EVALUATION OF THE OPTIMUM PROTEIN REQUIREMENTS FOR VIETNAMESE PIGS



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ABSTRACT

The studies reported in this thesis were carried out in Central Vietnam where pig production plays an important role and pig farmers face a general dietary protein shortage for their animals. The objectives of the work presented were (1) to investigate the crude protein (CP) supply to local Mong Cai (MC) pigs as well as lean type pigs (including crossbreds); (2) to derive CP requirements under high temperature conditions in the tropics; (3) to determine optimal lysine content in the diet of lactating Mong Cai (MC) sows and their piglets; (4) to evaluate the effects of floor types and dietary CP content on performance of sows and piglets. An interview based study of smallholders farmers showed that poor nutritive value of the diets for fattening pigs and sows is observed in three agro–ecological zones (Upland, Lowland and Coastal) in Central Vietnam. Pig on smallholder farms can produce more lean meat if they feed their pigs a higher dietary CP level. The optimum dietary CP level for the different breeds of pigs investigated (MC; F_1, Large White×Mong Cai and F_2, (Landrace×Mong Cai)×Large White) were found to be 13 % for MC, 15 % for F_1 and 16 % for F_2 pigs. High dietary CP levels (>19 % CP) for MC, F_1 and F_2 negatively affected growth performance. The optimum dietary CP content for lean type pigs kept under the hot humid tropical climate of Central Vietnam to ascertain the maximum growth performance and carcass characters in Large White (LW) and Landrace (LD) pigs must be more than 16 % CP. The other study indicated that increasing dietary lysine level from 0.7 to 1.2 % reduced the sows weight loss during lactation. No effect was found on the number of piglets born nor piglet survival at 7 days. The number of piglets weaned was improved by lysine levels of over 1.02 %. Using raised wooden floors resulted in a higher number of piglets and litter weight at weaning compared to piglets on ground clay and concrete floor. In conclusion, the current work indicates that improving protein quantity and quality in traditional diets for Vietnamese pigs kept by smallholder farmers can significantly improve productivity of MC, F_1 and F_2 pigs, and as such improve the income of farmers.

TABLE OF CONTENT

1

GENERAL INTRODUCTION

ROLE OF AGRICULTURE AND LIVESTOCK PRODUCTION IN VIETNAM

Vietnam is located in the South East Asia. It has a 3,000 km coastal line and its place on the Indochinese peninsular is from the Northern latitude of 6^o to 23^o and at a longitude of 103^o 11’ East to 109^o 27’East. The total natural land area of the country is about 332,000 km^2 and has a total of 84 million habitants (GSO, 2008).

Vietnam is an agricultural country with 80 % of the population living in rural areas and more than 70 % of the labour force is engaged in agriculture (GSO, 2006). The agricultural and rural economy contributes about 26 % of the gross domestic product (GDP) of the country. Agricultural exports are an important source of foreign currency for Vietnam. Agriculture can ensures food security for the Vietnamese people and farmers can sell their products to gain an income. As such livestock production has an important position in the Vietnamese agriculture (Livestock Department 2006).

Animal production produces food as well as provides income to farmers, has a role in providing opportunities for savings, insurance, asset accumulation, diversification, and maintaining social customs. In Central Vietnam, animal production provides about 40 % of the annual income and from the total animal production, pig production contributes about 40–60 % (Pham et al., 2000b).

ROLE OF PIG PRODUCTION IN CENTRAL VIETNAM

The pig is one of the most important livestock species raised by smallholder farmers in Central Vietnam. Pigs are raised mainly for (i) sale; (ii) home consumption; (iii) cultural purposes; and (iv) providing financial security (Bantugan et al., 1992). Pigs have the capacity to produce lean meat efficiently when fed on concentrated pig feed with an appropriate lysine (protein)/energy ratio. They have a very high production potential, and are capable of producing large litters (8 to 15 piglets) after a relatively short gestation period (114 days). In addition, they have a short generation interval, grow rapidly and can consume a large range of feeds and feed ingredients of low quality. Smallholder farmers raise pigs in small herds using family labour and locally available feedstuffs for the animals. Pigs are also of considerable importance for local traditions in low–income countries (Bantugan et al., 1992). Pigs contribute around 80 % of total animal meat consumption in Vietnam (Livestock Department, 2006). For these reasons, the pig population in Vietnam has increased rapidly in recent years, from 21.8 million in 2001 to 27.4 million in 2007 (GSO, 2008).

PIG BREEDS IN VIETNAM

The pig genetic resource in Vietnam is based on three groups of breeds, the local breeds, the exotic breeds and crossbreds. The local pig breeds are Mong Cai, Thuoc Nhieu, Ba Xuyen and Co breeds and they make up around 26 % of national pig herd. Among them, Mong Cai pigs are raised widely in all regions of the country. Mong Cai pigs have a lower carcass weight, a much lower lean meat percentage and a much higher backfat thickness compared to exotic breeds (Thien et al., 1995). In recent years, the number of exotic breeds like Large White, Landrace and Pietrain has increased. It has been estimated that the population of exotic sows in 2005 was 370,000 and they accounted for approximately 10 % of the total sow herd in the country (Livestock Department, 2006). However, these imported breeds were found to be less suitable to an extensive farming system, because they require higher investments and they are considered to be less well adapted to the tropical climate and to the often poor diets available. Now, the F_1 (Large White or Landrace x Mong Cai) crossbred is the most common type of fattening pig in rural areas throughout the country. The main characteristics of crossbreds are better growth rates and a high carcass lean percentage compared to indigenous breeds. They also have better adaptation to poor feed and management conditions than purebred exotics. In recent years, local governments have spent a large part of their annual budget to support pig–breeding programs by supplying imported exotic breeds to the smallholders. But now a problem arises in that hybrid pigs do not perform as well because of the very poor feeding conditions which exist throughout the country. An example comes from a district in one of the provinces in Central Vietnam, where 300 super–lean pigs were introduced to farmers. They did not perform well and there was a high rate of mortality due to the poor nutritive value of pig feeds and a lack of experience in raising and managing these hybrid pigs by the farmers (Le, 1996).

PIG FEEDING AND CONSTRAINTS OF PIG PRODUCTION IN CENTRAL VIETNAM

Many constraints are known to limit the productivity of pigs raised by smallholder farmers. Pigs are often fed household waste supplemented with the addition of a limited amount of other locally available feedstuffs including carbohydrate rich resources (such as cassava, rice bran, sweet potato, fruits), green leaves and on occasion protein which ingredients (such as fresh fish, ensiled fish, shellfish) (De Fredrick, 1977). Smallholder pig production is mainly based on the utilization of farm–produced feedstuffs and also agricultural by–products which are characterized by a high fibre and low protein content. The high fibre content means that the feedstuff does not supply much energy per unit of feed weight. In addition, the high fibre content results in the production of additional heat due to colonic fermentation for a longer time after the meal. Regarding the protein content, a low level limits protein gain which depends on the ratio between available energy and digestible essential amino acids and results in variability in protein and fat deposition. Common feedstuffs for pigs in Vietnam include rice bran, broken rice, cassava meal, maize, vegetables, agricultural by–products like soybean cake, fish meal, and salted fish waste. Also commercial feed and essential amino acids become increasingly being made available for feeding pigs.

A detailed survey about smallholder pig production in Vietnam was conducted including 1200 farm houses. Results indicated that there is a lack of knowledge on the protein (amino acid (AA) i.e. lysine) requirements in relation to the digestible energy (DE) intake for Vietnamese pigs. Also it is not well known how much feed should be supplied to growing pigs. The survey also showed that the low productivity of pig production in Central Vietnam is due to a low nutritive value of feeds given to pigs. Our survey data (Pham et al., 2002, 2010) showed that the total content of crude protein and amino acids fed by smallholders to pigs where the diet contained cereal grains were far below the nutritional requirement level of the NRC (1998). A correct amount of AAs in relation to DE for the various categories of pigs should be supplied to optimize production. Most local feedstuffs in Central Vietnam are low in protein. Many studies have shown amino acid imbalances in low protein feeds produced from these feedstuffs. In order to identify the amounts of essential amino acids available in feeds and to study additional amounts for essential amino acids required, studies on local feeds are needed. Also the response of local breeds and imported breeds to feeds containing locally available feed ingredients and the supply of various protein (AA) levels to these breeds should be studied.

ENERGY AND PROTEIN REQUIREMENTS

Since animals eat to meet both their energy and protein requirements, a method of expressing protein needs is in relation to the energy concentration as g per mega joule (MJ) of energy in the diet. Predominantly the digestible energy (DE) or the metabolizable energy (ME) contents of the diet are used as parameters. Digestible energy is a major characteristic for the energy evaluation system of feeds or feed ingredients. Farrell (1978), ARC (1981), and Morgan and Whittemore (1982) suggested that the DE system is preferable to the net energy (NE) system in describing the energy requirement of swine and the energy content of swine feed in the tropics because (i) DE is easy to determine and it can be determined precisely and NE can be derived from it if the amounts of nutrients and their digestibility are known in different ingredients in the feed, and (ii) DE value for separate feedstuffs are assumed to be more additive and the ratio of ME to DE does not change very much. Only with diets which have a high level of fermentable carbohydrates, a different ratio is found. It is well known that incorrect amino acid supplementation gives poor pig performance (Cole, 1978; Henry, 1988; Chiba et al., 1991). An incorrect amino acid supplementation means that the absorbed amino acid pattern is not ideal for optimal protein deposition. In most vegetable diets, the pattern of absorbed amino acids by pigs is not ideal and lysine is commonly the first limiting amino acid. In practice, the amount of amino acids available to the pig is determined by the feed intake and the ileal digestibility of each amino acid in the diet. In addition, the supply is expressed as a ratio to DE in the diet (Bikker et al., 1994b). This ratio can directly influence voluntary feed intake in growing pigs fed *ad libitum* (Chiba et al., 1991). Therefore, the level of amino acids should be related to the DE content of the diet. The optimal ratio of e.g. lysine to DE is not the same for each genotype and depends on the minimum amount of lipids that must be deposited per gram of protein. Pigs can only deposit protein optimally if sufficient lipid is deposited also. For a lean type of pig, this minimal amount of dietary energy per unit of dietary protein is less than for obese types of pig (Campbell et al., 1984, 1985).

There is little information on the above for local breeds in Vietnam like Mong Cai pigs. Amino acid imbalances and shortage in energy intake result in reduced rates of protein gain and thus in a poor feed conversion. Reducing the inclusion level of protein rich feedstuffs in the diet reduces the supply of both essential and non essential amino acids available to the animal. This limitation can be compensated by supplying the corresponding required amounts of limiting amino acids. Restricting dietary protein intake after weaning or during the grower periods results in reduced growth rates and a poor feed to gain ratio (Chiba, 1995). At the end of the restriction period, the adipose tissue content in the protein restricted animals is generally greater than in their non restricted counterparts (De Greef et al., 1992; Fabian et al., 2004). This problem occurs in pig production in Central Vietnam. In nearly all vegetable feedstuffs, lysine is the first limiting essential amino acid for pigs. So the work presented here focussed on how the CP content in diets with reference to the variation in lysine deficiency limits protein synthesis and thus weight gain. As a consequence of imbalances in the protein to energy ratio in the diet, part of the protein that cannot be used for maintenance will also not be retained as body protein, so it will contribute to carcass fatness.

