200	0.750	1.433	1.000	1.000	3.000
FISHMEAL	%	3.967	5.750	4.000	5.300	5.400	6.250
TALLOW	%				1.750	2.500	3.250
SALT	%	0.200	0.200	0.200	0.200	0.200	0.200
LIMESTONE	%	1.600	1.300	0.700	0.700	0.700	0.700
PALFOSS	%	0.733	0.700	0.733	0.750	0.733	0.250
LYSINE	%	0.250	0.080	0.113	0.100	0.143	0.260
METHIONINE	%	0.027	0.005	0.034	0.030	0.044	0.065
THREONINE	%	0.087	0.005	0.003		0.060	0.100
PREMIX †	%	0.200	0.200	0.200	0.200	0.200	0.200
CALCULATED ANALYSIS ‡							
DRY MATTER	%	90.08	90.13	90.17	90.31	90.42	90.65
DIGESTIBLE ENERGY	MJ/KG	12.63	13.11	13.61	14.16	14.61	15.13
CRUDE PROTEIN	g/kg	166.10	192.50	205.50	210.00	212.00	206.00
CRUDE FAT	g/kg	34.70	39.20	42.70	60.00	67.30	70.00
CRUDE FIBRE	g/kg	53.00	47.70	43.40	40.60	36.20	24.80
ASH	g/kg	67.10	63.80	57.80	57.10	55.20	50.50
CALCIUM	g/kg	11.80	10.80	9.00	9.10	10.00	9.10
AV.PHOSPHORUS	g/kg	4.00	4.00	4.00	4.10	4.10	4.10
TOTAL PHOSPHORUS	g/kg	6.60	6.40	6.40	6.40	6.40	5.80
LYSINE	g/kg	10.20	10.50	10.90	11.20	11.50	11.80
AVAILABLE LYSINE	g/kg	8.90	9.00	9.30	9.60	9.90	10.30
METHIONINE	g/kg	3.10	3.20	3.40	3.50	3.60	3.60
METH+CYSTEINE	g/kg	6.20	6.60	6.80	7.00	7.10	6.70
THREONINE	g/kg	6.90	7.10	7.40	7.50	7.70	7.90
ISOLEUCINE	g/kg	6.60	8.10	8.70	9.00	9.00	8.60
TRYPTOPHAN	g/kg	2.10	2.40	2.50	2.60	2.60	2.40
AVAILABLE LYSINE/ DIGESTIBLE ENERGY	g/MJ	0.70	0.70	0.68	0.68	0.68	0.68
SALT	g/kg	4.20	4.60	4.20	4.50	4.50	5.00

†provided the following nutrients: vitamin A-7.5miu/kg, vitamin D3-1.5miu/kg, vitamin E-35 mg/kg, Niacin-15mg/kg, Ca-D-Pantothenate-7mg/kg, Riboflavin- 2.2mg/kg, vitamin B12-10000mg/kg, Selenium 0.25mg/kg, copper-180mg/kg, iron-110mg/kg, Manganese-25mg/kg, Zinc-120mg/kg, Iodine-0.2mg/kg.

‡Diet composition calculated on the basis of chemical composition of ingredients from Bunge Meat Industries database.

3.2.3 Experiment 2 – Group housed Grower pigs

The experiment was designed as a three treatment randomized complete block design with three dietary energy densities (13, 14, 15 MJ DE/kg). Two hundred and forty male pigs, 10 weeks of age and 25±3kg liveweight were randomly assigned to each dietary energy treatment (Table 7). Pigs were a synthetic commercial crossbred genotype. The pigs were housed in group pens of 10 animals per pen; each pen measuring 2.5m by 3 m. The composition and calculated analysis of the formulated diets is shown in Table 3. Diets were formulated to the same available lysine to digestible energy ration of 0.71 g/MJ. All other amino acids were maintained at a ratio to lysine based on commercial ratios employed by Bunge Meat Industries. All diets were pelleted at a commercial feedmill. The experiment was carried out over a six-week period during the spring months. Pigs were individually weighed at the beginning of the experiment and at 3 weeks into the experiment and at the end of the experiment. Feed intake was also calculated at these times. A real time ultrasound fat depth measurement at the P2 site (located 6 cm from the mid line of the back of the pig adjacent to the last rib) was taken at the start of the experiment and at 3 weeks and again at the end of the experimental period (6 weeks). The pigs were then given a standard finisher diet for the next 38 days and then slaughtered as per normal commercial practices at the Bunge Meat Industries abattoir. Carcass weight was recorded as head on hot standard carcass weights. Fat depth measurements at the P2 site and on the midline at the shoulder, midline and over the rump (back leg) were recorded by a Hennesy Chong probe.

3.2.4 Statistical Analysis

The effect of energy density on growth rate, feed conversion efficiency and feed intake for each experimental period was determined using the General Linear Model Univariate procedure of SPSS for windows version 10.

Table 3. Composition of the diets A to C in Experiment 2.

RAW MATERIAL		A	B	C
WHEAT	%	7.500	61.767	59.600
BARLEY 10.5%	%	42.933		
LUPIN KERNELS	%	25.000	20.000	20.000
MILLMIX	%	10.000	10.000	
CANOLA MEAL	%	8.400	10.000	4.733
MEATMEAL	%	3.400	4.100	3.333
FISHMEAL	%	1.000		2.767
BLOODMEAL	%		2.467	4.000
TALLOW	%			4.000
SALT	%	0.200	0.200	0.200
LIMESTONE	%	0.433	0.333	0.333
PALFOSS	%	0.700	0.700	0.700
LYSINE	%	0.187	0.167	0.080
METHIONINE	%	0.063	0.073	0.067
PREMIX †	%	0.200	0.200	0.200
CALCULATED ANALYSIS ‡				
DRY MATTER	%	89.46	89.88	90.15
DIGESTIBLE ENERGY	MJ/KG	12.97	13.95	14.97
CRUDE PROTEIN	g/kg	202.8	208.5	216
CRUDE FAT	g/kg	43.8	40.2	75.6
CRUDE FIBRE	g/kg	50.0	33.8	27.3
ASH	g/kg	60.0	52.6	50.6
CALCIUM	g/kg	9.1	9.2	9
AV.PHOSPHORUS	g/kg	4.5	4.5	4.5
TOTAL PHOSPHORUS	g/kg	7.2	6.7	6.4
LYSINE	g/kg	11.0	11.5	12.1
AVAILABLE LYSINE	g/kg	9.1	9.8	10.5
METHIONINE	g/kg	3.3	3.5	3.7
METH+CYSTEINE	g/kg	6.9	7.3	7.3
THREONINE	g/kg	7.4	7.7	8.1
ISOLEUCINE	g/kg	8.3	7.7	7.7
TRYPTOPHAN	g/kg	2.3	2.4	2.5
AV.LYSINE/DE	g/MJ	0.7	0.70	0.7
SALT	g/kg	3.5	3.7	4.6

†provided the following nutrients: vitamin A-7.5miu/kg, vitamin D3-1.5miu/kg, vitamin E-35 mg/kg, Niacin-15mg/kg, Ca-D-Pantothenate-7mg/kg, Riboflavin- 2.2mg/kg, vitamin B12-10000mg/kg, Selenium 0.25mg/kg, copper-180mg/kg, iron-110mg/kg, Manganese-25mg/kg, Zinc-120mg/kg, Iodine-0.2mg/kg.

‡Diet composition calculated on the basis of chemical composition of ingredients from Bunge Meat Industries database.

3.3 RESULTS

3.3.1 Individual housed grower pigs

Table 4 and 5 contain the results of Experiment 1. There was a significant reduction in feed intake as digestible energy density increased. This was change was significant as a linear and quadratic function although the linear function was a better fit. Feed conversion efficiency was similarly linearly improved with increasing digestible energy density. There was no effect on the growth rate of the pigs with increasing digestible energy content of the diet. Daily digestible energy intake was not affected by increasing energy density of the diet.

There was a no significant effect on dressing percentage or P2 backfat with increasing digestible energy density but the inherent variability of this trait would suggest a greater number is required to determine any effect. Males had a significantly higher rate of gain, lower feed intake and lower feed to gain than females.

Table 6 indicates the economic benefit of increasing the digestible energy density of the diet. The subsequent Figures 5 and 6 reveal that increasing the energy density of the diet under ideal conditions linearly increases the cost of the gain despite the higher energy density reducing feed to gain.

Table 4. The response of grower pigs 63-98/105 days (30-70kg) to increasing energy density of the diet (Experiment 1).

Sex	Dietary Energy	Start Wt	Final Wt*	0-6 weeks Daily Gain	Feed:Gain	Intake	Daily DE Intake
	MJ/Kg	(kg)	(kg)	(Kg/d)		(kg/d)	(MJ/d)
Males							
	12.5	30.0	64.1	0.975	2.17	2.11	30.5
	13.0	30.0	64.6	1.007	2.18	2.20	28.4
	13.5	29.9	63.6	0.973	2.27	2.20	28.7
	14.0	30.0	65.3	1.009	2.06	2.07	29.4
	14.5	29.9	65.3	1.011	1.90	1.92	31.2
	15.0	30.0	65.7	1.020	1.95	1.97	31.2
Females							
	12.5	30.2	68.9	0.921	2.65	2.44	26.3
	13.0	30.2	68.3	0.908	2.40	2.18	28.6
	13.5	30.2	65.6	0.842	2.55	2.12	29.8
	14.0	30.1	67.6	0.893	2.36	2.09	28.9
	14.5	30.0	68.3	0.911	2.36	2.15	27.8
	15.0	30.2	67.7	0.893	2.33	2.08	29.5
STATISTICS(P=)							
SEM		0.202	0.430	0.010	0.028	0.023	0.297
Energy		0.681	0.654	0.553	0.000	0.003	0.387
Sex		0.999	0.001	0.000	0.000	0.014	0.014
Sex*Energy		0.999	0.919	0.842	0.191	0.042	0.054
Linear			0.675	0.653	0.000	0.000	0.040
Quadratic			0.618	0.697	0.001	0.000	0.117

*Male pigs were studied for 35 days and females for 42 days

Table 5. The resultant carcass measurements for grower pigs fed diets increasing energy density from 63-98/105 days (30-70kg) (Experiment 1).

Sex	Dietary Energy	Carcass weight	Dressing Percentage	P2
	MJ/Kg	(Kg)	(%)	(mm)
Males				
	12.5	46.0	71.7	10.95
	13.0	46.0	71.2	11.94
	13.5	46.0	72.3	12.28
	14.0	47.1	72.1	11.65
	14.5	44.3	72.5	11.40
	15.0	48.3	73.5	12.00
Females				
	12.5	52.3	76.1	13.35
	13.0	52.5	77.0	11.70
	13.5	49.0	74.9	11.50
	14.0	50.7	75.0	12.30
	14.5	49.5	72.7	12.65
	15.0	52.3	77.3	12.29
STATISTICS(P=)				
SEM		0.42	0.779	0.201
Energy		0.284	0.408	0.995
Sex		0.000	0.239	0.130
Sex*Energy		0.347	0.532	0.258
Linear		0.589	0.129	0.859
Quadratic		0.258	0.271	0.878

Table 6. The cost per kilogram of gain of increasing the energy density of the diet (Experiment 1).

Treatment	Energy level (D.E. MJ/kg)	Cost per kilogram of gain (cents/kg) Males	Females
A	12.5	0.40	0.48
B	13.0	0.42	0.46
C	13.5	0.45	0.51
D	14.0	0.43	0.50
E	14.5	0.42	0.52
F	15.0	0.46	0.55
Statistics (P=)			
SEM		0.036	
Energy		0.000	
Sex		0.000	
Energy*Sex		0.120	
Linear (Energy)		0.009	0.000

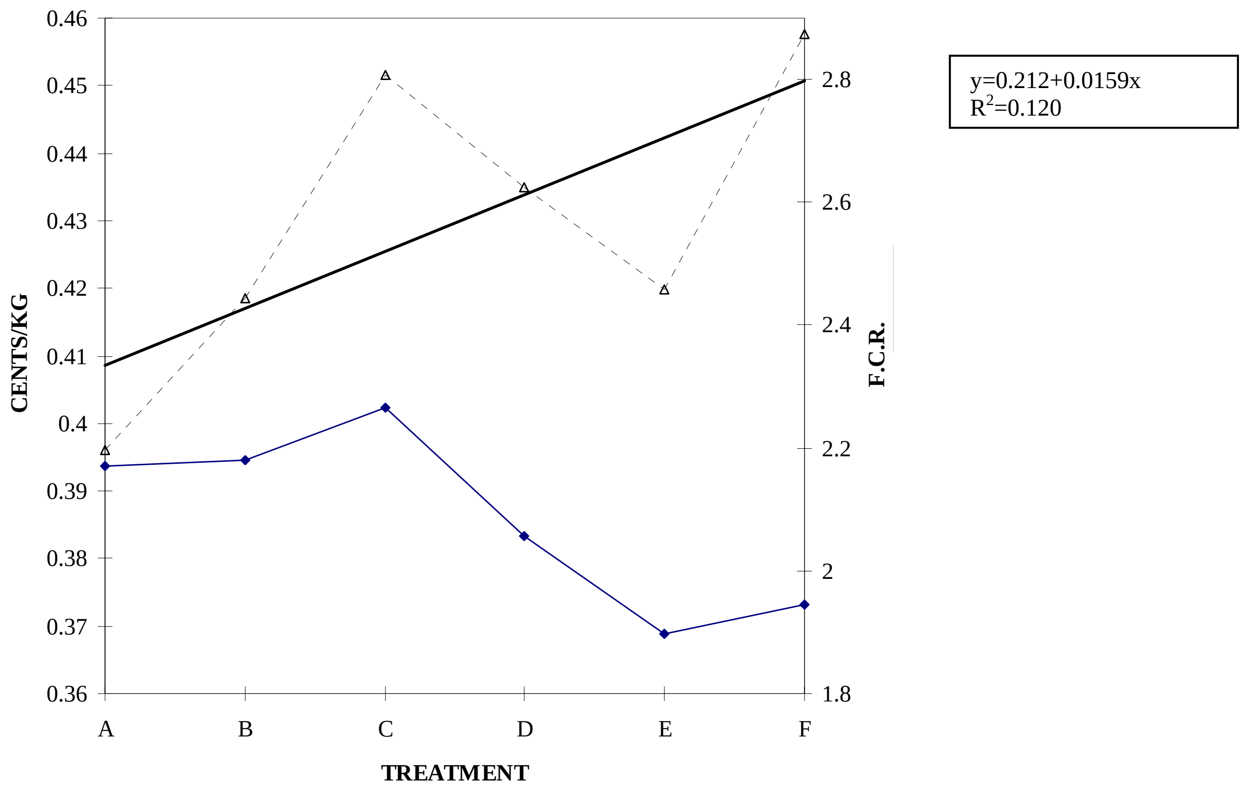


Figure 5. Cost per kg of gain – Males (Experiment 1).

COST PER KG OF GAIN
F.C.R. -Feed:gain
Linear (COST PER KG OF GAIN)

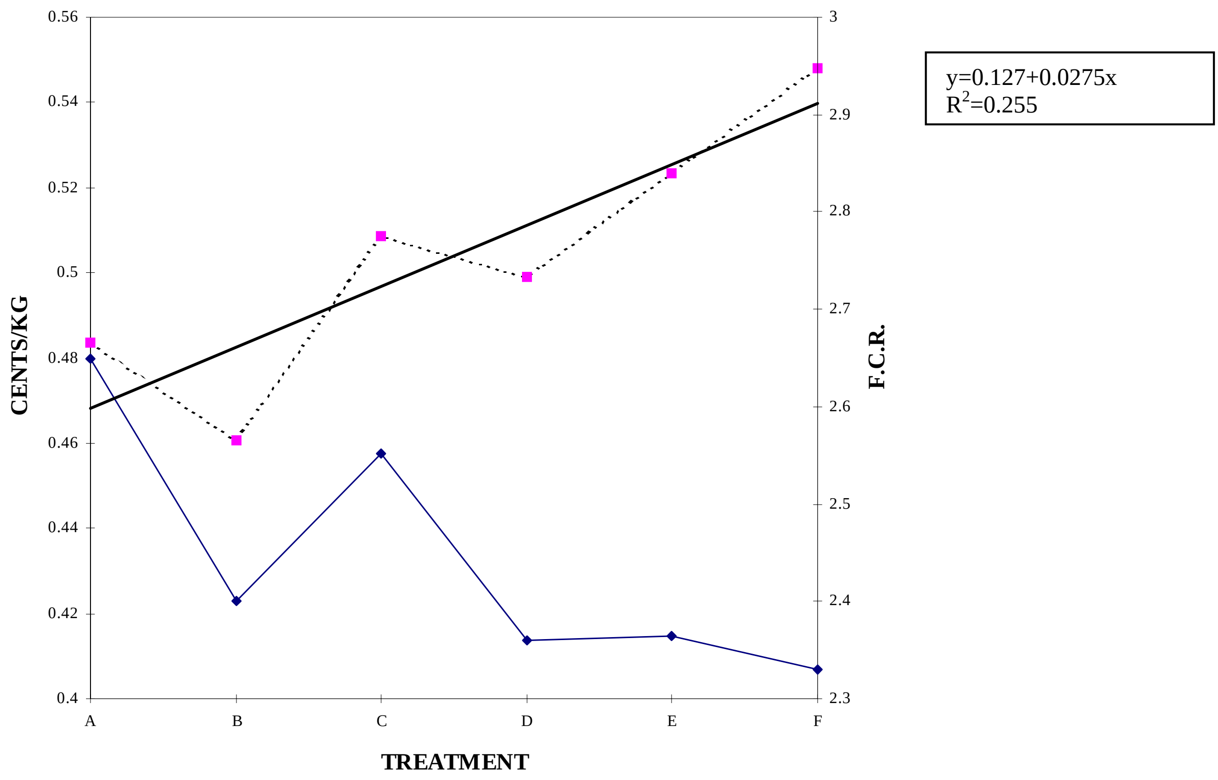


Figure 6. Cost per kg of gain – Females (Experiment 1).

COST PER KG OF GAIN
F.C.R. - FEED:GAIN
Linear (COST PER KG OF GAIN)

3.3.2 Group housed grower pigs

Tables 7 to 11 contain the results of experiment 2. The overall result is presented in Table 7 and shows that increasing the digestible energy density of the diet significantly increased the rate of gain ($p<0.04$) and P2 ($p<0.03$) of pigs 63-105 days of age. Feed to gain ($p<0.04$) and feed intake ($P<0.016$) are significantly reduced with increasing digestible energy density of the diet. The increase in grower performance was not significantly reflected in eventual carcass weight differences, as can be seen in Table 8.

Tables 9 to 11 display the results at two week periods during the grower phase and indicate that the differences in performance were magnified the longer the pigs were exposed to the treatments.

Figure 7 shows that under commercial conditions increasing the energy density of the diet increases the cost of the gain despite the higher dietary energy reducing feed to gain.

Table 7. The growth response of male grower pigs 63-105 days of age (25-65kg) to increasing energy density of the diet and housed under commercial conditions.

Treatment	Energy level (D.E.MJ/kg)	Average start weight (Kg)	Average final weight (Kg)	Rate of Gain (g/day)	Feed: gain	Feed Intake (Kg/d)	P2 (mm)	DE Intake (MJ/d)
A	13	25.44	60.70	0.735	2.28	1.67	7.3	21.7
B	14	25.84	62.16	0.757	2.18	1.65	8.4	23.1
C	15	25.35	63.78	0.800	1.99	1.59	8.7	23.8
SEM		0.339	0.681	0.011	0.039	0.016	0.233	0.317
Significance P=			0.191	0.016	0.001	0.030	0.024	0.004

Table 8. The subsequent finisher performance and carcass response of male pigs fed diet of increasing energy density of the diet during the grower phase and housed under commercial conditions.

Treatment	Energy level (D.E.MJ/kg)	Rate of Gain finisher (g/day)	Carcass weight (Kg)	Dressing Percentage (%)	P2 (mm)
A	13	0.969	70.2	71.7	14.4
B	14	0.939	71.9	73.3	13.8
C	15	0.914	72.4	73.1	14.0
SEM		0.014	0.653	0.437	0.253
Significance P=		0.272	0.367	0.273	0.290

Table 9. The growth response of male grower pigs 63-77 days of age (25-35kg) to increasing energy density of the diet and housed under commercial conditions.

Treatment	Energy level (D.E. MJ/kg)	Rate of Gain (g/day)	Feed:gain	Feed Intake (Kg/d)	DE Intake (MJ/d)
A	13	0.659	1.90	1.253	16.3
B	14	0.660	1.88	1.242	17.4
C	15	0.692	1.75	1.210	18.2
SEM		0.009	0.024	0.013	0.286
Significance P=		0.220	0.001	0.409	0.012

Table 10. The growth response of male grower pigs 77-91 days of age (35-46kg) to increasing energy density of the diet and housed under commercial conditions.

Treatment	Energy level (D.E. MJ/kg)	Rate of Gain (g/day)	Feed:gain	Feed Intake (Kg/d)	DE Intake (MJ/d)
A	13	0.774	2.12	1.640	21.3
B	14	0.804	1.96	1.572	22.0
C	15	0.844	1.85	1.562	23.4
SEM		0.017	0.038	0.024	0.398
Significance P=		0.264	0.001	0.363	0.073

Table 11. The response of Male grower pigs 91-105 days of age (46-65kg) to increasing energy density of the diet housed under commercial conditions.

Treatment	Energy level (D.E. MJ/kg)	Rate of Gain (g/day)	Feed:gain	Feed Intake (Kg/d)	DE Intake (MJ/d)
A	13	0.760	2.60	1.970	25.6
B	14	0.792	2.52	1.992	27.9
C	15	0.846	2.24	1.885	28.3
SEM		0.019	0.060	0.021	0.413
Significance P=		0.171	0.013	0.063	0.002

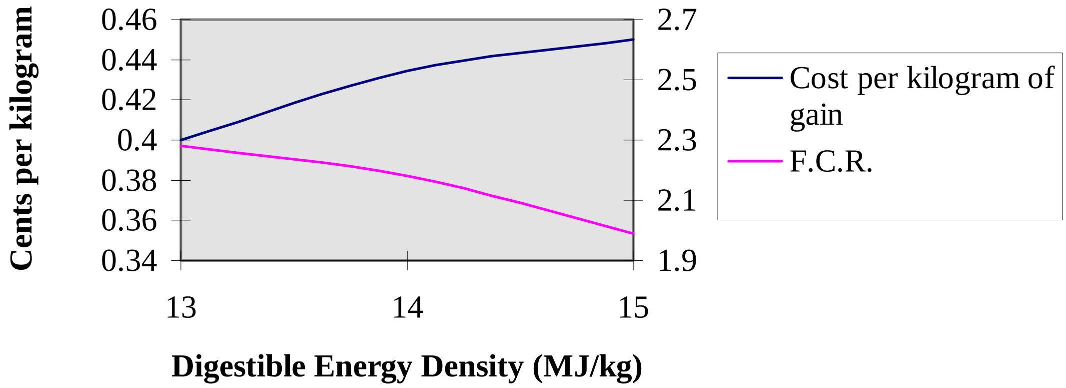


Figure 7. Cost per kg of gain under commercial conditions.

3.4 DISCUSSION

The results of Experiment 1 show that regardless of the digestible energy density of the diet, pigs grown under ideal conditions did not show any significant increase in daily liveweight gain or carcass weight. Since this effect was totally related to feed intake it is obvious that the pig will adjust its feed intake to meet a total energy demand under ideal growing conditions. This energy demand for the pigs under ideal conditions was approximately 29 MJ/day and supported expected maximal growth rate regardless of energy density.

There was a trend towards increasing dressing percentage of the pigs as energy density of the diet increased. This is likely a result of a decrease in the volume of the gastrointestinal tract due to the lower volumes of feed passing through the tract.

The cost effectiveness of increasing the energy density of the diet and reducing the feed to gain was explored in the graphical representation of the cost per kilogram of gain. The results show that the increase in the cost of the diets is greater than the savings made from the decrease in feed to gain as the energy density of the diet increases.

The results of experiment two show that under commercial conditions increasing the digestible energy density of the diet will increase the growth rate of male pigs over the growing period from 25-65kg. The increase in growth rate during the growing period was not significantly carried through to final carcass weight although there was a trend towards a heavier carcass weight. Thus the pig may compensate in the finisher period for the difference in growth rate during the grower period.

Feed to gain and feed intake reduced significantly with increasing energy density of the diet. Carcass fat was increased with increasing energy density. This result indicates that as the energy intake of the male pigs tended to increases from 21 MJ/day to 23 MJ/day with increasing energy density a proportion of the energy is diverted to fat reserves. Thus not all energy is invested in muscle synthesis. This is due to the pigs increasing fat deposition as they move towards maximum energy intake.

There was a significant decrease in feed to gain in the three phases of the grower period. Rate of gain, while not significant in any phase of the grower period, showed a trend of increasing with increasing energy density and also showed a trend of an increasing difference between each treatment at each phase.

On a feed to gain basis there would be no economical advantage of increasing energy density but if the increase in growth rate was maintained with possibly a higher energy finisher ration then on a carcase basis there maybe an economical advantage of increasing energy density.

Conclusion

The conclusion from these two experiments is that pigs under ideal conditions do not show a response to increasing the energy density of the diet and will adjust their feed intake to meet their energy demands to achieve maximal protein and fat deposition. Pigs under commercial conditions, however, had levels of performance 75-80% below that of pigs under ideal conditions. This was directly attributed to their reduction of feed intake as feed efficiency in both experiments were similar. On the lowest energy density feed intake was restricted to 75% of that of pigs in ideal conditions on the same energy density and was greater than that experienced on the other two treatments of 80% of maximal intake. This can be seen graphically in figure 8. A pig under commercial conditions is reduced in its capacity to respond to reductions in energy density of the diet below 14 MJ/kg due to social or environmental constraints that affect feed intake.

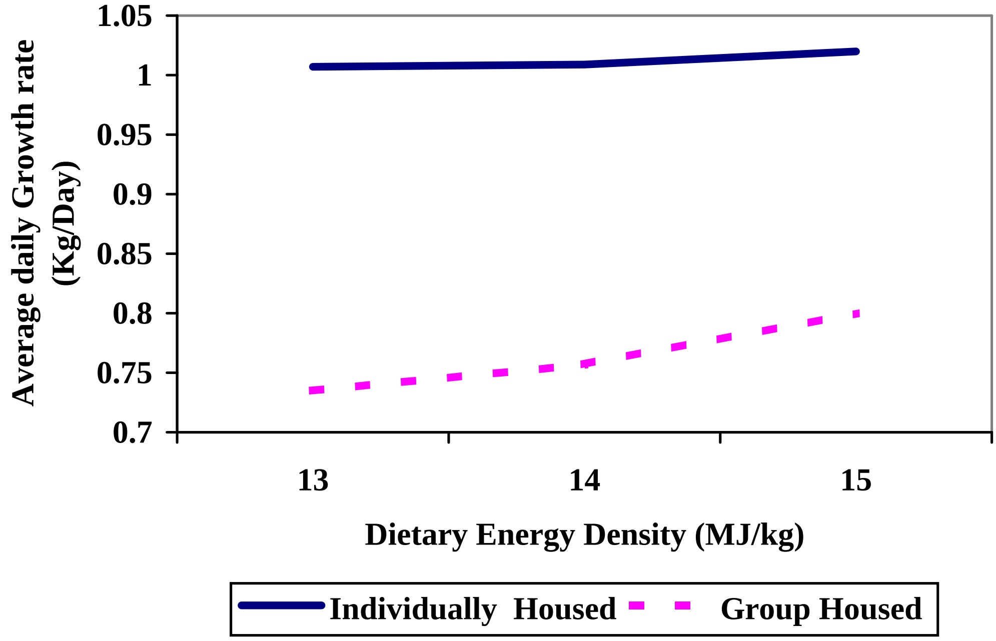


Figure 8: The effect of housing type (group or individual) on pigs' growth rate over the grower phase of production (30-70kg liveweight).