The amino acid composition of protein in meat is rather independent of live weight, genotype and sex (Bikker et al. 1994a). The ideal protein is a dietary digestible amino acid profile in which all essential amino acids are balanced against lysine. Bikker (1994), Campbell et al. (1984, 1985), and Rao and McCracken (1992) have derived the level of lysine and protein intake needed to maximize protein deposition for lean type pigs. Figure 1 shows the response of growing pigs given diets in which the amount of protein, with a constant amino acid profile, was varied while maintaining a constant energy supply by replacing starch with protein. In addition, the diets were given at three levels of feeding which increased both the protein and energy supply in a fixed ratio. Increasing protein from low and limiting levels at constant energy increased protein deposition in the carcass until energy limited the response. Providing more feed increased the energy supply and enables the response to dietary protein to continue until the new energy level again became limiting. This will continue until the genetic potential of the animal and/or other factors limit further protein accretion.

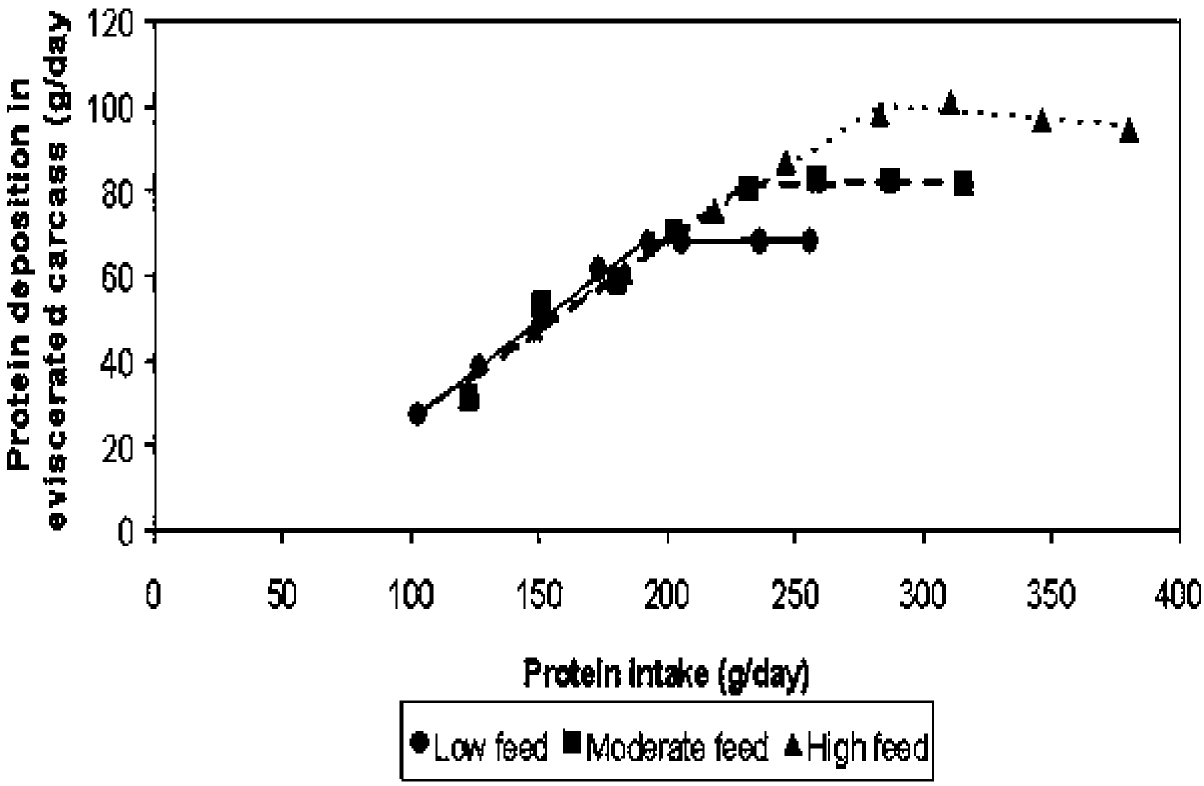

Figure 1. Relationship between increasing protein intake of constant amino acid composition and protein deposition in the carcass of pigs between 20 and 45 kg live weight (Source: Campbell et al., 1985).

In previous research in animals with the same live weight, Yen et al. (1986) and Campbell et al. (1988) suggested requirements of 0.80 and 0.71 g of lysine/MJ DE for female pigs, respectively and 0.72 g/MJ DE for female and barrows (Chiba et al., 1991). Bikker et al. (1994b) reported that the optimum lysine to energy ratio for average daily gain (ADG) and for minimal gain/feed were about 0.57 of ileal digestible lysine/MJ DE. For maximum protein deposition, this ratio was about 0.62. As can be seen the optimal ratio is not the same for all performance traits. Figure 2 is a theoretical model of the response to energy, in the presence of adequate protein, for pigs of different weights (NRC, 1998). The response is linear up to the maximum potential protein deposition and then reaches a plateau. The maximum potential protein deposition increases to a maximum at about puberty and then decreases as maturity is approached.

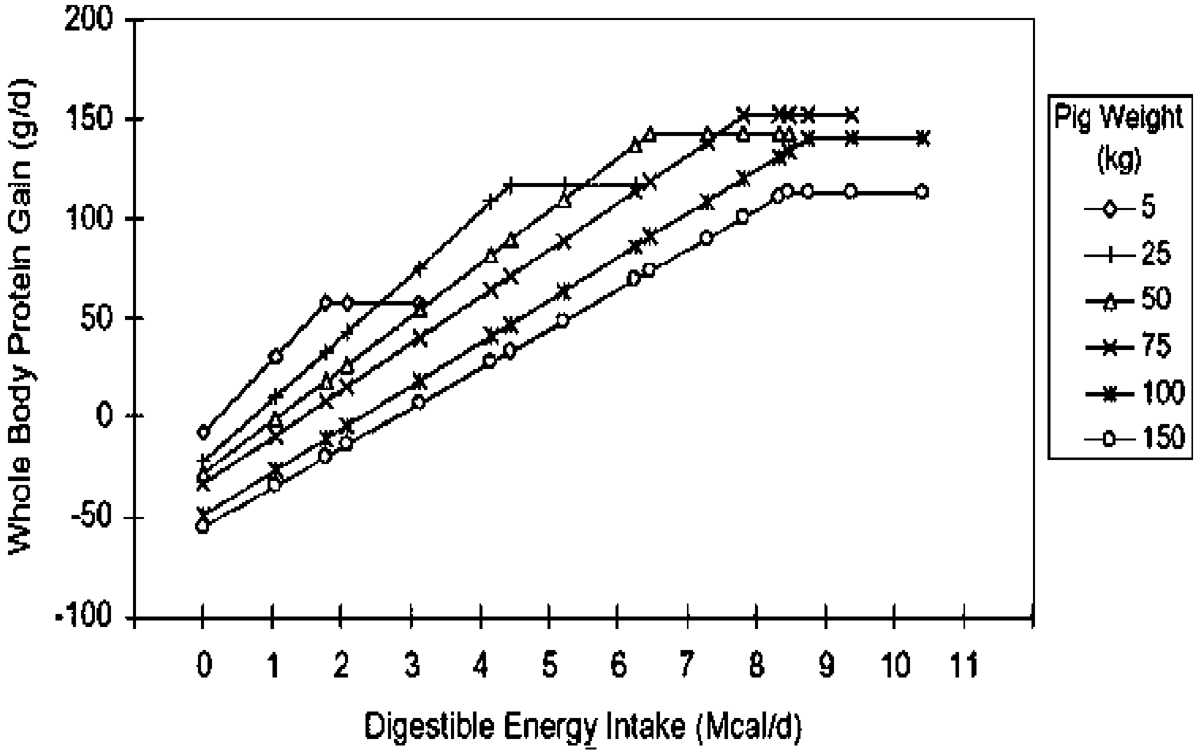

Figure 2. Theoretical relationship of whole body protein gain and digestible energy intake in pigs from 5 to 150 kg body weight when fed diets with adequate protein (Source: NRC, 1998)

In Vietnam, many pigs are produced in accordance with the principles of organic production. This means that mostly vegetable feedstuffs are used. Sundrum et al. (2000) recorded that pigs fed organic diets without amino acid supplementation grew more slowly and had decreased feed intake during the grower period compared to pigs fed control diets. Percentage of lean meat and longissimus area were higher in pigs with extra AA supplementation. Accounting for all amino acids by supplementing those which are deficient is required to formulate high performing low protein diets. However, some experiments still reported a tendency for lower nitrogen retention and performance with high additions of free amino acids, particularly in very low protein diets (Kies et al., 1992).

IDEAL PROTEIN CONCEPT

The concept of the "ideal" protein for pigs was introduced several decades ago by Cole (1978) and ARC (1981). This concept means that the apparent digestible protein content consists of the exactly those essential amino acids (and non-essential amino acid N) required for protein deposition. The biological value of such an ideal protein is 1.0. Proteins which have a very high biological value are body proteins. In addition, there should be an appropriate amount of non–protein energy, minerals and vitamins in the diet (Fuller and Chamberlain, 1983). More recently it was shown that the ideal protein composition for maintenance is different from that needed for growth (Moughan et al., 1987). The amounts of dietary protein required depend on weight, sex and breed. These animal properties can alter the ratio of protein to fat in the body. Also environment i.e. climatic conditions can influence requirements since feed intake tends to be lower in the tropical environments and thus maintenance becomes a larger portion of the feed intake (Le Dividich and Rinaldo, 1988).

Optimal crude protein and/or lysine content of swine diets will reduce carcass fatness (Cromwell et al., 1993; Kerr et al., 1995; Cisneros et al., 1996) and intramuscular lipid content (Essén–Gustavsson et al., 1988; Goerl et al., 1995; Cisneros et al., 1996). According to Stahly et al. (1990), Johnston et al. (1993) and Monegue et al. (1993), optimal dietary lysine level results in high weights of weaned piglets. In growing pig, protein deposition is closely associated with the deposition of water, and bone development. Each kg of deposited protein results in a weight increase of about 4.4 kg (Boisen and Verstegen, 2000). Often available lysine is used (Batterham, 1979) as the reference amino acid to establish an order of merit for protein sources. It is generally agreed that the supply of AAs should be evaluated on an ileal digestible basis. Batterham (1992) and Mosenthin et al. (2000) demonstrated that not all the lysine absorbed up to the distal ileum is completely utilized, probably due to structural change in the absorbed amino acid molecule caused by heating. So heat treatment of protein sources should not be too severe.

Studies carried out by Stahly and Cromwell (1987) and Le Dividich and Rinaldo (1988) have shown that if the protein: energy ratio in diets is optimal in a moderately warm climate, similar performance traits might be obtained as in a temperate climate. This may be important also for Vietnamese conditions. An optimal utilization of dietary protein is only possible if the diet contains sufficient DE, the absorbed amino acid pattern is ideal and if dietary energy is not limiting so that dietary protein will be used as a source of energy instead of being converted into body protein.