C h a p t e r 4

EFFECT OF ENERGY DENSITY ON THE PERFORMANCE CHARACTERISTICS OF FINISHER PIGS.

4.1 Introduction

Optimal nutritional management of the "finisher" pig is constrained by lack of quantitative information on the response of animals between 65 and 110 kg live weight to dietary energy content. Under "ideal" conditions modern genotypes appear to adjust feed intake to maintain a constant DE intake over a much wider range of dietary energy concentrations than previously thought (Mullan et al, 1998). However, under commercial pen conditions, voluntary feed intake is lower, pigs respond in terms of both growth rate and feed conversion to dietary DE density considerably above the levels currently thought to maximise biological and economic responses. Chapter three of this thesis highlighted that in grower pigs (30-70kg) individually housed pigs maintained a constant daily digestible energy intake whereas in group housed pigs increasing digestible energy density increased daily digestible energy intake and thus growth rate. The present study was designed to provide information on the response of finisher pigs to dietary energy content under ideal and commercial housing conditions.

4.2 METHODS

4.2.1 Experiment 3 – Individual finisher pigs

The experiment was designed as a two by five factorial with the factors being sex (male and female) and energy density (12, 12.8, 13.6, 14.4, 15.2 MJ DE/kg). Eight male and eight female pigs, 16 weeks of age, were randomly assigned to each dietary energy treatment. Pigs were a commercial crossbred genotype. The pigs were housed in individual pens measuring 1.5m by 1 m. Two basal diets were formulated to contain the high and low energy density diets. The composition of the basal diets is shown in Table 12. The low energy density basal diet contained 12.0 MJ DE/kg whereas the high energy density basal diet contained 15.2MJ DE/kg. The two basal diets were then combined in the ratio of 3:1, 1:1 and 1:3 to obtain the dietary treatments of 12.8, 13.6 and 14.4 MJ DE/kg respectively. The experiment was conducted over a six-week period during the spring months. Pigs were individually weighed at the beginning of the experiment, 3 weeks into the experiment and at the end of the experiment. Feed intake was recorded daily although only reported at 3 and 6 weeks of the experiment. A real time ultrasound fat depth measurement at the P2 site (located 6 cm from the back line of the pig adjacent to the last rib) was taken at the start of the experiment, at 3 weeks and again at the end of the experiment (6 weeks). The pigs were then slaughtered as per normal commercial practices at the Bunge Meat Industries abattoir. Carcass weight was recorded as head on hot standard carcass weights. Fat depth measurements at the P2 site and on the midline at the shoulder, midline and over the rump (back leg) were recorded by a Hennesy Chong probe.

Table 12. Composition of the basal diets A and B (Experiment 3).

RAW MATERIAL		Base A			Base B
		% Inclusion			% Inclusion
BARLEY	%	72.366		WHEAT	66.210
MILLMIX	%	10.000		GROATS	15.000
CANOLA MEAL	%	14.133		MEATMEAL	8.733
WATER	%	1.000		FISHMEAL	1.567
SALT	%	0.200		BLOODMEAL	3.000
LIMESTONE	%	1.167		WATER	1.000
PALFOSS	%	0.700		TALLOW-MIXER	4.000
DICALCIUM PHOSPHATE	%	0.100		SALT	0.200
LYSINE	%	0.134		LYSINE-HCL	0.063
PREMIX†	%	0.200		THREONINE	0.027
	%			PREMIX†	0.200
CALCULATED ANALYSIS ‡					
DRY MATTER	%	89.48			89.65
DIGESTIBLE ENERGY	MJ/KG	12.01			15.20
CRUDE PROTEIN	g/kg	139.10			174.30
CRUDE FAT	g/kg	22.00			76.60
CRUDE FIBRE	g/kg	65.00			21.30
ASH	g/kg	56.20			40.20
CALCIUM	g/kg	8.18			8.02
AV.PHOSPHOROUS	g/kg	3.01			4.76
TOTAL PHOS.	g/kg	5.73			6.40
LYSINE	g/kg	7.42			9.14
AVAILABLE LYSINE	g/kg	6.25			7.92
METHIONINE	g/kg	2.41			2.80
METH+CYSTEINE	g/kg	5.63			6.12
THREONINE	g/kg	5.19			6.40
ISOLEUCINE	g/kg	5.20			5.21
TRYPTOPHAN	g/kg	1.79			1.82
AV.LYSINE/DE	g/MJ	0.52			0.52
SALT	g/kg	2.86			4.72

†provided the following nutrients: vitamin A-5miu/kg, vitamin D3-1miu/kg, vitamin E-25 mg/kg, Niacin-10mg/kg, Ca-D-Pantothenate-5mg/kg, Riboflavin- 1mg/kg, Selenium-0.15mg/kg, copper-180mg/kg, iron-80mg/kg, Manganese-10mg/kg, Zinc-100mg/kg, Iodine-0.2mg/kg.

‡Diet composition calculated on the basis of chemical composition of ingredients from Bunge Meat Industries database.

4.2.2 Experiment 4 – Group housed finisher pigs

The experiment was designed as a two by five factorial with the factors being sex (male and female) and energy density (12, 12.8, 13.6, 14.4, 15.2 MJ DE/kg). Two hundred and fifty male and two hundred and fifty female pigs of 16 weeks of age were randomly assigned to each dietary energy treatment. Pigs were a commercial crossbred genotype. The pigs were housed in group pens of ten animals per pen each pen measuring 2.5m by 3 m. There were five pens allocated to each of the ten treatments. Two basal diets were formulated to contain the high and low energy density diets. The composition of the basal diets is shown in Table 12. The low energy density basal diet contained 12.0 MJ DE/kg whereas the high energy density basal diet contained 15.2MJ DE/kg. The two basal diets were then combined in the ratio of 3:1, 1:1 and 1:3 to obtain the dietary treatments of 12.8, 13.6 and 14.4 MJ DE/kg respectively. The experiment was carried out over a six-week period during the spring months. Five pigs per pen were randomly selected and individually weighed at the beginning of the experiment, at 3 weeks into the experiment and at the end of the experiment. A real time ultrasound fat depth measurement at the P2 site (located 6 cm from the back line of the pig adjacent to the last rib) was taken on the selected pigs at the start of the experiment, 3 weeks and again at the end of the experiment (6 weeks). All pigs were then slaughtered as per normal commercial practices at the Bunge Meat Industries abattoir. Carcass weight was recorded as head on hot standard carcass weights. Fat depth measurements at the P2 site and on the midline at the shoulder, midline and over the rump (back leg) were recorded by a Hennesy Chong probe.

4.3 RESULTS

4.3.1 Experiment 3

The results in Table 13 show the effect of the energy density on the growth performance of pigs from 65 kilograms for the next 3 and 6 weeks housed in individual accommodation. There was a significant linear decrease in feed:gain in the 0-3 week period and also over the entire 6 week period with increasing energy density of the diet. There was a non-significant trend towards increasing growth rate with increasing energy density of the diet. There was also a non-significant trend towards decreased feed intake with increasing energy density of the diet. Liveweight at 3 weeks and at 6 weeks increased with increasing energy density but was not significant. Female pigs ate significantly less than males in the 3-6 week period.

The increase in feed:gain in males on the 15.2 MJ diet as compared to the 14.4 MJ diet is probably an artifact of the experiment due to high wastage factor associated with this diet which may also have limited actual intake of feed and thus growth rate.

Figures 9 and 10 show graphically the effect of energy density on growth rate and feed conversion for each time period for each sex respectively.

The ultrasound measurements of P2 on the live animal (Table 14) showed a significant linear increase in P2 in females with increasing dietary energy density with no effect in the males for the first 21 days. The 42 day results indicated that while not significant there was a non-significant trend to increasing P2 with increasing dietary energy density in both sexes. The change in P2 was greatest in the higher dietary energy diets (14.4 and 15.2 MJ DE/kg).

The slaughter results shown in Table 15 indicate there was a significant increase in carcass weight with increasing energy density of the diet to 13.6 MJ/kg for male pigs. There was trend to increasing carcass weight in the female pigs but was not significant. Female pigs had a significantly higher dressing percentage than male pigs. Dietary energy density had no significant effect on dressing percentage although there was a trend towards increasing dressing percentage as dietary energy density increased.

The measurements of fat depth at several sites on the carcass indicate that there was no significant effect of energy density on fat deposition. There was some significant interactions in the shoulder and leg fat depth measurements between sex and energy density of the with the females but not males showing increased fat deposition with increased energy density of the diet.

The significant increases in P2 ($P<0.05$) change over the 6 week period of the experiment indicate that while feed efficiency in gross terms of feed to gain of the animals is improving the efficiency in terms of energy utilisation for lean deposition it is diminishing (Table 16).

In general the lowest cost per unit of gain is seen when the cost of the feed is lowest (dietary energy density is lowest) and feed:gain is the highest. The cost of feed for the purposes of this experiment is considered a linear relationship between the lowest and highest dietary energy densities and only raw material cost is used as a cost of feed as all other costs are considered fixed.

Figure 11 indicates the relationship between digestible energy intake and growth rate, which is linear over the entire range of digestible energy intakes for both male and females. The difference between males and females indicates that males tend to grow about 35 grams per day faster than females but respond in exactly the same manner in terms of increasing digestible energy intake.

Table 13. **Effects of energy density and sex on the growth performance of pigs offered feed ad libitum for 21 and 42 days from 65 kg liveweight (Experiment 3)**

Sex	Dietary Energy	Start Wt	21 day Wt	42 day Wt	0-6 weeks Daily Gain	0-6 weeks Feed:Gain	0-6 weeks Intake	0-3 weeks Daily Gain	0-3 weeks Feed:Gain	0-3 weeks Intake	3-6 weeks Daily Gain	3-6 weeks Feed:Gain	3-6 weeks Intake
	MJ/Kg	(kg)	(kg)	(kg)	(Kg/d)		(kg/d)	(Kg/d)		(kg/d)	(Kg/d)		(kg/d)
Males													
	12.0	65.10	79.5	97.8	0.780	3.034	2.357	0.687	3.171	2.045	0.873	3.154	2.668
	12.8	65.65	82.0	100.3	0.825	2.925	2.384	0.780	2.781	2.123	0.870	3.112	2.645
	13.6	65.13	82.7	103.1	0.905	2.644	2.350	0.839	2.602	1.988	0.971	2.831	2.711
	14.4	65.08	83.2	103.4	0.914	2.597	2.352	0.864	2.414	2.066	0.963	2.763	2.638
	15.2	65.25	81.3	99.9	0.825	2.674	2.176	0.763	2.503	1.883	0.887	2.920	2.468
Females													
	12.0	66.09	80.7	96.7	0.729	3.112	2.266	0.698	3.017	2.093	0.759	3.238	2.440
	12.8	65.38	81.4	98.6	0.790	2.747	2.147	0.765	2.620	1.959	0.815	2.966	2.335
	13.6	65.45	80.6	96.9	0.748	2.979	2.223	0.724	2.903	2.052	0.773	3.102	2.393
	14.4	65.38	80.5	99.2	0.806	2.771	2.166	0.723	2.758	1.958	0.889	2.817	2.374
	15.2	65.38	81.9	100.7	0.842	2.526	2.112	0.788	2.459	1.925	0.895	2.600	2.298
STATISTICS(P=)													
	SEM	0.316	0.578	0.797	0.016	0.378	0.032	0.021	0.055	0.034	0.020	0.059	0.038
	Energy	0.996	0.561	0.606	0.285	0.000	0.529	0.561	0.001	0.659	0.414	0.135	0.562
	Sex	0.664	0.239	0.123	0.032	0.417	0.232	0.239	0.548	0.660	0.026	0.928	0.000
	sex*energy	0.985	0.624	0.666	0.448	0.080	0.929	0.624	0.337	0.807	0.518	0.566	0.967
	Linear (E)				0.025	0.000	0.026	0.252	0.002	0.329	0.023	0.029	0.024

Table 14. Effects of energy density of the diet and sex on ultrasound P2 of pigs offered feed ad libitum for 21 and 42 days from 65 kg liveweight (Experiment 3).

	Energy Density (MJ/kg)	P2 - Start (mm)	21 day P2 (mm)	42 day P2 (mm)	P2 change 0-42 days (mm)
Males					
	12.0	8.88	10.25	12.00	3.13
	12.8	9.25	9.88	13.00	3.75
	13.6	8.13	10.38	11.75	3.63
	14.4	8.75	10.13	14.50	5.75
	15.2	8.25	11.25	13.25	5.00
Females					
	12.0	10.00	10.00	12.00	2.00
	12.8	8.38	9.25	10.38	2.00
	13.6	10.88	14.13	14.38	3.50
	14.4	9.63	12.00	13.75	4.13
	15.2	9.38	11.88	14.38	5.00
STATISTICS (P=)					
SEM		0.231	0.282	0.361	0.330
Energy		0.790	0.009	0.117	0.045
Sex		0.031	0.036	0.947	0.149
Energy*Sex		0.177	0.051	0.192	0.852
Linear		0.060	0.015	0.057	0.003

Table 15. Effects of energy density of the diet and sex on slaughter characteristics of pigs offered feed ad libitum for 42 days from 65 kg liveweight (Experiment 3).

Energy Density (MJ/kg)	HSCW (kg)	DRS% %	HC_P2 (mm)	SHLDR (mm)	MID (mm)	LEG (mm)
Males						
12.0	75.05	76.68	12.35	30.4	15.3	16.9
12.8	77.58	77.33	12.50	31.8	17.0	19.9
13.6	85.35	83.24	11.65	31.0	16.5	18.3
14.4	81.29	78.17	13.11	35.0	17.7	23.4
15.2	77.40	76.45	12.29	30.0	15.3	18.0
Females						
12.0	77.54	80.21	12.23	32.1	17.6	21.0
12.8	80.08	81.13	13.20	29.8	16.6	18.4
13.6	78.23	80.77	14.40	35.3	19.4	24.9
14.4	80.85	81.61	12.85	29.3	19.0	22.3
15.2	82.00	81.42	10.65	34.0	18.0	22.6
STATISTICS(P=)		*	*			
SEM	0.730	0.005	0.315	0.520	2.236	0.550
Energy	0.035	0.142	0.475	0.456	0.347	0.058
Sex	0.797	0.006	0.663	0.660	0.186	0.012
Energy*Sex	0.019	0.104	0.282	0.004	0.384	0.034
Linear (E)	0.187	0.588	0.670	0.646	0.396	0.012

HSCW- Hot standard carcass weight, DRS% - Dressing Percentage, HC P2 - Hennessy Chong P2, SHLDR - Shoulder Fat Depth, MID - Midline Fat Depth ,
LEG - Fat Depth on The Hind Leg
* HSCW was used as a covariant for dressing percentage and HC P2 statistics

Table 16. Effects of dietary energy density and sex on daily digestible energy intake, energy utilisation (digestible energy per kilogram of liveweight gain MJ/KG) and cost per unit of gain ($/Kg)

	Dietary	Daily Digestible Energy Intake (MJ/day)			Energy Utilisation (MJ/kg gain)			Cost per Kg gain ($/kg gain)		
Sex	**Energy**	**0-6 weeks**	**0-3 weeks**	**3-6 weeks**	**0-6 weeks**	**0-3 weeks**	**3-6 weeks**	**0-6 weeks**	**0-3 weeks**	**3-6 weeks**
Males										
	12	28.28	24.54	32.02	36.37	35.73	36.70	0.543	0.535	0.549
	12.8	30.52	27.18	33.85	36.99	34.86	38.90	0.590	0.556	0.621
	13.6	31.96	27.04	36.88	35.30	32.22	37.96	0.595	0.542	0.639
	14.4	33.87	29.75	37.99	37.07	34.42	39.44	0.653	0.606	0.695
	15.2	33.07	28.63	37.51	40.08	37.51	42.30	0.734	0.687	0.774
Females										
	12	27.20	25.11	29.28	37.33	35.98	38.57	0.558	0.539	0.577
	12.8	27.48	25.08	29.88	34.76	32.76	36.65	0.555	0.523	0.585
	13.6	30.23	27.91	32.55	40.40	38.56	42.13	0.680	0.649	0.709
	14.4	31.19	28.20	34.18	38.70	39.02	38.44	0.682	0.687	0.677
	15.2	32.10	29.27	34.93	38.14	37.13	39.02	0.698	0.680	0.715
STATISTICS(P=)										
SEM		0.485	0.504	0.504	0.423	0.430	0.754	0.011	0.011	0.014
Energy		0.002	0.035	0.001	0.177	0.567	0.653	0.000	0.000	0.000
Sex		0.034	0.748	0.001	0.454	0.504	0.874	0.518	0.538	0.815
Energy*Sex		0.924	0.799	0.971	0.088	0.284	0.519	0.075	0.329	0.454
Linear (E)		0.000	0.002	0.000	0.024	0.421	0.131	0.000	0.005	0.002

Figure 9: Effect of dietary energy density of the feed on growth performance of male pigs housed individually (Experiment 3)

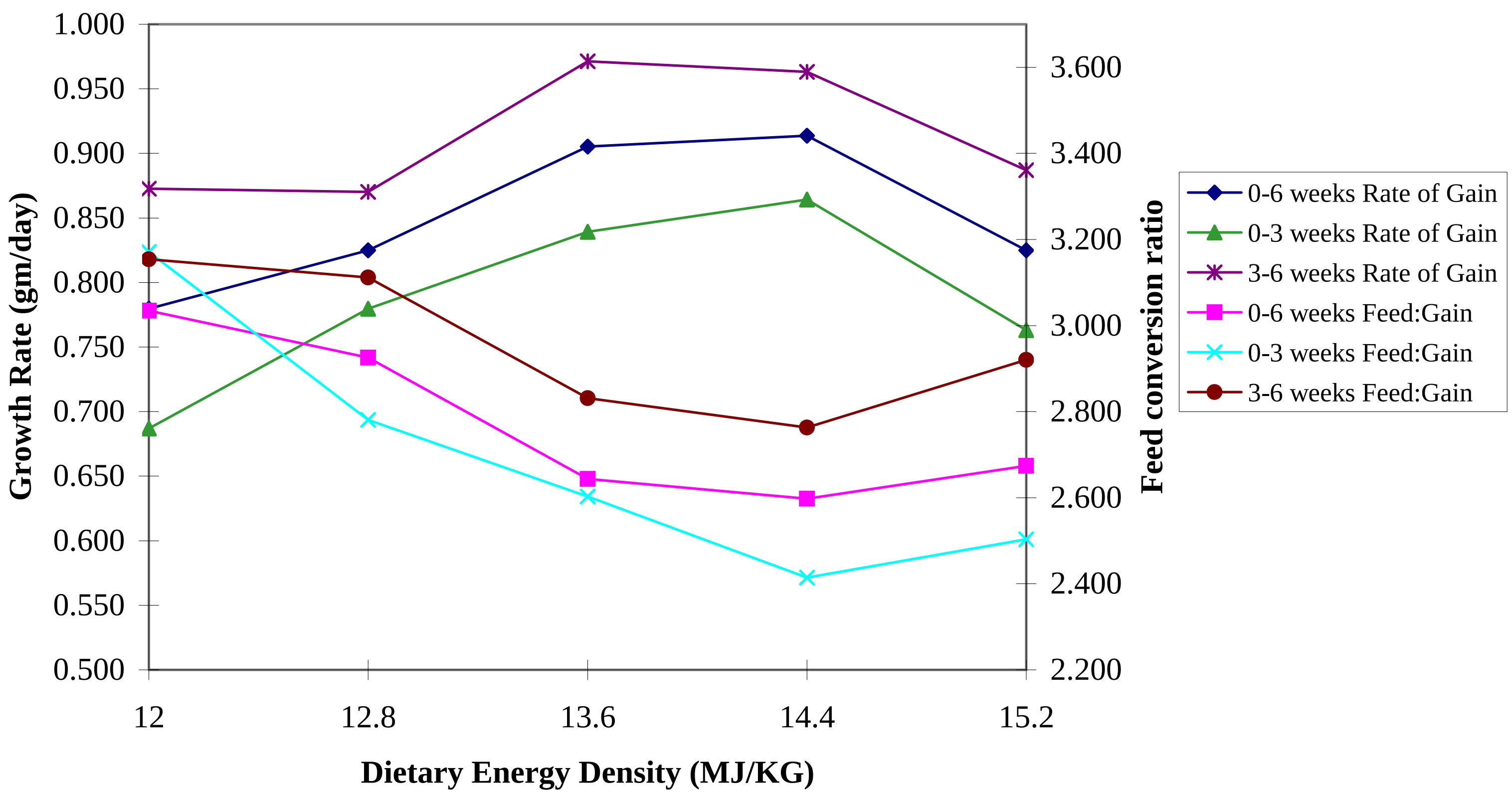


Figure 10: Effect of dietary energy density of the feed on growth performance of female pigs housed individually (Experiment 3)

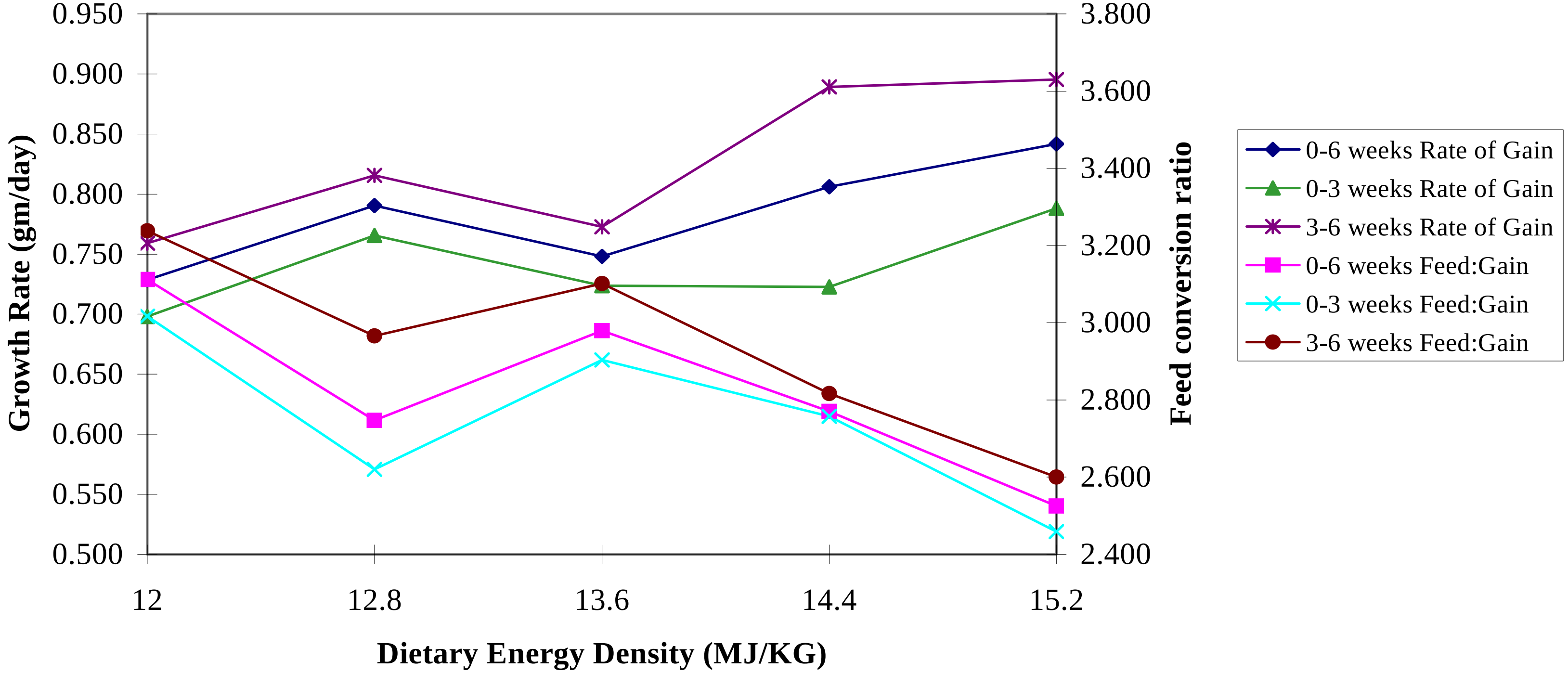
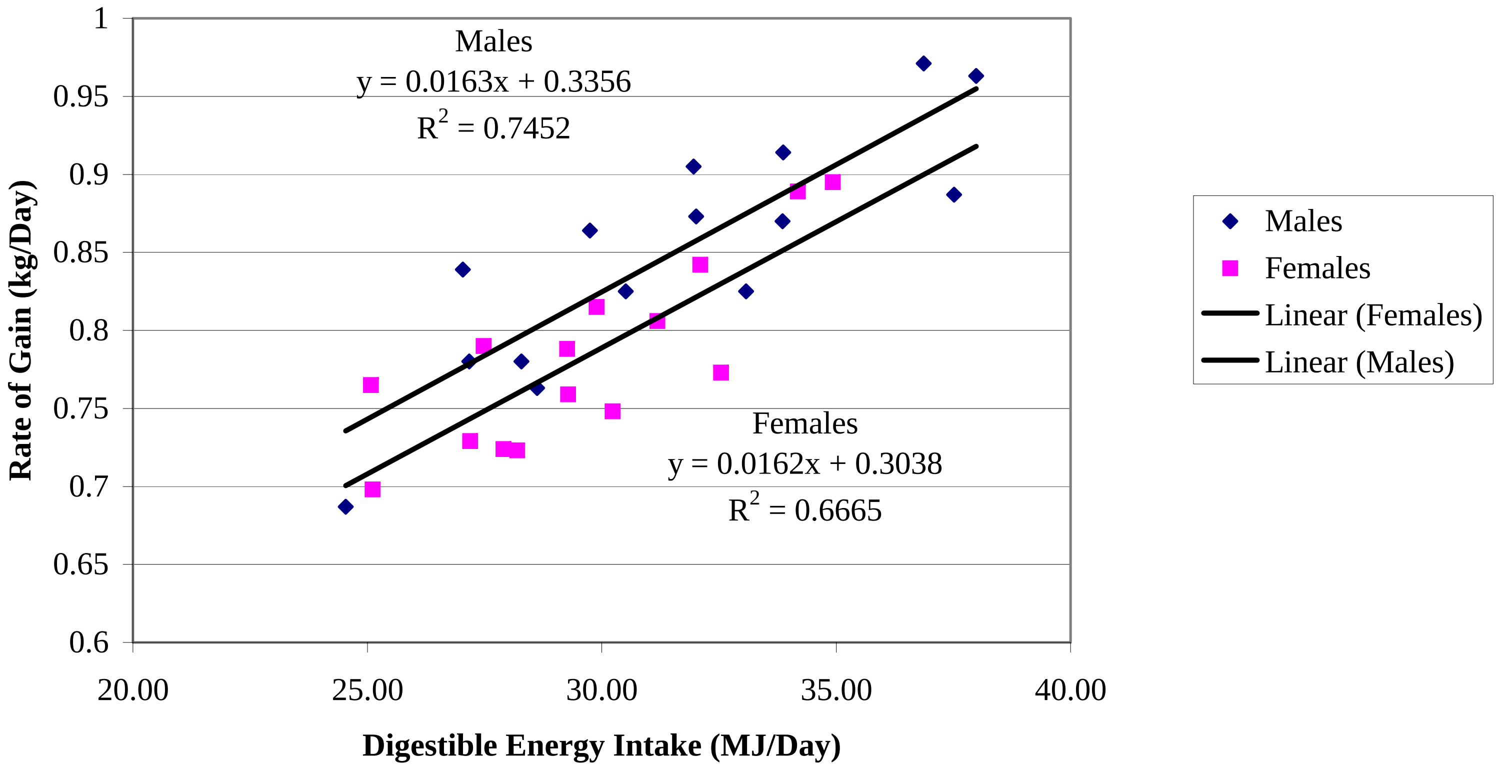


Figure 11: Effect of digestible energy intake per day on growth rate in individually housed pigs from 65-100kg (Experiment 3)



4.3.2 Experiment 4

The results for pigs housed commercially in group pens are given in Tables 17-19. There was a significant ($p<0.001$) linear increase in growth rate with increasing energy density of the diet in all growth periods resulting in a linear increase in 42 day weight with increasing energy density of the diet. There was a significant ($p<0.001$) linear reduction in feed conversion ratio with increasing energy density for the 3-6 week period and over the total finisher period. This is represented graphically for males in Figure 12 and for females in Figure 13. Male pigs had a significantly lower feed to gain than females. Feed intake was unaffected by energy density of the diet or by sex of the animal.