THE RELATIONSHIP BETWEEN PROTEIN AND ENERGY

The utilization of dietary proteins must be placed in the context of the available energy supply. Energy is the main driving force of metabolism. If energy is limiting dietary protein will be used inefficiently as another source of energy instead of being converted into body protein.

Increasing protein from low to high must be such that there is sufficient energy to support the increase in protein gain to the maximum possible at that energy intake. At a higher energy intake level more protein gain will occur. The response to dietary protein and dietary energy will continue until the genetic potential of the animal for protein deposition or minimal fat to protein deposition level has been reached. Bikker et al. (1995) recorded that digestible lysine/DE ratio needs to be higher in animals with a high potential for protein accretion. Increasing the protein level also reduced the fat deposition in the carcass at constant energy intake. Providing extra energy at the low and medium levels of protein had hardly any effect on protein retention. At the high level of protein, additional energy gave a marked increase in protein deposition in animals with a high genetic potential but not in animals with a low potential.

Figure 3 provides a theoretical model of the response of animals to dietary energy, in the presence of adequate protein, for pigs of different sex. Prediction of the maximum rate of protein retention in male, female and castrated pigs of an improved breed type at different stages of growth can be done by supplying a very high energy dense diet with high protein and find the point at which protein gain is maximal. This technique can be employed to determine optimum levels for Vietnamese pigs.

O'Connell et al. (2006) indicated that a maximum ADG was found at 11.8 and 9.9 g lysine per kg and a minimum in feed conversion ratio (FCR) was predicted at 11.9 and 10.0 g lysine per kg diet for lean boars and gilts, respectively. ADG and FCR improved curvilinear with an increase in dietary lysine concentration. The relationship between protein intake and protein deposition at constant energy intake has been described in a linear (Zhang et al., 1984), two–phase linear (Batterham et al., 1990), curvilinear (ARC, 1981), and linear plateau way (Campbell et al., 1984, 1985). In all models at low levels of protein intake, additional energy allowance has no beneficial effect on the rate of protein gain. With extra energy intake only lipid deposition increased at this low protein (lysine) level (Bikker, 1994b). The protein requirements of animals are given in terms of the amount of protein and its constituent amino acids per day. The daily requirement for protein is the sum of both the requirements for maintenance and for production (growth or milk production) (Pettigrew, 1993).

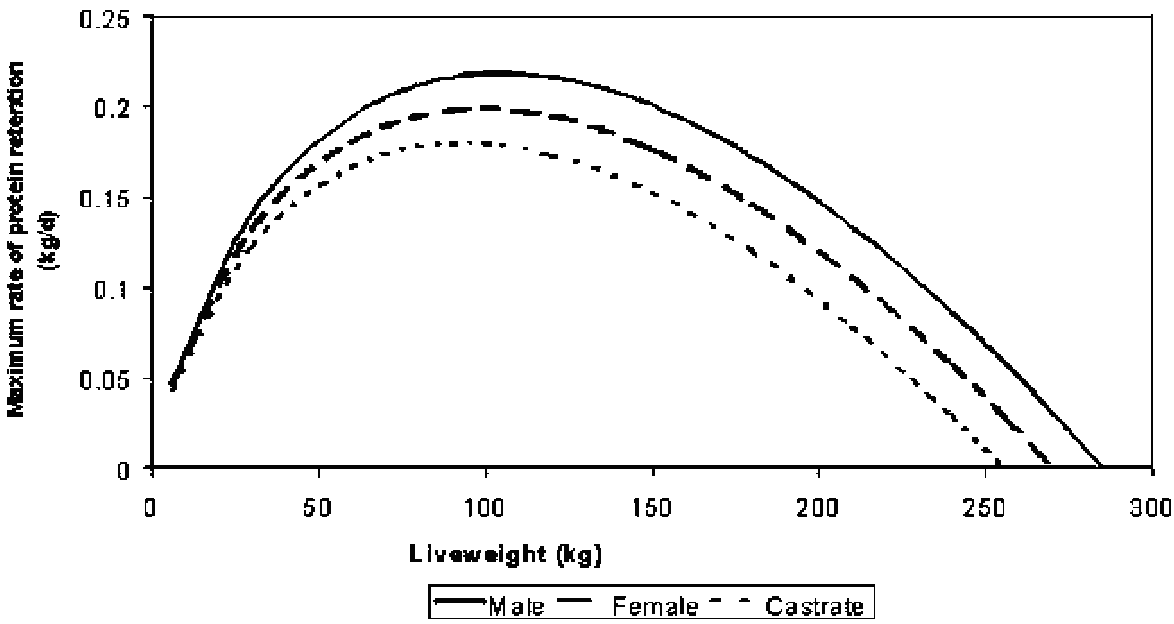

Figure 3. The change in maximum potential protein deposition for different sexes of improved European pig breeds (Source: Whittemore et al., 2001).

The maximum protein deposition (Pdmax) is influenced by genotype (breed and strain), gender and age, and mean values reported in the literature range from as low as 90 g/d to values exceeding 200 g/d (Campbell, 1985). As animals are grown over progressively wider live weight ranges, it has become necessary to model the effect of age on Pdmax (Moughan, 1999; Whittemore et al., 2001). Pigs may not achieve the Pdmax value for their strain/breed as determined under breeding station or research centre conditions, presumably because of effects due to factors such as subclinical disease, thermal environment, and social conditions (Baker and Johnson, 1999; Black et al., 1999; Burrin et al. 2001). For this reason, the term “operational Pdmax” has been coined (Moughan et al., 1995), and operational Pdmax values have been determined on–farm (Morel et al., 1993; Moughan et al., 1995). Under conditions on farms in Central Vietnam an operational Pdmax may be derived also.

LACTATING SOWS

Many studies have shown that sows, especially primiparous sows, sometimes loose excessive amounts of live weight or body condition (both protein and fat) during lactation. Clearly, lysine/protein requirements are related to the weight and litter of sows so they should be determined on the basis of expected litter gain. Because the appetite of first litter sows is usually low it has been suggested to formulate two lactation diets, one containing a high amount of lysine/protein (1.2 %) for parity one sows and one with a lower amount (0.90 %) of lysine for multiparous sows. The amino acid requirement during lactation is closely related to the production of milk by the sow. During lactation, the milk composition changes continuously, especially immediately after delivery. The obtained values for milk composition can be influenced by the way of milk sampling (Verstegen et al., 1998).

Milk proteins are used by piglets very effectively and the composition of their amino acids is very similar to the composition of piglets’ tissues (ARC, 1981). The composition of amino acids in the sow’s milk can therefore be a clue for optimal piglet development (ARC, 1981; Close and Cole, 2000). A high lysine concentration in milk will increase piglet development. Stahly et al. (1990), Johnston et al. (1993), Monegue et al. (1993), and Richert et al. (1994) found that a high dietary crude protein content in sow diets reduced weight loss of the sow during lactation. Kusina et al. (1999) recorded that increasing lysine intake from 8 to 16 g/d for pregnant sows increased their weight gain.

RELATIONSHIP BETWEEN GENOTYPE AND FEED IN PIGS

One of the strategies to improve genetic potential of pigs in developing countries is cross-breeding of local pig breeds with exotic modern breeds. According to the literature, pigs of local breeds have a poorer growth performance, they are fatter and have a less favourable body conformation than those of modern breeds (Legault et al., 1996; Warriss et al., 1996; Santos et al., 2000). In recent decades, pig producers have included genetic selection in their production programs in order to improve meat quality by obtaining meat with a low fat content (Visscher et al., 2000; Tarrant, 1998) as a response to an increased consumer appreciation of meat and meat products with a low fat content. Pham et al. (2000a) found that crossbred pigs (3/4 Landrace + 1/4Mong Cai) fed diets of 16 % CP had higher meat percentages and a lower fat content compared to indigenous breeds.

HOUSING CONDIONS FOR PIGS

The positive influence of housing systems with bedding on the welfare of pigs is now clearly established (De Oliveira et al., 1999; Beattie et al., 2000). Several studies (Geverink et al., 1999; De Jong et al., 2000; Klont et al., 2001; Lambooij et al., 2004) evaluated the effect of the enrichment of the indoor environment (extra space and straw vs. conventional) on pig behaviour and physiology during pre–slaughter handling and subsequent meat quality. García–Rey et al. (2005) studied the influence of genetics and effect of seasonality (time of the year when pigs were slaughtered) on physical–chemical parameters of meat. Cameron et al. (1990) reported effects of breed (genotype) on the chemical composition and eating quality of pork. So, it is important to derive also which genotypes used in Vietnam react most favourably to the warm and cool season in relation to dietary protein content.

SCOPE OF THE THESIS

Growth performance of fattening and productivity of sows may be assessed by improving genetics but also by nutrition in addition to improving the housing conditions. The aim of the study in this thesis was to investigate the importance of different feeding regimens suitable for pigs fattened on a farm. Studies on different protein levels resulting in different lysine contents were conducted. In pigs grown under hot Vietnamese conditions, the relationship between protein/lysine intake to energy intake with difference genotypes is unclear and the subject of study of this thesis. This thesis consists of 7 chapters and focuses first on analysis of the situation of nutrition and housing in the hot–humid condition in smallholder farms of Central Vietnam.

Chapter 1: The introduction provides a general view of the literature within the research field.

Chapter 2: A survey to analyze the characteristics of smallholder pig farms in Central Vietnam. A survey of feed management, nutrition and housing conditions was conducted.

Chapter 3: Describes trials designed to derive the required dietary crude protein level for three genotypes with regard to performance of fattening pigs. The study provides an optimal dietary protein level in 3 genotypes of pigs commonly used in Central Vietnam with regard to performance in the hot–humid condition.

Chapter 4: Describes a study on dietary lysine level and performance of Mong Cai sows. Supplying additional lysine was tested and its effect on the performance of sows and lactating sows with their piglets.

Chapter 5: Describes trials designed to determine effects of dietary protein level and season with regard to performance of exotic pigs. The hypothesis was tested that there is an interaction between dietary crude protein level, genotypes and season on performance of Large White and Landrace pigs. The study provides an optimal dietary protein level for lean type pigs with regard to performance in the hot–humid condition.

Chapter 6: Describes a study to determine if housing condition (e.g. types of floor) influences the optimal protein level with regard to performance of Mong Cai sows and piglets.

Chapter 7: General discussion and implications.