The carcass results are shown in Table 20 and graphically in Figure 14. The energy density of the diet significantly ($p<0.001$) increased the final carcass weight. The fat thickness measurements and dressing percentage results show a significant linear increase with increasing energy density, however when carcass weight is taken as a covariate there is no significant effect of dietary energy density on these measurements with the exception of shoulder fat depth ($p<0.05$). Male pigs had a significantly lower dressing percentage and fat depth at all sites.

Table 21 shows the growth performance, ultrasound fat measurements and carcass results measured on 25 individuals per treatment group. There was a significant linear increase in final weight and carcass weight with increasing dietary energy density. There was a significant linear increase in ultrasound P2 with increasing energy density although this effect was dependant on the method of measurement of carcass P2, use of the Hennessy Chong method produced higher carcass fat thicknesses resulting in the conclusion that the carcass fat in females was higher than in males. Similar effects were also observed when measurements were made in other fat depots. Dressing percentage showed a highly significant linear increase with increasing energy density; males having a significantly lower dressing percentage than females.

Table 22 shows the effect of increasing dietary energy density on the utilisation of dietary energy. Males had a better efficiency of energy utilisation than females and the trend seen in individual pigs of increasing inefficiency was not as evident for group housed pigs. Similarly to pigs in the individual housed study the lowest cost per unit of gain is seen when the cost of the feed is lowest (dietary energy density is lowest) and efficiency of energy utilisation is the highest.

Figure 15 indicates the relationship between digestible energy intake and growth rate for group-housed pigs that is linear over the entire range of digestible energy intakes for both male and females. The difference between males and females indicates that males tend to grow faster than females and increases with increasing digestible energy intake. This indicates that the male has a greater capacity for increased growth rate at weights between 60 and 100 kgs.

Table 17. Effects of dietary energy density and sex on growth performance of pigs offered feed ad libitum for 42 days from 65 kg liveweight housed in group pens (Experiment 4).

Sex	Dietary Energy	Start Wt	21 day Wt	42 day Wt	0-6 weeks Daily Gain	Feed:Gain	Intake	DE Intake
	MJ/Kg	(kg)	(kg)	(kg)	(Kg/d)		(kg/d)	(MJ/d)
Males								
	12.0	62.1	80.2	95.3	0.824	2.989	2.456	29.5
	12.8	62.2	82.8	99.4	0.926	2.767	2.564	32.8
	13.6	62.0	82.3	101.3	0.982	2.634	2.581	35.1
	14.4	62.4	85.7	102.7	1.002	2.481	2.484	35.8
	15.2	62.0	83.8	102.0	0.995	2.456	2.436	37.0
Females								
	12.0	64.1	83.6	96.9	0.806	3.161	2.535	30.4
	12.8	64.2	83.0	97.7	0.826	3.068	2.525	32.3
	13.6	64.0	84.6	100.3	0.889	2.921	2.601	35.4
	14.4	64.1	85.3	101.0	0.902	2.826	2.537	36.5
	15.2	64.2	86.0	101.3	0.909	2.725	2.471	37.6
STATISTICS (P=)								
SEM		0.325	0.770	0.588	0.014	0.039	0.026	0.506
Energy		0.999	0.628	0.002	0.001	0.000	0.597	0.000
Sex		0.004	0.645	0.051	0.013	0.000	0.511	0.587
Energy*Sex		0.999	0.938	0.821	0.740	0.838	0.971	0.974
Linear (E)			0.117	0.000	0.000	0.000	0.524	0.000
Quadratic (E)			0.285	0.000	0.000	0.000	0.241	0.000

Table 18. Effects of dietary energy density and sex on growth performance of pigs offered feed ad libitum for 21 days from 65 kg liveweight housed in group pens (Experiment 4)

Sex	Dietary Energy	Start Wt	21 day Wt	0-3 weeks Daily Gain	Feed:Gain	Intake	DE Intake
	MJ/Kg	(kg)	(kg)	(Kg/d)		(kg/d)	(MJ/d)
Males							
	12.0	62.1	80.2	0.790	2.925	2.311	27.7
	12.8	62.2	82.8	0.895	2.703	2.421	31.0
	13.6	62.0	82.3	0.951	2.547	2.423	32.9
	14.4	62.4	85.7	1.006	2.369	2.375	34.2
	15.2	62.0	83.8	0.953	2.449	2.324	35.3
Females							
	12.0	64.1	83.6	0.785	2.955	2.298	27.6
	12.8	64.2	83.0	0.819	2.902	2.371	30.3
	13.6	64.0	84.6	0.901	2.642	2.380	32.4
	14.4	64.1	85.3	0.928	2.625	2.408	34.7
	15.2	64.2	86.0	0.888	2.610	2.310	35.1
STATISTICS(P=)							
SEM		0.325	0.770	0.016	0.038	0.031	0.564
Energy		0.999	0.628	0.002	0.111	0.808	0.000
Sex		0.004	0.645	0.099	0.012	0.895	0.805
Energy*Sex		0.999	0.938	0.917	0.777	0.996	0.995
Linear (E)			0.117	0.000	0.000	0.931	0.000
Quadratic (E)			0.285	0.000	0.000	0.413	0.000

Table 19. Effects of dietary energy density and sex on growth performance of pigs offered feed ad libitum for 21 days from 80 kg liveweight housed in group pens (Experiment 4)

Sex	Dietary Energy	21 day Wt	42 day Wt	3-6 weeks Daily Gain	Feed:Gain	Intake	DE Intake
	MJ/Kg	(kg)	(kg)	(Kg/d)		(kg/d)	(MJ/d)
Males							
	12	80.2	95.3	0.861	3.045	2.601	31.2
	12.8	82.8	99.4	0.956	2.889	2.756	35.3
	13.6	82.3	101.3	1.017	2.680	2.707	36.8
	14.4	85.7	102.7	0.983	2.680	2.632	37.9
	15.2	83.8	102.0	1.050	2.472	2.590	39.4
Females							
	12.0	83.6	96.9	0.832	3.394	2.804	33.7
	12.8	83.0	97.7	0.818	3.331	2.687	34.4
	13.6	84.6	100.3	0.869	3.321	2.890	39.3
	14.4	85.3	101.0	0.850	3.197	2.670	38.4
	15.2	86.0	101.3	0.921	2.828	2.596	39.5
STATISTICS(P=)							
SEM		0.770	0.588	0.016	0.061	0.034	0.572
Energy		0.628	0.002	0.010	0.000	0.227	0.000
Sex		0.645	0.051	0.000	0.000	0.465	0.323
Energy*Sex		0.938	0.821	0.517	0.620	0.753	0.728
Linear (E)		0.117	0.000	0.006	0.002	0.234	0.000
Quadratic (E)		0.285	0.000	0.025	0.007	0.206	0.000

Table 20. Effects of energy density of the diet and sex on slaughter characteristics of pigs offered feed ad libitum for 42 days from 63 kg liveweight housed in group pens (Experiment 4).

Sex	Dietary Energy	Carcass Weight	P2	Dressing Percentage	Fat Thickness Leg	Midline	Shoulder
	MJ/Kg	(kg)	(mm)	(%)	(mm)	(mm)	(mm)
Males							
	12.0	72.94	10.59	76.59	16.88	15.02	25.66
	12.8	76.20	10.68	76.61	18.30	16.06	27.92
	13.6	77.91	11.98	76.93	19.10	16.36	28.18
	14.4	80.15	12.30	78.04	20.16	16.78	30.40
	15.2	79.05	12.32	77.46	19.90	17.30	30.28
Females							
	12.0	75.60	12.22	78.08	20.38	17.68	30.26
	12.8	76.43	12.64	78.19	22.46	18.48	31.72
	13.6	79.48	13.12	79.25	22.76	19.90	31.42
	14.4	80.84	14.48	80.10	24.28	20.76	33.06
	15.2	82.01	14.71	80.98	24.60	21.32	34.68
STATISTICS(P=)			*	*	*	*	*
SEM		0.538	0.249	0.246	0.468	0.356	0.444
Energy		0.000	0.683	0.214	0.744	0.874	0.036
Sex		0.695	0.000	0.000	0.000	0.000	0.000
Energy*Sex		0.767	0.605	0.134	0.654	0.623	0.722
Linear (E)		0.000	0.000	0.001	0.005	0.002	0.000
Quadratic (E)		0.000	0.002	0.005	0.015	0.009	0.001

* Carcass weight was used as co-variate.

Table 21. Effects of dietary energy density and sex on growth performance and slaughter characteristics of finisher pigs (25 selected Individuals within each treatment) (Experiment 4)

Sex	Dietary Energy	Start Wt	P2 Start	42 day Wt	P2 end	Carcass Weight	Carcass P2	Dressing Percentage	Fat Thickness Leg	Fat Thickness Midline	Fat Thickness Shoulder
	MJ/Kg	(kg)	(mm)	(kg)	(mm)	(kg)	(mm)	(%)	(mm)	(mm)	(mm)
Males											
	12	61.73	7.68	93.28	11.04	71.42	11.05	76.54	16.83	15.08	25.63
	12.8	62.90	7.04	99.75	12.00	76.55	10.85	76.75	18.72	16.44	27.48
	13.6	62.92	7.40	101.62	13.00	78.94	12.02	77.64	19.54	16.38	28.88
	14.4	62.35	7.36	100.98	13.42	79.41	12.33	74.68	20.23	17.14	30.41
	15.2	62.98	7.44	101.32	12.76	79.54	12.30	78.47	20.00	17.75	29.71
Females											
	12	63.56	8.48	96.37	11.48	75.48	12.82	78.29	21.17	18.42	30.75
	12.8	64.03	8.72	98.77	12.17	77.73	13.10	79.05	23.33	19.14	32.14
	13.6	63.60	8.28	99.13	12.08	78.94	13.32	80.26	23.05	19.68	33.05
	14.4	65.01	8.44	100.28	12.56	81.46	13.37	80.38	23.23	19.59	32.77
	15.2	62.12	7.92	98.12	13.40	79.83	13.38	81.32	23.96	21.13	34.48
STATISTICS(P=)											
SEM		0.468	0.117	0.669	0.190	0.565	0.210	0.154	0.367	0.266	0.338
Energy		0.925	0.866	0.000	0.014	0.000	0.927	0.000	0.830	0.788	0.129
Sex		0.252	0.000	0.006	0.778	0.357	0.001	0.000	0.000	0.000	0.000
Energy*Sex		0.815	0.546	0.305	0.547	0.580	0.874	0.345	0.951	0.972	0.566
Linear (E)				0.011	0.001	0.000	0.038	0.000	0.012	0.268	0.000
Quadratic (E)				0.010	0.001	0.000	0.108	0.000	0.029	0.008	0.000

Carcass weight was used as co-variant for carcass P2 and dressing percentage analysis. Fat thickness measurements were analysised as a group

Table 22. **Effect of dietary energy density and sex on energy utilisation (digestible energy per kilogram of liveweight gain MJ/KG) and cost per unit of gain ($/Kg) group housing (Experiment 4)**

Sex	Dietary Energy	Energy Utilisation (MJ/kg gain) 0-6 weeks	0-3 weeks	3-6 weeks	Cost per Kg gain ($/kg gain) 0-6 weeks	0-3 weeks	3-6 weeks
Males							
	12.0	35.1	36.2	35.8	0.535	0.525	0.543
	12.8	34.6	36.9	35.4	0.566	0.553	0.589
	13.6	34.6	36.2	35.8	0.602	0.583	0.609
	14.4	34.0	38.6	35.7	0.629	0.599	0.679
	15.2	37.1	37.5	37.2	0.681	0.679	0.686
Females							
	12.0	35.1	40.5	37.7	0.565	0.526	0.605
	12.8	37.1	42.1	39.1	0.624	0.591	0.671
	13.6	35.9	45.2	39.8	0.670	0.605	0.761
	14.4	37.4	45.2	40.5	0.713	0.658	0.797
	15.2	39.5	42.8	41.3	0.757	0.724	0.784
STATISTICS(P=)							
SEM		0.423	0.430	0.754	0.011	0.011	0.014
Energy		0.130	0.046	0.380	0.000	0.000	0.001
Sex		0.004	0.036	0.000	0.006	0.044	0.000
Energy*Sex		0.397	0.358	0.579	0.329	0.307	0.433
Linear (E)		0.052	0.033	0.281	0.000	0.000	0.004
Quadratic (E)		0.141	0.037	0.365	0.000	0.000	0.016

Figure 12: Effect of dietary energy density and sex on growth performance of males housed in group pens from 65 kg liveweight (Experiment 4).