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2

NUTRITIONAL CONSTRAINTS AND POSSIBILITIES FOR PIG PRODUCTION ON SMALLHOLDER FARMS IN CENTRAL VIETNAM

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ABSTRACT

This study aimed to evaluate the nutritional situation of pigs kept in three ecological zones of Central Vietnam: Upland, Lowland and Coastal areas. An interview-based questionnaire was developed and surveys were conducted in 27 villages collecting data from 1,200 participating households. It was found that the amounts of feed and the crude protein content in the diets for fattening pigs and sows were insufficient for all three regions. Amounts of feed DM (kg/d) fed to growing pigs of 20-50 kg BW was 0.54 to low (29 %) in Lowland, 0.53 (28.6 %) to low in Coastal and 0.42 (22.6 %) in Upland areas. The shortage in CP in the diets of growing pigs in this period (20-50 kg) was 205 g/d (62.1 %) in Lowland, 219 g/d (66.4 %) in Coastal and 230 g/d (69.7 %) in Upland areas. Amounts of feed DM fed to growing pig of 50-90 kg BW was 1.27 (49.3 %), 1.25 (48.5 %) and 1.14 kg/d (44.3 %) to low in Lowland, Coastal and Upland areas, respectively. The shortages in crude protein in the growing diet for the Lowland, Coastal and Upland regions were 272 (68.2 %), 287 (71.9 %) and 298 g/d (74.7 %), respectively. The shortage of DM intake (kg/d) of pregnant sows in the Lowland area was of 0.04 (2 %), 0.19 (9.7 %) in the Coastal area and 0.43 (22.0 %) in Upland areas. Dietary crude protein content of pregnant sow raised in Lowlands was 80 g/d or 31.6 % short while in the Coastal region the shortage was 108 g/d (42.7 %) and in Upland this was 155 g/d (61.3 %). The amount of feed provided to lactation sows (kg DM) was lowest in the Lowland (shortage of 31.8 %) and highest in the Upland (shortage of 57.1 %) areas. The daily lack of DM intake of lactating sows raised in Lowland areas was 1.47 kg (31.1 %), in Coastal areas 1.69 kg (39.2 %) and in Upland areas the highest 2.46 kg, (57.1 %). The crude protein intake of sows raised in Lowlands was 419g/d to low or (59.6 %) short, in the Coastal region the shortage was 457 g/d (65.0 %) and in Upland regions was 555 g/d (78.9 %). The low input of feed in these areas is especially due to a low quality and to the insufficient intake of nutrients by the pig. As a result the productivity of pigs and their contribution to the income for farmers is low.

INTRODUCTION

Vietnam is situated along the Southeast margin of the Indochina peninsula. It has a total land area of 330,541 km^2 and a length of 1,600 km ranging from 23° to 6° Northern Latitude and from 103° 11 to 109° 27 Eastern Longitude. About three quarters of the land area consists of hills, mountains and high land areas. The agricultural land occupies 23.8 % (7,907,207 ha) of the land with natural pasture occupying 1 % (330,000 ha) and forests occupying 30 % (9,650,000 ha). The remainder of the land area is uncultivated or open lands (GSO, 2006).

Central Vietnam consists of 14 provinces located from the 20° to the 11° North latitude. Its surface area is about 97,000 square kilometers and it has about 17 million inhabitants. A common feature of these provinces is the presence of Truong Son Mountain and a narrow coastal zone. Compared with other regions of the country, Central Vietnam is poor and agriculturally not well developed. This is mainly due to climatic conditions which can be harsh as well as the fact that the Upland areas are not very fertile. The annual average temperature is about 25.9°C. During winter time, the lowest temperature sometimes falls below 15°C with a humidity of 95 % while during summer, temperature can go up to 39°C with lower than 60 % humidity. These conditions combined with western hot winds cause a very high rate of water evaporation. As a result, water shortage can be a serious problem during summer. These climatic conditions are not always ideal for thermal comfort of animals (NAP, 1981; Hatfield, 2008).

Vietnam is an agricultural country with over 80 % of the population living in rural areas and their livelihood is mainly based on agriculture. In Central Vietnam, mixed farming systems (the mix of animals and crops) are most prominent where pigs are one of the most-important livestock species raised by smallholder farmers. Pigs are raised for sale, home consumption, festivals and financial security. These animals can convert concentrated food to meat efficiently. They produce a large number of offspring after a relatively short gestation period, have a short generation interval and can grow rapidly. Hence, these animals are a great interest for studies on smallholder farms and for possible development of these smallholder farms. Descriptive observational studies of pigs held by smallholders have been conducted in Nepal by Gatenby and Chemjong (1992) and in the Solomon Islands by De Fredrick (1977).

Smallholder farmers keep pigs in small numbers, use family labour and locally available feedstuffs. Pigs are also of considerable importance in customs and in traditions in many developing countries (Bantugan et al., 1992). Many constraints are known to limit improvement of the productivity of pigs on smallholder farmers. Animals are frequently fed household waste complemented with a small amount of other feedstuffs. According to De Fredrick (1977), these feedstuffs include: i) carbohydrates resources such as cassava, rice bran, sweet potato and fruits ii) leaf green materials and occasionally iii) protein resources such as fresh fish, ensiled fish and shellfish. Central Vietnam has the potential for further animal production development, if the constraints of low nutritional quality and quantity of feedstuffs, which are the main limitations to husbandry and management, can be overcome. Obviously, the economic contribution of pig production as yet is not very high.

This study aimed to survey the situation of pig production on smallholder farms in Central Vietnam with special emphasis on nutrition. It is expected that based on the results of this survey specific nutritional investigations may be needed to study possibilities for improvements in pig nutrition.

MATERIAL AND METHODS

STUDY DESIGN

Interviews were held with 1,200 smallholders raising pigs and conducted in three ecological zones of Central Vietnam. The distinction between the farmers in the zones was related to their main crops:

- Upland area with cassava and upland rice
- Lowland area with paddy rice cultivation and vegetable
- Coastal area with sandy land rice and aquaculture

QUESTIONNAIRE SURVEY

This study was carried out by means of an interview-based questionnaire. Households surveyed were selected based on the following criteria:

- Location (from different villages in the community and from different regions in provinces)
- The pig raising situation (at least one fattening pig and /or one sow present)
- The wealth of the farmer (rich, average and poor households). These households have the main characteristics of their respective group in the household socio-economic classification group which is annually certified by The Ministry of Labor War Invalid and Social Affairs (MOLISA 2003).

In general, the aspects covered in the farm questionnaires included farm-management practices, type of feeds and feeding practices, housing, preventive medicine and production constraints encountered in pig production.

General information was collected on farm and household characteristics such as family size, age, education, sex, occupation, farm size, number of parcels, household assets, etc. The production system included cropping and the livestock systems included information on by-product use. Furthermore information on household revenue and income was obtained and regarding the main constraints as they were perceived by farmers.

All selected farmers had at least one sow or one fattening pig. If the selected farmers were not present on the pre-arranged day of the interview, arrangements were made for another day or mutually convenient meeting. If the selected farmers proved ineligible or was not present on the pre-arranged day of the interview, an additional farmer was randomly chosen immediately from the other farmers. At the three agro-ecological zones, information about each selected pig farmer was collected before the start of the interviews. Interviews were only conducted with farmers who met the definition of a smallholder pig farmer (at least one pig present at the farm visit).

The interview questionnaire used for this study contained four sections: i) the pig farmers, ii) the number of pigs, iii) the kind of feed resource used and iv) years of relevant experience. For our study only the pig farmer and the feed resources are relevant. The pig feedstuffs section also covered information about the caretaker.

Questions were related to the major feedstuffs for non-pregnant pigs, pregnant sows, lactating sow and fattening pigs. Questions were related to the use of available feed resources, commercial concentrated high protein feedstuffs, uncooked green feeds, kitchen waste, pre-mixed vitamin-mineral additives and methods of feed processing. Also amounts of feed fed to non-lactating sows, the lactating sows, and the fattening pigs were determined. The interviewer weighed the animals, feeds and feedstuffs (uncooked) on the day of the interview.

DATA SOURCES

Primary data were collected by interviewing the farmers. The secondary data were collected from yearly statistical books published by the General Statistical Office (GSO, 2006).

PROVINCIAL AND DISTRICT LEVEL

A review of the current agricultural production and farming systems in the Lowland, Coastal and Upland was conducted. The provinces involved in these surveys are Nghe An, Quang Binh, Quang Tri, Thua Thien Hue, Quang Nam, and Binh Dinh. The data were collected from provincial animal husbandry departments and divisions in districts from reports, statistical books, development strategies and open - ended interviews.

COMMUNE LEVEL

To determine the major animal production systems and animal feeding in the commune data from community was collected as follows:

- PRA (Participatory Rural Appraisal) work in communes and villages which included commune leaders, organization mass and village leaders.
- The direct interviews and observations were carried out by 10 staff members of the Department of Animal Science and Department of Agriculture and Rural Development of Hue University, by 20 final year student in Animal Science and by the chiefs of 27 villages.
- The smallholder pig raisers were selected for inclusion in the study by the use of a multistage stratified random sampling process.

Necessary information related to social, economic and agricultural topics were recorded.

FOOD SAMPLE ANALYSIS

Feed ingredients were analyzed in triplicate for DM, GE and CP at the Animal Nutrition Laboratory of Department of Animal Nutrition of Hue University, Vietnam. For the determination of DM, feed was freeze-dried and DM determined according to Vietnam Standard (TCVN) 6952: NIAH. 2001 (ISO 1998). Crude protein content was determined by Kjeldahl (N×6.25) according to Vietnam Standard (TCVN) 4328: NIAH. 2001 (ISO 1997). Other values (Ca and P) were calculated from NRC (1998) and NIAH (2001).

FARM INCOME

The income of households was estimated from animal income, crop income and off-farm income. This was grouped in relation to different types of households and types of animals. An animal income level was estimated from the ratio of measured weight and reported age of each fattening pig and the same for each sow. Data on pigs in each smallholder unit were used to calculate pig population and performance in each specific zone.

OFF-FARM INCOME

Typically refers to money or wage received when labor is provided to other farms. This includes payment in cash or in-kind (such as paddy and food) and other non-wage type income.

NON-FARM INCOME

Non-farm income is defined as non-agricultural income sources. The common non-farm income sources identified are non-farm wage or salary, non-farm rural self-employment (business income), rental income obtained from leasing land or property, remittance from both internally (rural-urban immigration labor) and international labor.

DATA ANALYSIS

In order to meet the research objectives, households were divided into different categories, firstly, based on ecological region (Lowland, Coastal and Upland).

Theoretically, ecological ranking is intended to analyze the different farming systems among smallholders and among pig production categories. This gives especially the assets and situation of the nutrition of pigs. Secondly, it was classified based on type of pig production: fattening or breeding pigs.

Data analysis was done by a model with region as factor by using SPSS software version 11.5. Descriptive information about pig production at the three ecological zones was compared to test for categorical and continuous data.

RESULTS

CHARACTERISTICS OF HOUSEHOLDS IN CENTRAL VIETNAM

Smallholders are a heterogeneous group whose resources, livelihood patterns and income sources are very diverse. The farm-level categorical variables of the 1200 smallholder pig farmers enrolled for the cross-sectional study are as shown in Table 1. The mean family size in Lowland, Coastal and Upland areas was 5.6, 6.1 and 6.7 persons, respectively. The mean farm size was larger in the Upland and Coastal areas compared to the Lowland area. On average, the cultivated area was about 0.62 ha/farm in the Lowlands, 0.88 ha/farm in the Coastal area and 1.17 ha/farm in the Uplands.

Traditional farming is an integrated system of rice, root crops, fruit tree, vegetables and livestock. The specific character of multi-purpose farms in Central Vietnam is the diversity of animal species used on the farm. Livestock raised by smallholders in Central Vietnam consists of pigs, cattle, poultry (especially ducks) and fish. The number of ruminants per household was higher in Upland areas whereas the number of pigs per household was higher in Lowland areas.

The majority of the income of the farmers in the country as well as in Central Vietnam comes from both crops and animal production. The total income of households in Lowland and Upland areas was higher than in the Coastal area. Household income from animal production was higher compared to income from crop production and other income. The working time/ year was higher in Lowland and lower in Upland area. Average income/day was higher in Upland compared to that in Lowland and Costal areas (Table 1).

Table 1. Number of households and mean size standard deviation within region in Central Vietnam.

Characteristics	Region			SEM
	Lowland	Coastal	Upland	
Number of interviewed households (n)	400	400	400	-
Size of family (n)	5.6^{a}	6.1^{ab}	6.7^{b}	0.37
Farm size (m^2)	$6,163^{a}$	$8,618^{b}$	$11,772^{c}$	597
Number of ruminants (n)	1.4^{a}	1.6^{b}	2.3^{c}	0.03
Number of pigs/hh[1] (n)	3.3^{a}	3.1^{b}	2.3^{c}	0.04
Number of poultry/hh (n)	14.3^{a}	21.7^{b}	19.7^{b}	1.20
Total income/year (1,000 VND)[2]	$16,410^{a}$	$12,440^{b}$	$17,560^{c}$	595
Crop income/year (1,000 VND)	$6,060^{a}$	$5,960^{a}$	$4,760^{b}$	575
Animal income/year (1,000 VND)	$6,400^{a}$	$4,530^{b}$	$8,620^{c}$	451
Other income/year (1,000 VND)	$3,950^{a}$	$1,950^{b}$	$4,180^{a}$	237
Average working time/year (day)	216^{a}	201^{b}	209^{ab}	5.34
Average income/day (1,000VND)	76.0^{a}	61.9^{b}	84.0^{c}	0.53
Experience for pig husbandry (year)	7.5^{a}	6.2^{b}	4.5^{c}	0.03
Interviewed farmer was trained on pig husbandry (%)	10.0	7.1	2.5	-

[1] hh: households.

[2] VND: Vietnamese dong per household.

[a, b, c] Means with different superscripts within rows differ ($p<0.05$, 0.01, 0.001).

PERFORMANCE OF THE ANIMALS

The number of fattening pigs/farm for Lowland, Coastal and Upland areas were 4.15, 2.97 and 1.95 and the number of sows raised by smallholders in these areas was 1.35, 1.27 and 0.90 sows/farm, respectively (Table 2).

Smallholders in the Lowlands have the highest number sows per farm and those in Upland areas have the lowest number. The sows raised by smallholders in different ecological zones perform differently. Sows (inseminated by semen of LW or LD male pig) raised in the Lowlands and in the Coastal areas have the largest litter size. Sows raised in Lowland and Coastal areas also have the highest number of weaned piglets and the highest weaned piglet weights after 60 days lactation period. Table 2 also shows that fattening pig raised by smallholders in Upland areas grew slower than pigs in the Lowland and Coastal areas.

Table 2. The performance of sows and fattening raised by smallholders in Central Vietnam.

Variable	Region			
	Lowland	Coastal	Upland	SEM
No. interviewed farm	150	150	150	-
The performance of the sows				
Number observed sows[1]	220	190	135	-
Average number sows/farm	1.35^{a}	1.27^{b}	0.90^{c}	0.01
Number of piglets born alive	10.5^{a}	9.1^{b}	8.4^{c}	0.02
Number of weaned piglets	9.5^{a}	8.6^{b}	7.3^{c}	0.02
Piglet weight at birth (kg)	0.53^{a}	0.67^{b}	0.60^{c}	0.02
Weaned piglet weight (kg)	9.8^{a}	9.1^{b}	8.2^{c}	0.04
The performance of the fattening pigs				
Number of fattener/farm	4.15^{a}	2.97^{b}	1.95^{c}	0.01
Average starter weight (kg)	10.66^{a}	9.55^{b}	7.15^{c}	0.02
Average fattening time (mo)	6.05^{a}	6.75^{b}	8.25^{c}	0.03
Average selling weight (kg)	85.5^{a}	77.2^{b}	68.0^{c}	0.02
Average daily gain (g/d)	436^{a}	344^{b}	235^{c}	0.08

$^{a\,bc}$ Means with different superscripts within rows differ ($p<0.05$, 0.01, 0.001).
[1] Pig breed : Sow =Mong Cai and Piglet =F_1(Large WhitexMong Cai)

SITUATION OF PIG HUSBANDRY IN CENTRAL VIETNAM

SWINE BREED

The pig genetic resource in Vietnam is based on three groups of breeds, the local breed, exotic breeds and crossbreds. The local pig breeds consist of Mong Cai, Thuoc Nhieu, Ba Xuyen and Co breed and they constitute around 26 % of national pig herd. Among them, Mong Cai pigs are raised widely in all regions of the country. Compared to exotic breeds, Mong Cai pigs have lower carcass weight and a much lower lean meat percentage and a much higher back fat thickness compared to exotic breeds (Thien et al., 1996). Sexual mature age of Mong Cai pigs is from 4 to 5 month and mature weight is about 120 to 150 kg. In recent years, the number of pigs belonging to the exotic breeds like Large White, Landrace and Pietrain has increased. The lean type pig (LD and LW) sexual mature age is about 7 to 8 months and mature weight of the male animal range from 190 to 260 kg. Mature weights of female pigs range from 180 to 240 kg while the lean percentage of Landrace, Yorkshire and Pietrain pigs ranges from 47 to 59 % (Thien et al., 1995, 1996, Leroy and Verleyen, 1999).

The F_1 crossbred (Large White×Mong Cai or Landrace×Mong Cai) is the most common type of fattening pig in rural areas (including three zones Lowland, Coastal and Upland) throughout the country. The main characteristics of crossbreds are: better growth rates and higher amount of carcass lean than indigenous breeds and better adaptation to poor feed and management conditions than purebred exotic breeds. Lean percentage of two way crosses (Landrace, Yorkshire×Mong Cai) is about 43 to 45 % and three way crosses ((Yorkshire × Mong Cai)xLandrace)) is about 45 to 48 % (Thien et al., 1995, 1996).

Pig populations and cattle/ poultry populations throughout Central Vietnam are expanding rapidly. Production is increasing steadily in all agro-ecological zones, Lowland, Upland and Coastal areas. Production is carried out at three levels; state, private companies and smallholders. Among them smallholders pig production take the highest proportion (GSO, 2006).

FEED SOURCES FOR PIG PRODUCTION IN CENTRAL VIETNAM

Feed sources, which are available for pigs vary greatly among agro-ecological zones in Central Vietnam. Feed composition for pregnant/lactating sows and fattening pigs raised on smallholder farms are presented in Table 3. Sows are mainly fed rice bran, cassava meal, fresh sweet potato vine and a small amount of salted fish. During the survey we found that only very few smallholder in the Lowland area use supplements (Premix) in their pig diet. Almost all farmers use sweet potato vine in the diet of the sows. Farmers, especially the older ones, mention that they provide sweet potato to prevent constipation in the sow and to facilitate the sow’s farrowing. Table 3 presents the amounts of feed components given to fattening pigs in the different zones.

The main protein feed sources in Central Vietnam are fishmeal and seafood by-products like fish heads and shrimp heads. Other sources include coconut, sesame, and soybean, but the use of these ingredients are minimal. Fishmeal is produced mostly from salt-water fish. Other animal products are fed which originate from those parts of the animal not suitable for human consumption.

NUTRITION AND FEEDING

Table 3 presents estimates for digestible energy (DE) and crude protein (CP) in the diets for fattening pigs and for sows raised on smallholder farms in different zones of Central Vietnam. The average crude protein content in the pig diet is about 10 %. Restricted feeding is practiced in all the herds and commercial feeds that are not specifically formulated for pigs. Table 3 also shows that feeds for fattening pigs and sows are not very complicated and contain insufficient amounts of energy and protein. Ensiled fish is used as a supplement but it is available only in small quantities. Amino acids and fatty acids are not added to pig feed. The crude protein, lysine and DE intake were calculated from locally available feedstuff data. Table 3 shows the differences in the latter nutrients among the three regions.

NUTRITIVE VALUE OF FEEDSTUFFS

The contents of energy, protein and minerals given per day were compared with the NRC (1998) requirement estimates of fattening and reproductive sows and are presented in Tables 4 and 5 as amounts of shortage per day. From the analyses of the feed given to pigs and estimation of the DM (kg/d) supplied to growing pigs of 20-50 kg BW shortages were calculated. The shortage of DM intake of growing diet was 29.1 % in Lowland areas, 28.6 % in Coastal areas and 38.5 % in Upland areas. The shortage of DM (kg/d) fed to growing pigs of 50-90 kg body weight in the three zones Lowland, Coastal and Upland were 49.3, 48.5 and 44.3 %, respectively. The crude protein content of diets fed to growing and fattening pig was deficient for all regions. The shortage of crude protein in the growing diets was 62.1 % in Lowland areas, 66.4 in Coastal and 69.7 % in Upland areas. The shortage in crude protein in fattening diets in Lowland, Coastal and Upland regions was 68.2, 71.9 and 74.7 %.

Table 3. Amount feed given for pregnant, lactating sows and fattening pigs in different ecological parts of Central Vietnam.

Variable	Pregnant sows				Lactating sows				Fattening pigs			
	Lowland	Coastal	Upland	SEM	Lowland	Coastal	Upland	SEM	Lowland	Coastal	Upland	SEM
Number interviewed households	150	150	150	-	150	150	150	-	150	150	150	-
Rice (kg)[1]	0.66^{a}	0.59^{b}	0.25^{c}	0. 005	1.30^{a}	1.10^{b}	0.50^{c}	0.003	0.60^{a}	0.34^{b}	0.20^{c}	0.002
Rice bran (kg)[1]	0.68^{a}	0.59^{b}	0.50^{c}	0.006	0.60^{a}	0.70^{b}	0.90^{c}	0.002	0.45^{a}	0.44^{a}	0.50^{b}	0.003
Cassava meal (kg)[1]	0.41^{a}	0.45^{b}	0.60^{c}	0.003	0.25^{a}	0.50^{b}	0.60^{c}	0.003	0.20^{a}	0.30^{b}	0.40^{c}	0.002
Sweet potato vine (kg)[1]	0.50^{a}	0.70^{b}	0.10^{c}	0.004	0.80^{a}	0.50^{b}	0.20^{c}	0.005	0.12	0.10	0.10	0.003
Banana stem (kg)[1]	0.10^{a}	0.20^{b}	0.40^{c}	0.002	0.20^{a}	0.30^{b}	0.60^{c}	0.002	0.10^{a}	0.23^{b}	0.40^{c}	0.002
Salted fish (kg)[1]	0.10^{a}	0.15^{b}	0.05^{c}	0.001	0.10^{a}	0.05^{c}	0	0.001	0.01	0.02	0	0.001
Pre-mixed feed (kg)[1]	0.10	0	0	-	0.15	0	0	-	0.05	0	0	-
Amount feed (kg DM /pig /d)	1.92^{a}	1.77^{b}	1.53^{c}	0.035	2.94^{a}	2.52^{b}	1.98^{c}	0.033	1.31^{a}	1.33^{a}	1.17^{b}	0.023
Crude protein (g/d)	173	145	98	-	284	246	148	-	127	112	101	-
Lysine (g/d)	8.00	7.70	5.00	-	10.14	9.10	6.38	-	4.40	3.70	3.46	-
DE intake/animal/d (kJ/d)	24,673	22,757	21,514	-	38,454	34,272	25,705	-	17,395	17,804	15,947	-

[1] As amount of kg of product intake/d.