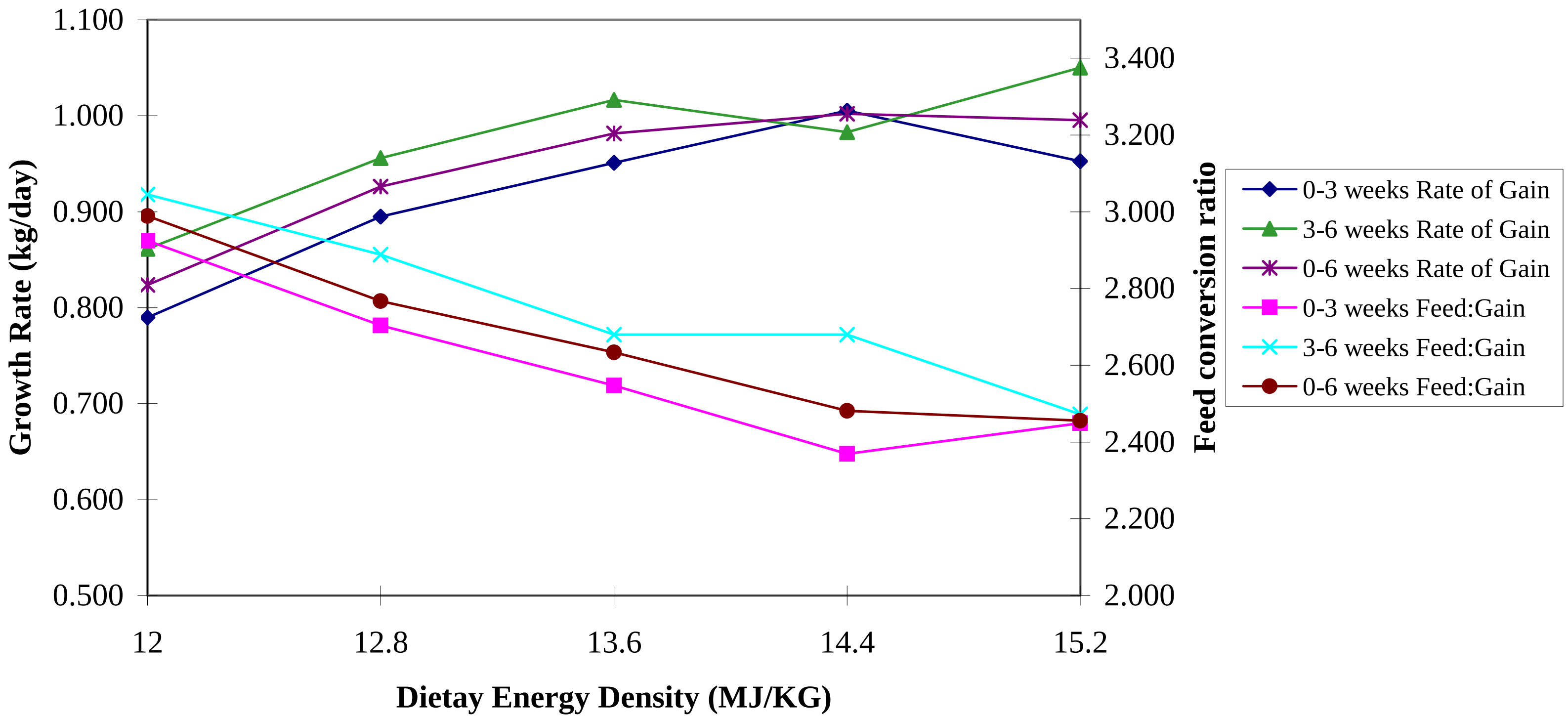


Figure 13: Effect of dietary energy density and sex on growth performance of females housed in group pens from 65 kg liveweight (Experiment 4).

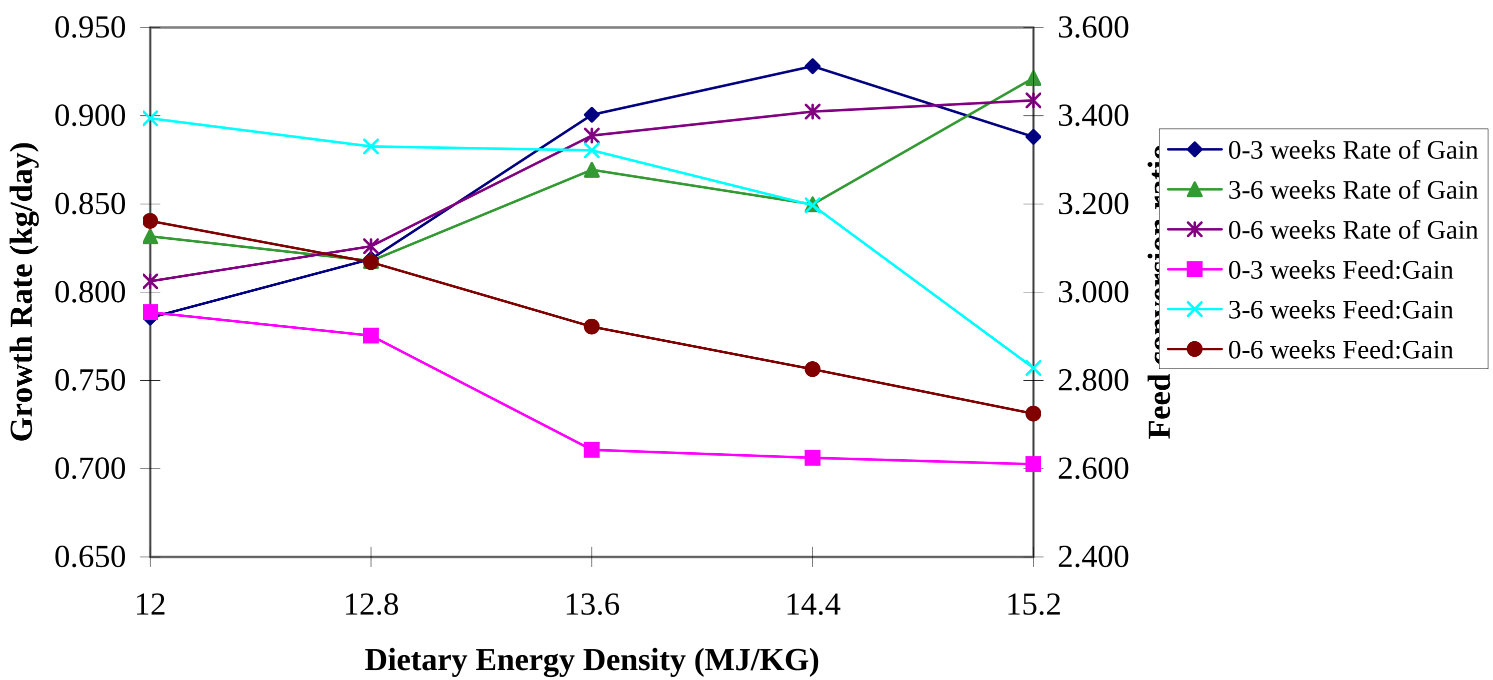


Figure 14: Effect of dietary energy density and sex on slaughter performance of finishers housed in group pens from 65 kg liveweight (Experiment 4).

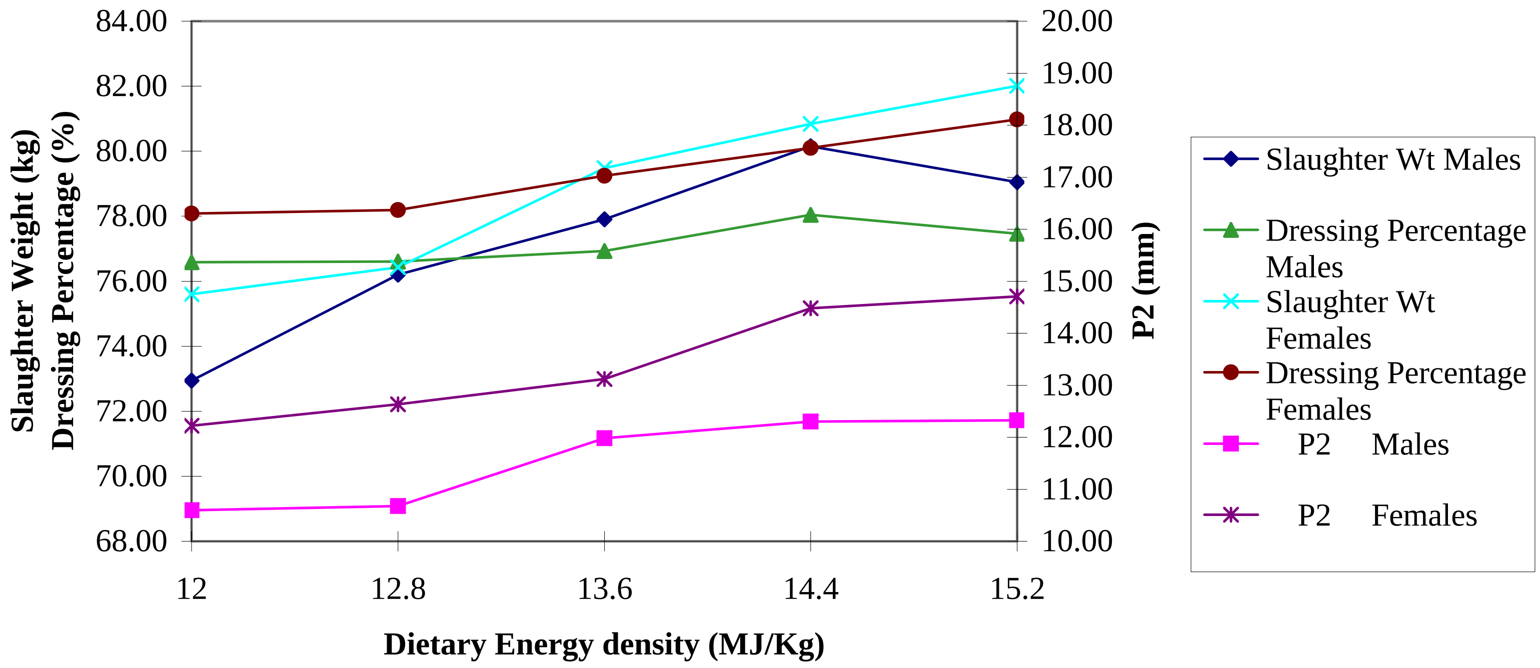
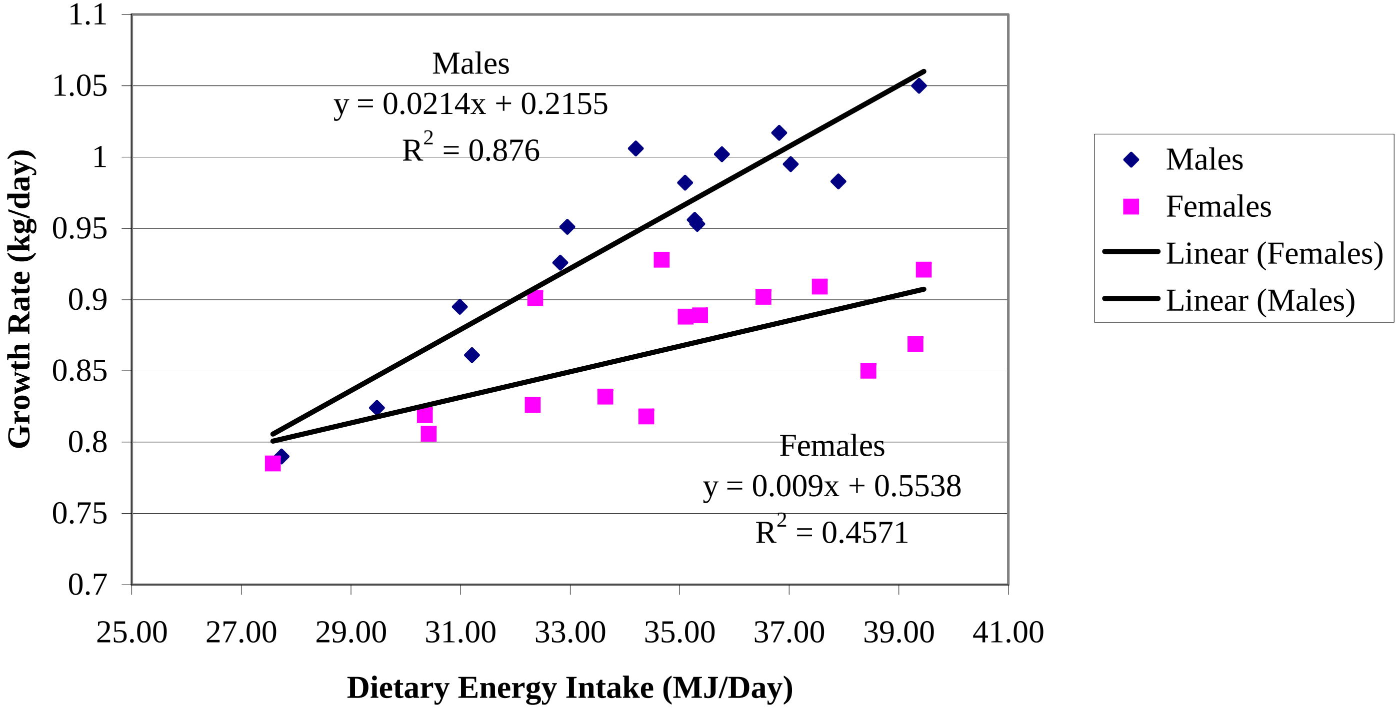


Figure 15: Effect of daily digestible energy intake on growth rate in group housed pigs from 65-100kg (Experiment 4)



4.4 DISCUSSION

4.4.1 Individual housed pigs

The growth rate of finisher pigs housed in individual pens did not significantly change over the dietary energy density range investigated but feed conversion declined with increasing dietary energy density. Feed intake was not significantly affected by energy density of the diet, which is in contrast to the result seen in grower pigs (experiment 1). There was, however a numerical difference in rate of gain due to the fact that digestible energy intake linearly increased with energy density in this experiment (Table 16). Growth rate was linearly related to digestible energy intake (figure 11). This suggests that for modern pig genotypes in individual pens there are factors other than energy demand influencing the total digestible energy intake. These factors are likely to include a gut fill limitation on the heavier pig, which is not overcome until the highest energy density of the diet is offered to the animals.

The significant increases in P2 change over the 6 week period of the experiment indicate that while the feed efficiency of the animals is improving the efficiency in terms of energy utilisation is diminishing (Table 16). The change in energy utilisation is linked to the total body fat as represented by P2. The higher the P2 in the carcass the poorer the energy utilisation which would be expected since in terms of energy it costs more to deposit fat than lean.

The cost per unit of gain generally increases for each increase in dietary energy density and generally reflects that the decrease in feed to gain is not sufficient enough to overcome the effect of the increasing feed cost. However, this does not take into account the effect of any increase in growth rate and carcass characteristics. The relative changes in dietary energy density and diet cost will also be influenced by the availability and price of different ingredients.

The variation in carcass weight between the sexes showed a positive trend for females but a more quadratic effect in males. The results mirrored the energy utilisation indicating that energy, as expected is the major driver of carcass weight. This increase in carcass weight does not fit the classical theory and is a reflection of energy intake and utilisation. The effect of dressing percentage appears to be a reflection of the increasing carcass weight and this was used as a co-variant in the analysis. However dressing percentage is very important in terms of its economic impact and the statistics still imply a positive relationship between dressing percentage and dietary energy content.

The results suggest that maximising dietary energy intake will maximise growth rate and carcass weight but at a cost in terms of increased carcass fatness. Increases in dietary energy density relative to the increase in energy intake does not lead to an increase in growth rate for animals housed in individual pens. There was an unexplained environmental factor that may have limited feed intake to levels below that recorded previously in this facility. The significant effect of dietary energy density on feed to gain may be related to the capacity for fat deposition in the finisher pig. Thus efficiency of utilisation of energy is dependent on the fat status and rate of deposition in the body at any point in time.

4.4.2 Group housed pigs

The results showed that growth rate increased linearly with increasing dietary energy density. There was no significant difference in feed intake across any of the energy density levels although there was a significant decrease in feed to gain to the highest level of energy density. The decrease in feed intake at the 15.2 MJDE/kg may have been associated with the physical quality of this diet, which had a higher percentage of broken pellets and dust and thus feed wastage was proportionally higher for this diet. These findings are in contrast to the classical theory that increasing energy density results in a consistent decline in feed intake. The present results suggest that under commercial conditions feed intake is maintained with increasing energy density of the diet and maybe constrained more by physical or social constraints than by physiological constraints.

The improvement in carcass weight with increasing dietary energy density reflects growth rate responses with males tending to respond up to 14.4 MJDE/kg and females up to 15.2 MJDE/kg. Fat depth also increased with increasing dietary energy density although it was also associated with increasing carcass weight. Fat thickness was no longer significant when carcass weight was taken as a covariate.

The linear increase in dressing percentage with increasing dietary energy density seen in the experiment is also a reflection of the increasing carcass weight when taken on a group basis. However, the result from the individual pigs showed that dressing percentage increased significantly with increasing energy density of the diet when carcass weight was taken as a covariate and this relationship needs to be further investigated.

The utilisation of energy when pigs are kept in groups tends to be more efficient compared to animals housed in individual pens and reflects the fact that the feed intake is likely to be limited when pigs are housed in group pens. The drop in efficiency with the highest level of dietary energy density is likely not a true reflection as feed wastage was higher in this treatment due to the high level of fat in the diet resulting in a poor durability pellet and thus more fine particles in the feed in front of the animals.

The cost per unit gain (Table 22) reflects that diet cost increases with increasing energy density levels and the reduction in feed to gain can not adequately adjust for the increases in diet costs. However, this does not take into account the effect of any increase in growth rate and carcass characteristics.

The relationship between digestible energy intake and growth rate for group housed pigs (Figure 15) indicates that male pigs respond to increasing digestible energy intake at a faster rate than do females when in a group housed environment. This suggests that for male pigs there will be a return by using strategies to increase energy intake but for female pigs these strategies would be of limited use. Any increase in energy intake is likely to increase backfat thickness in female pigs.

4.4.3 Comparison of group and individually housed pigs.

The relationship between dietary digestible energy density and feed intake for male finisher pigs in individual and group housing is shown in figure 16 and for female pigs in figure 17. In these experiments group housed pigs ate more than individually housed pigs. The reason for this is unclear for the experimental data and observations. There were no significant differences in intake with increasing energy density in finisher pigs housed in individual pens as would be expected from the grower experiment and the literature review. The feed intake of pigs in individual pens was significantly below expectations for these animals. The significant interaction between feed conversion and digestible energy density of the diet indicated that the pigs had still reached a maximum growth rate and feed conversion was adjusted rather than feed intake. The results then suggest there was some environmental or sub-clinical disease interaction with feed intake in the individual pen experiment. For group housed pigs there was no interaction for feed intake and digestible energy density but pigs did increase growth rate and improve feed efficiency similar to the results of the grower trial.

Figure 16. Feed intake of male pigs in group and individual housing

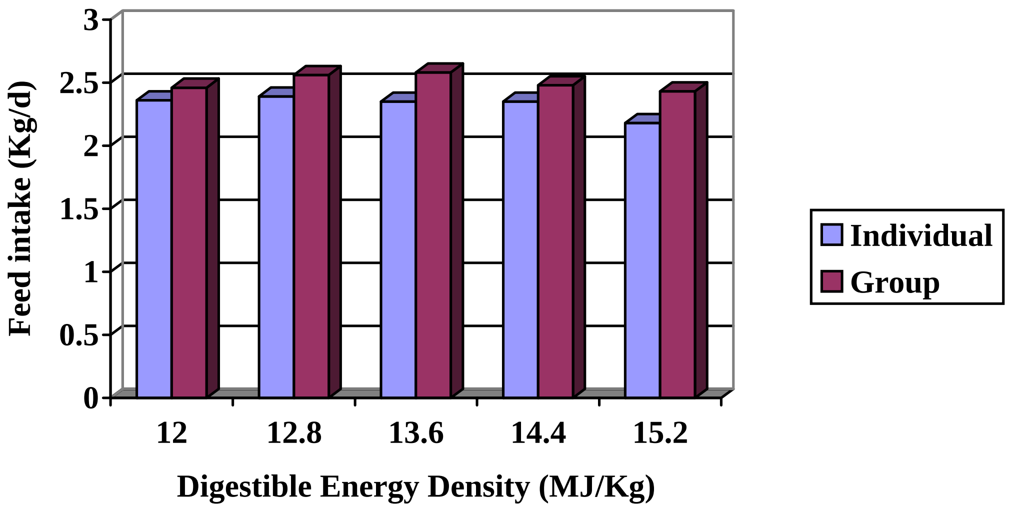
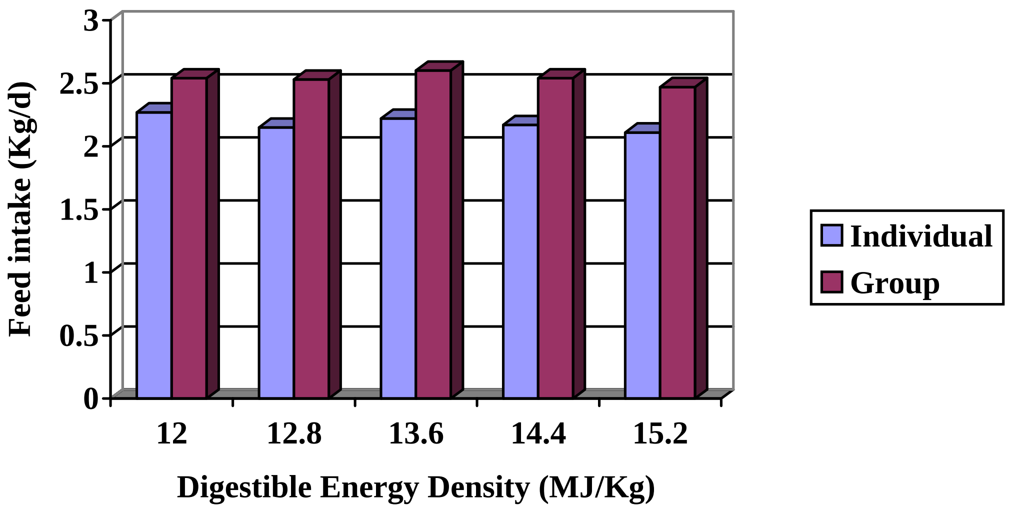


Figure 17. Feed intake of female pigs in group and individual housing



4.4.4 Economic evaluation

In this experiment the pigs in individual pens did not follow the classical theory of adjustment in feed intake to maintain a fixed energy intake but did maintain a constant growth rate. This is in opposition to most of the scientific literature and maybe as a result of factors that could not be controlled in this experiment. When pigs are placed into group-housed conditions the feed intake of the animals is constant unless very high energy densities are fed. In this case growth rate adjusted to reflect total energy intake. This is commercially very important as it changes significantly the economics of where to aim energy density levels of finisher pigs. The nutritionist has previously done the determination of dietary digestible energy density in a more arbitrary manner or by determining the least cost per megajoule of digestible energy. To more efficiently take into account the effects of changing growth rate and feed conversion a growth modelling system needs to be used to determine where the most profitable level will be. This is obviously not at the least cost per megajoule (as Auspig would indicate). The other factor not usually considered is the effect of energy on dressing percentage or more precisely the growth in carcass rather than liveweight gain per se. The present results do not conclusively link increasing energy density with dressing percentage although the increase in liveweight seen from increasing energy density will indirectly increase carcass weight. There is still enough evidence from these experiments to further investigate finisher dietary energy density levels and dressing percentage.

For commercial evaluation of the results an economic model developed by Bunge Meat Industries was used. The model takes into account the effects of growth rate, feed conversion, carcass characteristics and diet costs on profit. Auspig has several limitations in determining response due to dietary energy densities as it is based on the classical theory and does not take into account the limitations on intake and hence growth rate to the degree necessary to make the economic judgments. These results will be used to adjust Auspig to be able to better determine responses in this area.

For the economic analysis the diet cost differences between the high and low diets were adjusted to better reflect the model in Figure 16 which is a better representation of the real differences that exist over this range of dietary energy densities.

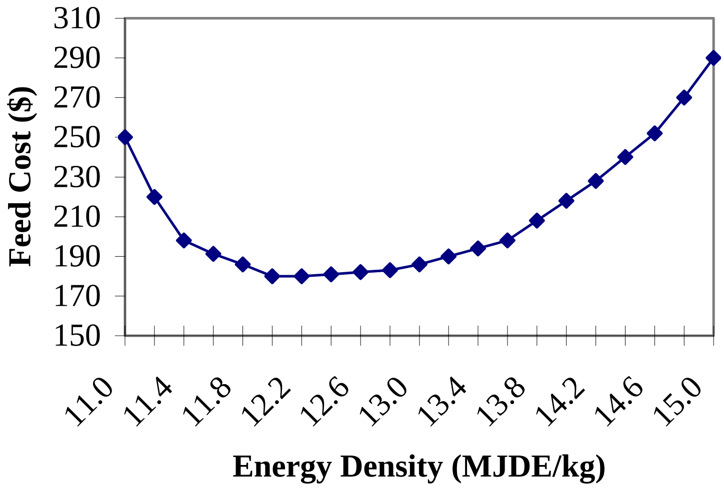


Figure 16. Relationship between dietary energy density and raw material cost

The traditional approach suggested by Auspig indicates that the most profitable dietary energy density is at the point where cost per megajoule of digestible energy is lowest. This does not take into account the other important responses in growth rate and feed conversion.

The economic analysis of the data from the group housed animals is shown in Table 23 and indicates that the most profitable point under the diet cost conditions is at an energy density of 14 MJ of digestible energy per kilogram. The optimum point calculated by the economic program was 13.6 MJDE/kg. This is not a static point as the marginal changes in diet costs are a reflection of the relativities of the raw materials used to derive the diet composition at a particular point in time. The model showed that the changes in dressing percentage associated with the changing liveweight and energy density were very influential in determining the optimum dietary energy density. Thus indirectly the increase in growth rate had a substantial effect on determining the optimum profit point.

Factors that were not considered in this economic analysis were the effect that lower feed to gain would have indirectly on the fixed costs of pig production and also how the actual cost of feed could be reduced further due to less total costs associated with the manufacture and delivery of feed.