NRC 1998: DE content of diet (kJ/kg): 14,230 kJ. Nutrient requirement for gestation sow 125 kg BW: Feed intake: 1.96 kg DM/d, Energy: 27,890 kJ DE/d; Protein: 253 g/d. Nutrient requirements for lactation sows of 125 kg BW: Feed intake: 4.31 kg DM/d, Energy: 61,331kJ DE/d, Protein: 703 g/d. Nutrient requirement for fattening pigs of 50-80 kg BW: Energy: 36,654 kJ DE; Feed intake: 2.575 kg DM/d, Protein: 399 g/d.

[a, b, c] Means with different superscripts within rows differ and within type of pig ($p<0.05$, 0.01, 0.001).

Table 4. Deficiency of energy and nutrients intake for fattening pigs as % of requirements.

Item	Region								
	Lowland			Coastal			Upland		
	Sufficient	Shortage %	Amount shortage	Sufficient	Shortage %	Amount shortage	Sufficient	Shortage %	Amount shortage
Growing Pig of 20-50 kg BW									
DE (kJ/d)	No	36.1	9,542	No	32.6	8,593	No	39.6	10,450
DM intake (kg/d)	No	29.1	0.54	No	28.6	0.52	No	38.5	0.71
CP (g/d	No	62.1	205	No	66.4	219	No	69.7	230
Lysine (g/d)	No	74.9	13.1	No	78.9	13.8	No	80.2	14.0
Ca (g/d)	No	54.0	4.1	No	64.0	4.9	No	66.0	5.0
P (g/d)	No	31.0	4.9	No	39.0	6.2	No	41.0	6.5
Fattening pig of 50-90 kg BW									
DE (KJ/d)	No	52.5	19,242	No	51.4	18,838	No	56.5	20,695
DM intake (kg/d)	No	49.3	1.27	No	48.5	1.25	No	44.3	1.14
CP (g/d)	No	68.2	272	No	71.9	287	No	74.7	298
Lysine (g/d)	No	77.7	15.3	No	81.2	16.0	No	82.5	16.3
Ca (g/d	No	61.4	9.8	No	54.4	8.7	No	40.3	6.5
P (g/d)	No	29.3	3.9	No	13.1	4.4	No	27.6	3.7

NRC 1998 requirement: DE content of diet (kJ/kg): 14,230 kJ. Growing pig of 20-50 kg BW estimated feed intake 1.855 kg DM/d, energy: 26,397 kJ DE, crude protein: 330 g/d and total lysine 17.5 g/d. Fattening pig of 50-80 kg BW estimated feed intake 2.575 kg DM/d, energy: 36,642 kJ DE; crude protein: 399 g/d and total lysine 19.7g/d.

Similar to the composition of feedstuffs given to fattening pigs, we also estimated the nutritive value of feedstuffs for pregnant and for lactating sows. The data in Table 5 show that feed fed to pregnant and lactating sows was not only provided in low amounts but the feed also had a low nutritive value. The shortage of DM intake (kg/d) of pregnant sows raised in the Lowland, Coastal and Upland areas were 2.0, 9.7 and 21.9 %, respectively. The shortage of crude protein of pregnant sows in these three zones was 31.6, 42.7 and 61.3 %, respectively. The shortage of DM intake (kg/d) of lactating sow raised in Lowland, Coastal and Upland areas was 31.8, 39.2 and 57.1 %, respectively. The shortage in crude protein in the lactating diets in Lowland, Coastal and Upland regions was 59.6, 65.0 and 78.9 %, respectively.

Table 5. Deficiency of energy and nutrients intake for reproductive sows raised in Central Vietnam.

Item	Region								
	Lowlands			Coastal			Upland		
	Sufficient	Shortage %	Amount Shortage	Sufficient	Shortage %	Amount shortage	Sufficient	Shortage %	Amount shortage
Gestating sows									
DE (KJ)/d	No	11.5	3,217	No	19.1	5,315	No	22.9	6,376
DM intake (kg/d)	No	5.0	0.1	No	9.7	0.2	No	22.0	0.4
CP (g)/d	No	31.6	80.0	No	108.1	42.7	No	61.3	155
Lysine (g/d)	No	29.8	3.4	No	32.5	3.7	No	56.1	6.4
Ca (g/d)	No	6.5	0.8	No	32.0	3.9	No	32.0	3.9
P (g/d)	No	30.0	4.8	No	39.0	3.6	No	29.0	2.3
Lactating sows									
DE (KJ/dl)	Lack	37.3	22,877	Lack	43.4	26,604	Lack	58.1	35,626
DM intake (kg/d)	Lack	31.8	1.4	Lack	39.2	1.7	Lack	57.1	2.5
CP (g/d)	Deficit	59.6	419	Lack	65.0	457	Deficit	78.9	555
Lysine (g/d)	Lack	71.3	25.2	Lack	74.2	26.2	Lack	81.9	29.9
Ca (g/d)	Deficit	34.5	7.4	Lack	40.0	6.5	Lack	42.0	6.7
P (g/d)	Deficit	22.9	3.8	Deficit	28.0	3.2	Deficit	38.0	5.3

NRC (1998) requirement: DE content of diet (kJ/kg): 14,230, Gestation sows estimated feed intake as 1.96 kg DM/d, Energy: 27,890 kJ/d, Crude protein: 253 g/d and total lysine: 11.4 g/d. Lactation sows estimated feed intake as 4.31 kg DM/d, Energy: 61,331 kJ DE/d, Crude protein: 703 g/d. and total lysine 35.3 g/d.

PIG HOUSING OF SMALLHOLDERS IN CENTRAL VIETNAM

Most pig houses in Central Vietnam are simple constructions and show a great variation. Pig housing in the Upland areas of Van Kieu, Taoi, Muong keep pigs as scavengers and occasionally confine them in paddocks or in wooden or bamboo-made pens. Pig housing in Lowland and Coastal areas are often in enclosed pens with a concrete floor. Walls between the pens and the slatted floor manure collection pit are made from brick while the roof is mostly made from iron sheet and clay tiles or fibro-cement on a framework of timber or bamboo stems. Almost all farmers keep the gilts and sows in the same place from pregnancy, farrowing and lactation until weaning of piglets. Manure is not stored. Natural ventilation of pig housing system in Central Vietnam is associated with the local micro-climate and affects animal welfare. The average temperature in Lowland, Coastal and Upland areas is about 25.9, 25.3 and 24.5°C with a relative humidity of about 82.6, 83.4 and 84.2 % respectively. In the wet season, the mean minimum temperature for Lowland, Coastal and Upland areas was about 19.5 18.2 and 17.3°C and the mean maximum temperature for these areas was about 26.2, 25.3 and 23.4°C, respectively. Mean minimum relative humidity during the wet season for these regions was 71.5, 72.7 and 75.8 % and the mean maximum relative humidity was 92.7, 95.3 and 95.7 %, respectively. In the dry season, the mean monthly minimum temperatures for Lowland, Coastal and Upland areas was 25.9, 24.5 and 23.7°C and the mean monthly maximum temperature was 35.2, 33.5 and 31.7°C, respectively. Mean monthly minimum relative humidity in the three zones was 57.8, 58.7 and 61.5 % and the mean maximum relative humidity was 84.7, 87.7 and 86.3 %, respectively.

Farmers were asked to identify the constraints responsible for their fragile pig production situation and to suggest possible solutions to alleviate these constraints. Obviously, many factors contribute to poverty of the farming family. Pig breeds, nutrition and housing do not directly contribute much to their wealth. The survey identifies the need of an integrated approach to improve pig production and living standards of rural smallholders in Central Vietnam. Scientific, technical, social and economic research involving all aspects of animal production systems (animal genotypes, nutrition, human and environmental condition interactions) is a great challenge for researchers.

DISCUSSION

In the context of social science, peasant societies are described as communities rather than as single individuals or households. Communities are halfway between the traditionally agricultural and industrial society. In the peasant society the household is an important social unit because within it the decisions concerning the activities of the individual members and their consumption (and thus their welfare) and their social status are made (Ellis, 1993).

The median farm size of 0.62 to 1.17 ha was small and this was attributed to the natural ecological zone of the study sites and the land-tenure system of inheritance (with subsequent subdivisions). In common with other reports on smallholder farming systems (Gitau et al., 1994; Simon et al., 1999), the smallholder pig farmers also kept other livestock and grew cash and subsistence crops. Most farms depended on family labor for pig production and had an off-farm income activity as has been observed previously on smallholder dairy farms (Schaik van et al., 1996). Present study showed that oversupply of labor in all region lead to low wages and average income/ household/day was about 61,900 to 84,000VND (about 5 to 6 USD/day).

The large importance of pigs in customs and traditions was probably brought about by scarcity. Fish, vegetable and fruit were relatively plentiful, available and provided every day and these pigs are reserved for momentous and important occasions. The keeping of village pigs is still a non-commercial activity illustrated by the small size of herds, the frequent change in ownership, and generally poor nutrition.

The results of our study show a low production output for different zones in Central Vietnam. This is clearly related to low input. Feeding just a small amount in an unbalanced way causes a low performance of sows and of fattening pigs raised in smallholder farms in Central Vietnam. The most common factor is the insufficient supply of nutrients with the feed. This makes it impossible to reach a good production level. The differences between high and low quality-feeds are mainly with regard to energy and protein supply. This low supply of energy and nutrients is undoubtedly the greatest limit to production of pigs in Central Vietnam. Also the pigs are fed the same materials as people consume, so they are in direct competition with humans for food (paddy rice).

The availability and utilization of feedstuffs varies greatly according to geographical region. Farmers tend to use whatever is available and reasonably palatable, including commercial feed, crop products and by-products, kitchen waste and fresh forages. From the two surveys of Tran et al. (2003) and Hoang (2003), it is clear that in rural areas, the use of by-products from crop production as feedstuffs is common in particular rice bran is used. The use of rice bran is very common because wet and rain-fed rice cultivation is practiced throughout the country.

The production system used throughout the country and thus also in Central Vietnam is a traditional one with a local breed pig that is fed crop by-products, crop residues and or/ any green material produced in the home garden or nearby areas (Vo et al., 1995). Costs and net returns are both very low in this system. Green forage is also provided as a significant part of the pig's diet by many smallholders, particularly in Upland area. Forage provides up to 25 % of the energy (ME) for fatteners and 40 % for pregnant sow in these areas (Le, 1998). Since a vitamin premix- is not added to the daily pig diets, green forage is the major source of vitamins for village pigs. There are shortages of nutrients in pig feed and the higher the body weight, the larger the shortage of DM is. Particularly, more than 50 % in DM and CP is lacking in the lactation diets.