Table 23 Economic analysis of increasing dietary energy density in finishing pigs for a herd of 5000 sows

Energy Density MJDE/kg	Cost/kg carcass ($/Kg)	Profit/kg carcass ($/Kg)	Income/kg carcass ($/Kg)	Cost ($)	Profit ($)	Income ($)	Herd feed conversion
12.0	1.694	0.414	2.068	15,359,043	3,756,846	18,750,378	3.76
12.5	1.673	0.428	2.062	15,547,774	3,980,657	19,162,920	3.73
13.0	1.657	0.438	2.057	15,714,290	4,159,247	19,508,026	3.69
13.5	1.647	0.443	2.052	15,876,423	4,275,301	19,786,213	3.64
14.0	1.646	0.441	2.049	16,059,530	4,303,736	19,997,756	3.59
14.5	1.656	0.428	2.047	16,299,530	4,208,653	20,142,672	3.53
15.0	1.684	0.399	2.046	16,646,928	3,939,298	20,220,715	3.47

The model does increase the profit figures by a fixed amount to account for sales of cull animals. This was held constant across all energy densities but not reported in cost or income values.

Chapter 5

IMPLICATIONS

The determination of energy density of grower and finisher feed was often thought not to be of major concern to nutritionists as they aimed at producing feed with the lowest cost per megajoule of digestible energy. The result was that the pig would eat to a desired energy intake per day regardless of the energy density of the feed. The lowest cost per megajoule of digestible energy would then ensure that the feed supplied produced the lowest cost per kilogram of liveweight gain. Under "ideal" conditions, simulated through the use of individually housed animals, this is the case and has been shown in figure 17 for grower pigs. The limitations to this appear to be at the extremes of energy density where feed intake capacity and the physical characteristics of the feed can limit the intake. In our experiments in the finisher pig kept in individual pens digestible energy intake per day with increased with greater energy density (Figure 19). The feed intake in this experiment was actually below that of group housed pigs which suggests that feed intake was constrained by factors not discernable in this experimental design: for example subclinical disease may have influenced this result. The proportional increases in energy intake with energy density observed in finisher pigs is in contrast to that reported previously (Cole et al., 1971; Owen and Ridgman 1967).

Placing pigs into groups does reduce the feed intake of the pig as compared to that in individual pens by approximately 10%. This reduction appears to be a result of the social stress resulting from group dynamics and can not be influenced by changing dietary energy density as with individually pened animals. Thus as the energy density of the feed is increased the daily energy intake of the pig also increases (figure 18, figure 20). This results in a change in either the growth rate of the pigs or carcass composition if maximum protein deposition is approached. The limitation of feed intake that occurs in group housed situations is most noticeable between dietary energy densities of 13.0 and 14.5 MJ DE/kg. Outside this range the higher fibre content of the low energy diets has the same gut limitations as would be expected in individual housed pigs and the high fat content of the high energy density diets tends to influence the physical quality of the diet and therefore feed intake.

Increasing daily digestible energy intake in pigs during the finisher stage in particular increases the fat status of the animal as represented by the P2 fat depth measurement. This change is very important in markets that seek leaner pigs. This has a genetic component to it in terms of the capacity of the genotype to deposit lean, which will be negatively correlated to the propensity to fatten at any given level of daily digestible energy intake. Feed intake is also under genetic control and in general the leaner genotypes tend to eat less and therefore have a lower daily digestible energy intake and as a result deposit less fat than older genotypes.

The implications from this work are that a change in methodology is required when determining the optimum dietary digestible energy density for growing and finishing pigs. The use of simulation models such as Auspig will become essential in determining the optimum dietary digestible energy density when the model can be adjusted to more accurately reflect the limitations seen in group situations on feed intake. In terms of overall throughput and total inputs the results suggest a move towards higher energy density diets for finisher pigs: this is likely to have a marked positive effect on the profitability of most pig meat businesses. The limitation on this will be the quality (fat status) of carcass accepted by markets will accept.

Further work is required to examine the difference that may occur in the maintenance energy requirement between male and female pigs that is suggested by figure 11 and figure 15. However this must be confirmed with specifically designed studies. Further work is also suggested on the effect of energy density on the portioning of protein and fat between visceral and skeletal components of the carcass. Undoubted this will have a major impact on feed utilisation for the pig industry in the future.

Figure 17. Schematic of the relationship between the effect of digestible energy density on feed intake and digestible energy intake in male grower pigs housed in individual pens

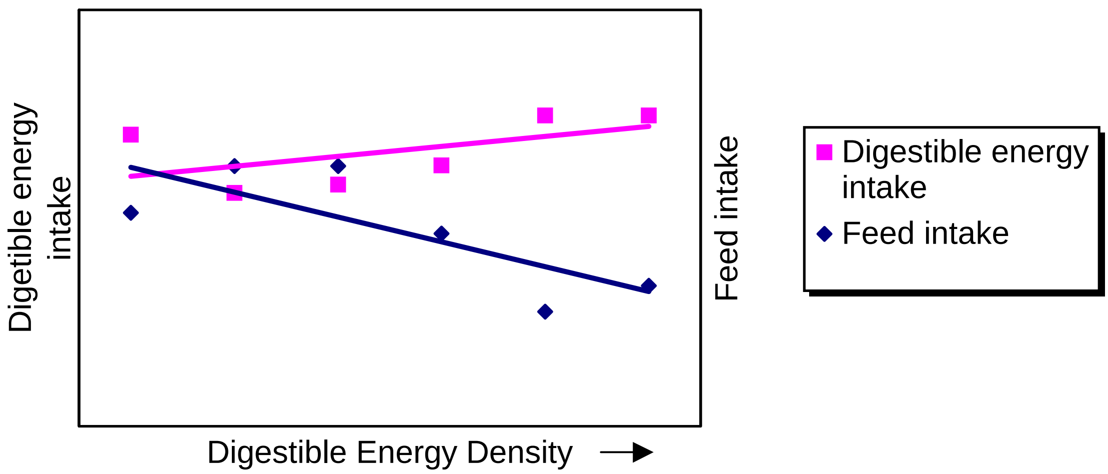


Figure 18. Schematic of the relationship between the effect of digestible energy density on feed intake and digestible energy intake in male grower pigs housed in group pens

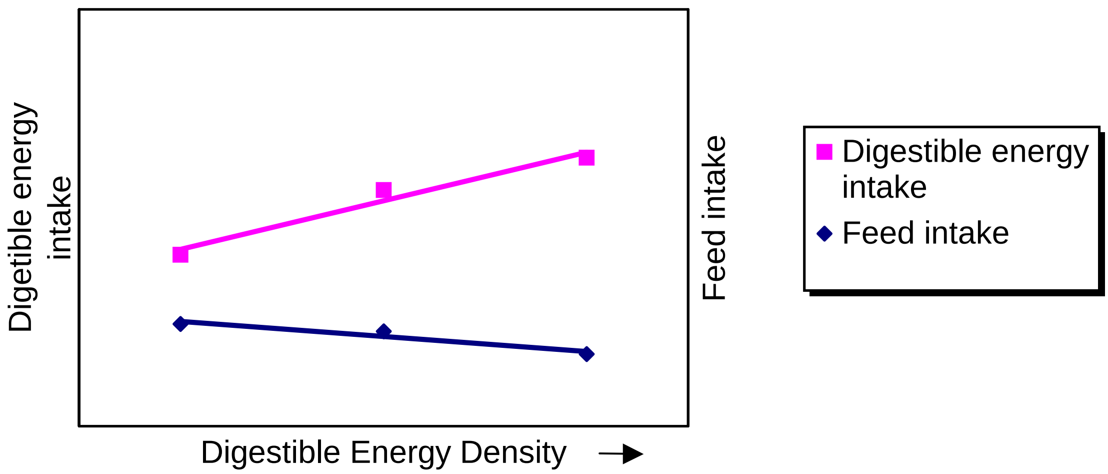


Figure 19. Schematic of the relationship between the effect of digestible energy density on feed intake and digestible energy intake in male finisher pigs housed in individual pens

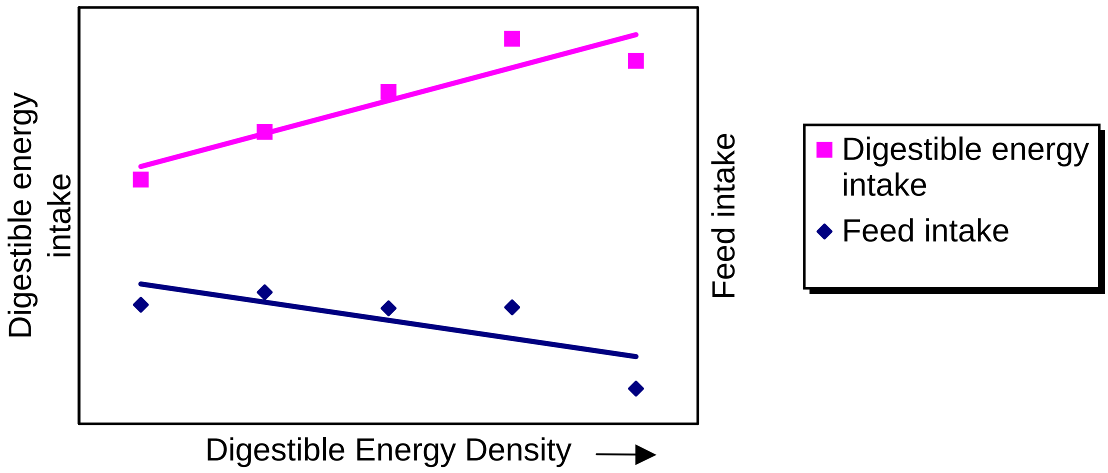
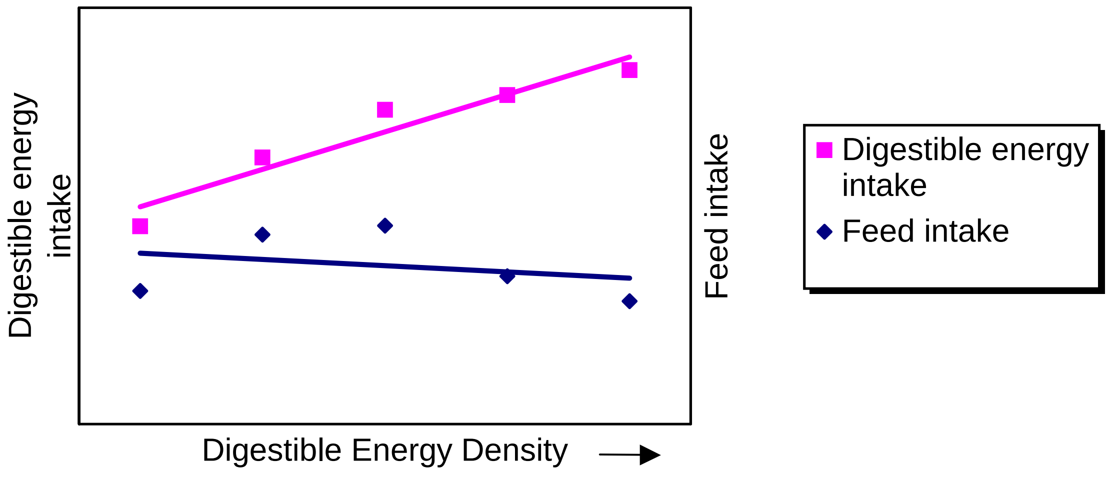


Figure 20. Schematic of the relationship between the effect of digestible energy density on feed intake and digestible energy intake in male finisher pigs housed in group pens



Chapter 6

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Appendix 1 – Published Papers – Manipulating pig Production 1999. Editor P.Cranwell. APSA

RESPONSE OF MALE AND FEMALE FINISHER PIGS TO DIETARY ENERGY DENSITY.

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Optimal nutritional management of "finisher" pig is constrained by lack of quantitative information on the response of animals between 65 and 110 kg live weight to dietary energy content. Under "ideal" conditions modern genotypes appear to adjust feed intake to maintain a constant DE intake over a much wider range of dietary energy concentrations than previously thought (Mullan et al, 1998). However, under commercial pen conditions, voluntary feed intake is lower, pigs respond in terms of both growth rate and feed conversion to dietary DE density considerably above the levels currently thought to maximise biological and economic responses. The present study was designed to provide information on the response of finisher pigs to dietary energy content under commercial housing conditions.

Five hundred female and male pigs allocated to five levels of dietary DE density (12.0, 12.8, 13.6, 14.4 and 15.2 MJDE/kg. Pigs were kept in commercial pens of 10 animals per pen. The diets were offered *ad libitum* to animals for six weeks commencing at 16 weeks of age and treatment effects were assessed for growth performance.

Table 1. Effects of dietary energy density and sex on growth performance of pigs offered feed adlibitum for 42 days from 65 kg housed in commercial conditions.

Sex	Dietary Energy (MJDE/Kg)	Start Lwt (kg)	42 day Lwt (kg)	Daily Gain (Kg/d)	Feed to Gain	Feed Intake (kg/d)
Males	12.0	62.1	95.3	0.824	2.989	2.456
	12.8	62.2	99.4	0.926	2.767	2.564
	13.6	62.0	101.3	0.982	2.634	2.581
	14.4	62.4	102.7	1.002	2.481	2.484
	15.2	62.0	102.0	0.995	2.456	2.436
Females	12.0	64.1	96.9	0.806	3.161	2.535
	12.8	64.2	97.7	0.826	3.068	2.525
	13.6	64.0	100.3	0.889	2.921	2.601
	14.4	64.1	101.0	0.902	2.826	2.537
	15.2	64.2	101.3	0.909	2.725	2.471
Significance [1]			**	**	**	NS

[1] Dietary Energy effect only. NS- Not Significant **P<0.001

The results showed that growth rate increased linearly with increasing dietary energy density. There was a tendency for a plateau in growth rate at 14.4 MJDE/kg. There was no significant difference in feed intake across any of the energy density levels, although there was a significant increase in feed efficiency at the highest level of energy density. The decrease in feed intake at the 15.2 MJDE/kg may not have been real as the physical quality of this diet was very poor and feed wastage was observed to be higher for this diet. These findings are in contrast to the classical theory that increasing energy density would result in a consistent decline in feed intake. Feed intake maybe restricted more by physical or social rather than physiological constraints.

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