There was close similarity between pig breed and pig feeding regimen seen in three regions in this study. There is a great importance of pigs in customs and in traditions and this was probably brought about by the scarcity according to de Fredrick and Osborne (1977). Central Vietnam has a variety of pig breeds of which some lean breeds like Large White, Landrace and some are not considered lean breeds like local breeds as Mong Cai, Co, VanPa. The indigenous breeds survive well in local conditions but they show a low productivity (Pham et al., 2007). The pigs on the farms were local pigs and F1 were mainly crossbreds of (Large White or Mong Cai) or (Landrace × Mong Cai) and only a few farmers possessed more than one sow (Pham et al., 2007). Such breeds perform well under tropical conditions if they are properly managed (de Fredrick and Osborne, 1977; Kunavongkrit and Heard, 2000). Most farmers in the current study do not keep a breeding boar because their sows are served by artificial insemination. Similar observations have been made in other tropical smallholder farms (Gatenby and Chemjong, 1992; Lanada et al., 1999). Most pig farmers did not seek extension information about pig farming and this might explain the poor pig-management practices observed.

During our investigations, we found that pig houses on smallholder farms in Central Vietnam are simple and show a great variation. The pig housing is constructed from local available materials and constructed in a traditional way. According to

Astroem (2000), the prevailing systems in rural areas are free-range systems or housing in simple pens, both with a minimum of inputs.

The constraints to pig production as perceived by the farmers in the current study were largely in accordance with findings in other tropical smallholder pig-production systems (de Fredrick, 1977; Kambarage et al., 1990; Gatenby and Chemjong, 1992; Lanada et al., 1999; More et al., 1999; Kunavongkrit and Heard, 2000). The production constraints might hinder improvement to productivity of pigs raised by the smallholder farmers.

The survey of the 150 farmers who raised only fattening pigs and the 150 farmers who raised only reproductive sows in the three zones, we found some differences in the number of fattening and number of sow/farm (compared to the average number of pig/household for the three zones). The questions about the reason for these differences were answered by the interviewed farmers. Pigs are raised in Lowland and Coastal areas more than Upland areas because these are main areas of rice and cassava production which are feed sources for pig production. The farmers of the regions responded differently with regard to cash money, meat consumption and also practical experience of animal husbandry. That was also an effect of the way they believe pork prices change and whether they can sell surplus pigs at a good price.

Only a few farmers kept written records. All survey data, except objective measurement such as weight or other measures that enable estimation of weight were based on information provided by each participating pig farmer. Because only a few farmers kept any written records about management or production, these data were generally based on recall. Although this data could not be all verified, we judge the accuracy of the dataset to be reasonable.

Firstly, in common with the principles underpinning participatory rural appraisal (Young, 1993), we have considered smallholder farms to have substantial knowledge about the few animals they have under their care. Secondly, although recall of some questionnaire issues (notably: the birth dates of growing animal) may be subject to considerable error, misclassification has been minimized by dichotomizing continuous variables wherever appropriate. This approach is particularly reflected in our analytical method. Although statistical power was reduced we elected to use logistic (with the outcome being dichotomized weight-for age) rather than multiple regression to minimize misclassification that may have resulted from inaccurate estimates of age. Most of the data collected during the cross-sectional study (such as level of ownership, piglet management procedures) were likely to change a slightly (if at all) over time. Relevant questions were phrased to specific periods of interest.

Similarly with previous studies (Slater et al., 1992; Wilesmith et al., 1992 Wittum et al., 1994) there is a problem with accurate assessment of some nutritional information. During this study we collected those data about diets that likely influenced weight at a certain age. These data include basal feedstuffs (the feed that forms the largest part of diet weight) and the use of commercial feeds, green feeds and any protein sources. These data were collected from all farms. We considered that the use of commercial feeds or not and the inclusion of some source of protein was indicative of a long term trend. The key problems in feed supply may be: i) inadequate supply of amounts of protein and or amino acids ii) lack of knowledge of fatty acid composition of feeds iii) lack of understanding of the level of concentrates or supplements required in a diet iv) appropriate level of feed energy for pigs at each live stage. To improve the quality of feed for pigs, it is essential that farmers first know the requirements of the animals. So it will be best to train the farmer on this aspect of pig husbandry. A number of opportunities have been identified for improvement of the production of smallholder pig farms in a sustainable way. The formulation of appropriate and cost effective diets proved problematic, particularly because of considerable overlap in feedstuffs consumed by pigs and people (de Frederick and Osbone, 1977). Nonetheless, significant improvements in growth rate have been achieved when more attention was paid to the nutritive value of locally grown feedstuffs and to the value of added vegetable protein, fish and shrimp -by product and sources rich in energy e.g. carbohydrate rich feeds like cassava and sweet potato.

The strategies to promote increased pig production by providing more nutrient-rich feeds would be more effective when combined with a nutrition education intervention. This ensures that increased household food supply and income translates into improved dietary quality for pigs. Nutritional interventions generally focuses on increasing knowledge level, changing attitudes, and improving practices related to good nutrition, namely health care, and dietary intake. Our results show that very few farmers were trained on pig husbandry, especially the farmers in the Upland areas. It is thought that swine nutrition education can stimulate the demand for certain foods, but the farmer must have the means and opportunities to act on that knowledge.

In a previous study of Honeyman (1991), several opportunities were provided to enhance sustainability, including: i) feeding with increased use of forage and by products ii) nutrient cycling through improved handling of manure iii) low capital but higher quality of animal houses that offer a better environment for operator and animals iv) preventative approaches to reduce swine health risks and v) use of a broader genetic base. In the long term a sustainable pig production system should maintain or enhance the environment and natural resources (land, water, human, and feedstuffs), increase welfare for producer, serve the market, meet pork consumer demands, and social aspects.

The small scale of pig production in Central Vietnam is not only due to small farm houses but according to the interviewed farmers it is also due to the lack of capital for investment. Lack of technical knowledge and husbandry experience were reasons of making feed which does not have a proper nutritional quality for the animals. Low amounts of capital for housing and for the provision of sufficient quality feed and thus the situation of deficiencies in nutrient supply by feeds provided to the animal are considered by the farmers as a main reason for low yields of animal production and the low income of farmers in Central Vietnam.

IMPLICATION

Increased feed supply will undoubtedly help to develop pig production in Central Vietnam and this will result in increased income for farmer and better nutrition of people in rural area. To solve the situation of low quality pig feed in smallholder pig farms, there are some possibilities to improve the amounts of nutrients consumed by the pig. One such solution is to have feed in front of the animals for a longer time of the day so they can ingest more energy and protein. The optimum nutrition of pigs on smallholder farms would be to provide highly balanced rations which may include supplements or growing particular crops to be used as supplements to standard feeds.

Education to farmers should be given a high priority and linked with the supply of financial means to apply the knowledge in practice. Better understanding of nutritional requirement is essential to increase production.

Basic cost-efficient housing for small-scale farms should be studied with emphasis on heat control and disease prevention. Farmers require simple units and be able to use locally available materials to provide cheap solutions to be implemented.

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3

EFFECT OF GENOTYPE AND DIETARY PROTEIN LEVEL ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF FATTENING PIGS IN CENTRAL VIETNAM

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ABSTRACT

This study aimed to determine the optimum dietary crude protein level in a typical diet for ad libitum fed fattening pigs under normal climate conditions in Central Vietnam. One hundred and ninety two gilts of Mong Cai local breed (MC), F_1 (Large White×Mong Cai) and F_2 crossbreds of ((Landrace×Mong Cai)×Large White) were used. At the start of the experiment, Mong Cai pigs weighed 12 kg at 11 weeks of age, F_1 pigs 12.1 kg at 8 weeks of age and F_2 pigs 12.2 kg at 8 weeks of age. Four diets differing in crude protein (CP) content (10.1, 13.1, 16.1 and 18.9 % in DM) were formulated from the ingredients: rice bran, corn meal, cassava meal and fish meal. Calculated digestible energy content of the diets ranged from 13.5 to 13.8 MJ per kg DM. Pigs were housed individually in pens of 2.5 m^2 each and had ad libitum access to feed in a trough as well as to water in bowls. The final weights after a growing period of 150 days were 66, 86 and 96 kg for MC, F_1 and F_2, respectively. Feed intake of MC pigs was highest at 13.1 % CP while F_1 and F_2 had the highest feed intake at 16.1 % CP. The results showed that for MC the maximum gain was obtained at levels between 13 to 16 % CP. For the F_1 the maximum gain was at dietary protein levels of 16 to 17 %. For F_2 the max gain was obtained at CP levels of 16 to 18 %. Feed conversion was highest in MC pigs (~4.0) followed by F_1 (~3.3) and F_2 (~3.1) and within genotypes was lowest at the optimum CP level ($p<0.05$). Back fat thickness in MC (33.1 mm), F_1 (23.0 mm) and F_2 (20.5 mm) pigs was different and within genotypes was the lowest at intermediate CP levels. In conclusion, increasing the dietary crude protein contents in practical diets for pigs in Vietnam can increase the production on small holder farms. Optimal performance for MC, F_1 and F_2 pigs is achieved at different dietary crude protein contents.

INTRODUCTION

In recent years, pig production in Vietnam has seen the use of more lean genotypes of pigs for meat production and as a result fattening performance and carcass value have increased (Pham et al., 2000). Pure lean type pigs and local breeds are very different in terms of lean meat percentage. Warriss et al. (1983) showed that different genotypes may respond differently to various environmental factors. There is evidence (Pham et al., 2010) that conditions in Central Vietnam may not be well suited for the production of pure lean types of pigs. Therefore crossbreeds between lean type of pigs and local breeds are often used e.g. an F_1 with (Large White or Landrace×MC) and an F_2, a three breed crossing of ((Large White×MC)×Landrace) or ((Landrace× MC)×Large White) to produce fattening pigs. The main reason for the latter is to improve performance and carcass traits. Growth rate and carcass traits however, are not only influenced by genotype and environment but also by nutrition, especially by dietary protein (i.c. amino acid) content. Cromwell et al. (1993) found that increasing the dietary protein or lysine level resulted in improved rates of gain and in increased carcass leanness in gilts.

Campbell et al. (1985) reported that increasing the dietary crude protein level results in less fat deposition in the carcass of pigs at a similar metabolizable energy intake. It is apparent that under practical farming conditions, pigs of a particular strain/breed may not achieve their maximal protein gain (Pdmax) as determined under almost ideal research/laboratory conditions. The environmental, nutritional and social circumstances of pigs held at most farms and especially in Vietnam, are less than optimal (Burrin 2001). The term “operational Pdmax” has been introduced and represents the Pdmax value determined on farm (Moughan et al., 1995). Lysine is the first limiting essential amino acid in practical diets for pigs in Vietnam. This is especially true for pigs that are raised by smallholders in an extensive system where local feeds are used. From a survey of pig production at smallholder farms, Pham et al. (2010) concluded that nutrition is the main reason for the low level of production of Large White×Mong Cai pigs. The ADG for pigs raised on smallholder farms in Vietnam is approximately 330 g/d (Pham et al., 2010) while an ADG of 400-500 g/d can be achieved under these conditions if compound feeds are used. Sundrum et al.

(2000) reported a very high fat content in fattening pigs fed compound diets indicating that the protein to energy ratio of the feed used was unbalanced and did not allow optimal protein deposition and feed efficiency.

The aim of the present study was to obtain the optimum dietary crude protein content for different genotypes of female pigs commonly used in Vietnam to optimize performance. The hypothesis was that different genotypes will require a different dietary crude protein level to obtain the maximum rate of protein gain during fattening under practical environmental conditions.

MATERIALS AND METHODS

ANIMALS

Animals of three different genotypes, commonly used in Vietnam were compared in this study namely: Mong Cai (MC), a local breed widely used in all regions of Vietnam; F_1, a crossbred between Large White and MC and F_2, a crossbred between F_1 (Landrace x Mong Cai)×Large White. All animals originated from the Central Pig Breeding Company (National Trieu Hai farm) in Quang Tri, Vietnam. The Large White and Landrace were offspring of boars which had been imported previously from Australia.

A total of 64 female animals per genotype were used. The reason of using female pigs in this study that was at the breeding farm only females pigs were available, and as such the effect of gender on dietary crude protein level could not be investigated. Average initial weight of the MC pigs was 12.0 kg at 11 weeks of age while the average initial weight of the F_1 was 12.1 kg at 8 weeks of age. The initial weight of the F_2 was 12.2 kg at 8 weeks of age. Upon arrival each pig of each genotype was randomly assigned to one of four levels of dietary protein (10, 13, 16 and 19 %) and fed their respective diet throughout the growing period until slaughter. The design was a 3 by 4 factorial with 3 genotypes and 4 CP levels.

HOUSING

All pigs were housed individually at the experimental facilities of Hue University, Vietnam in a naturally ventilated fattening unit containing a series of 2.5

m^2 pens enclosed by two open walls above 1 m, an iron roof (3.6 m) and a solid concrete floor. The pigs were exposed to natural ambient temperatures and lighting. The temperature during the experiment (spring-summer season) ranged from 20 to 28°C with an average temperature of 25°C. Pigs were randomly distributed to pens within each half side of the fattening unit according to genotype and dietary treatment.

DIETS AND FEEDING

Four nearly isocaloric (on a GE and DE basis) diets containing: 10, 13 16 and 19 % CP on a DM basis were formulated and fed throughout the 150 days study until slaughter of the pigs. The diets were formulated using four major ingredients; rice bran, corn meal, cassava meal and fish meal. These compounds constituted approximately 98.5 % of the diet (Table 1).

Table 1: **Ingredients and analyzed chemical composition of the four experimental diets.**

Ingredient (%)	Dietary Crude Protein (%)			
	10	13	16	19
Rice bran	45.0	39.5	30.2	36.5
Corn meal	31.5	29.0	30.0	29.0
Cassava meal	20.0	20.0	20.0	10.0
Fish meal (44 % CP)	2.0	10.0	18.3	23.0
Vitamin-premix[1]	0.5	0.5	0.5	0.5
Mineral-premix[2]	0.5	0.5	0.5	0.5
L-lysine[3]	0.5	0.5	0.5	0.05
Crude protein (g/kg DM) (analyzed value)[4]	101.3	130.7	161.4	189.2
GE (MJ/ kg DM)	17.3	17.2	17.1	16.9
DE (MJ/ kg DM)[5]	13.8	13.7	13.6	13.5

[1] Supplied per kg diet: 0.24 mg folic acid, 1380 IU Vitamin A, 180 IU Vitamin D_3, 11 IU vitamin E.
[2] Supplied per kg diet: 108 mg Zn (as ZnO), 108 mg Fe (as Fe_2SO_4), 60 mg Mn (as MnO), 65 mg Cu (as $CuSO_47H_2O$), 0.96 mg I (as $Ca(IO_3)_2$, 0.11 mg Co (as $CoSO_47H_2O$), 0.07 mg Se (as Na_2SeO_3), 2 g calcium phosphate (as $CaHPO_42H_2O$).
[3] HCL Lysine, manufactured by CJ CHEILJEDANG Cooperation, Seoul, Korea.
[4] CP value analyzed by laboratory of Animal Nutrition of Hue University of Agriculture and Forestry.
[5] Calculated using digestibility values of individual ingredients from the NIAH (2001).

The diets were formulated using the nutrient composition as provided by the NIAH (2001). The digestible energy (DE) content of the diets was calculated from the analyzed feed composition and assuming digestibility values of the feed ingredients used as provided by the NIAH (2001). Pigs had *ad libitum* access to feed from a bin as well as to fresh water from bowls. Animals were weighed each month and at slaughter. Average daily feed intake (ADFI) was determined by frequent weighing of the feeding bins. Feed conversion ratio (FCR) was calculated from the ADFI and weight gain (ADG). Feed ingredients were analyzed in triplicate for DM, GE and CP at the animal nutrition laboratory of Department of Animal Nutrition of Hue University, Vietnam. For determination of DM content, feed was freeze-dried and DM determined according to ISO (1998). Crude protein content was determined as Kjeldahl N×6.25 according to ISO (1997).

CARCASS DATA

Food was withheld for one day before each pig was slaughtered at precisely 150 days after the start of the study. The pigs were electrically stunned and slaughtered according to normal commercial practice. Eight pigs were randomly chosen from each treatment groups and used for carcass testing. The carcasses of the eight pigs within each treatment group were weighed and chilled at 4°C before physical dissection (as described by Neito et al., 2003).

Briefly, middle line backfat measurement was made at the fist rib, last rib and at the last lumbar vertebrae. Carcass measurements collected in the cooler included: dressing percent, average backfat thickness (mm), (at first rib, last rib, and last lumbar vertebra) depths, and at a point 6.5 cm from the midline at the last rib (P2). Carcass length was measured from the anterior edge of first rib to anterior edge of pubic bone (in cm) immediately after slaughter. The longissimus loin eye area (in cm^2) was measured at a point ¾ the length of the muscle from the medial side at the 10^{th} rib ham yield in relation to pork/leg. One half of the carcass was subjected to physical dissection as described by Nieto et al. (2003). The shoulder was separated from the loin and belly by a straight cut between the second and third rib and a straight cut 2.5 cm ventral to the ventral edge of the scapula. The ham was removed from the loin by a straight cut between the second and third sacral vertebrae approximately perpendicular to the shank bones. Each cut retained its corresponding skin and subcutaneous fat. The loin was separated from the belly by a cut that began just ventral to the ventral side of the scapula at the cranial end and followed the natural curvature of the vertebral column to the ventral edge of the psoas major at the caudal end of the loin. The weight of each cut was determined. After weighing, shoulder and ham were separated by knife into skin, subcutaneous fat, intermuscular fat, muscle (including blood vessels, ligaments, tendons and connective tissue) and bone. Carcass lean and fat ratio (%) was calculated from total weight half carcass (not included head and feet) and lean ratio in this half after dissection, included (%) lean, fat, bone and skin.

PROTEIN AND FAT DEPOSITION CALCULATIONS

The deposition rate of protein and fat in the empty body of the three genotypes were calculated assuming one gram of protein and fat contained 23.4 and 39.7 kJ of energy, respectively and ME intake = DE intake×0.96 (NRC, 1998). The following two equations were used:

ME intake = MEm+MEp = MEm + cP + dF (1)

0.9ADG = F+P/0.21 (2)

in which MEm is the energy required for maintenance (460 kJ of ME per kg of metabolic body weight, $W^{0.75}$), MEp is the energy required for production, c represents the amount of ME needed for the deposition of 1 g of protein (= 53kJ), P is the amount of protein deposited (g/d), d represent the amount of ME needed for the deposition of 1g of lipid (= 53kJ) and F is the amount of fat deposited (g/d).

STATISTICAL ANALYSES

The data (initial weight, final weight, ADFI, ADG, FCR, back fat measurements) were statistically analyzed by the ANOVA procedure using GLM-multivariate analysis. The experimental data were analyzed to include genotype and protein level as factors according to the model:

$Y_{ijk} = \mu+G_i+P_j+GP_{ij}+e_{ijk}$

in which Y_{ijk} is the observed value of the dependent variable of individual k of genotype i and dietary protein level j, μ is the overall mean, G_i is the effect of genotype i = $1\rightarrow3$, P_j is the effect of dietary protein level j = $1\rightarrow4$, GP_{ij} is the interaction between G and P, and e_{ijk} is the random error associated with each observation (0, σ^2), k = 1→n.

A model with quadratic terms was fitted to the feed intake, ADG, FCR, back fat thickness and lean percentage data with crude protein content as the independent variable. If the coefficient of the quadratic term was significantly different from zero, a cubic model was fitted for describing the relationship. In no instance was the quadratic term non-significant. The derived quadratic and cubic polynomial equations were used to determine the optimum dietary protein levels for several traits. All statistical analyses were performed in SAS version 9.1.3 (SAS Institute Inc., Cary, NC, USA) with a probability level of 5 % being regarded as significant.

RESULTS

All pigs remained healthy and finished the 150 day study. The effects of the dietary crude protein concentration on the performance of the different genotypes are presented in Table 2. Final weights, ADG, ADFI and FCR after 150 days of fattening were significantly different between the different genotypes of pigs and across the four crude protein concentrations. MC pigs were performing worst than the F_1 and the F_2 genotypes. In the case of carcass length and dressing percentage across crude protein levels, there was no significant difference between the F_1 and F_2 genotypes. Highly significant effects were observed for dietary crude protein level across the performance and carcass trait data. There was a significant interaction between genotype and crude protein concentration for the final weight, ADG, ADFI and FCR. Carcass traits were also significantly affected by an interaction between genotype and dietary crude protein level for back fat, longissimuss muscle length, dressing percentage, lean percentage and fat percentage with the exception of carcass length.

Figure 1 to 4 present the mean group values per genotype for ADG (Figure 1), ADFI (Figure 2), FCR (Figure 3) and back fat thickness (Figure 4) at each dietary crude protein level and the best fit curve. The equations, mean square error and coefficient of determination for each equation are presented in Table 3.

Table 2. **Growth performance and carcass characteristics of the three breed as affected by genotype and dietary protein concentration.**

Traits	Genotype (G)					Crude Protein (CP)	GxCP
	MC	F_1	F_2	Pooled SEM	Significance p<	Significance p<	Significance p<
Final weight (kg)	61.9[a]	87.2[b]	98.2[c]	0.37	0.001	0.001	0.001
ADG (g/d)	328[a]	500[b]	572[c]	2.6	0.001	0.001	0.001
ADFI (kg/d)	1.34[a]	1.75[b]	1.82[c]	0.01	0.001	0.001	0.001
FCR (kg/kg)	4.05[a]	3.49[b]	3.19[c]	0.02	0.001	0.001	0.001
Water consumption (L/d)	4.60[a]	5.30[b]	5.80[c]	0.03	0.035	0.259	0.175
Carcass length (cm)	66.4[a]	78.4[b]	80.0[c]	0.11	0.001	0.001	0.418
Back fat (mm)	33.1[a]	23.0[b]	20.7[c]	0.15	0.001	0.001	0.001
Longissimus muscle (cm^2)	22.9[a]	25.8[b]	27.4[c]	0.02	0.001	0.001	0.001
Dressing percentage (%)	67.8[a]	68.2[b]	69.6[c]	0.09	0.001	0.001	0.001
Lean percentage (%)	42.5[a]	44.5[b]	46.5[c]	0.04	0.001	0.001	0.001
Fat percentage (%)	37.6[a]	35.4[b]	31.6[c]	0.02	0.001	0.001	0.001

[abc] Means within rows for genotype and dietary crude protein level with different superscripts differ ($p<0.05$).
ADG = Average daily gain, ADFI = Average daily feed intake, FCR = Feed conversion ratio.

Table 3. Best fit models describing the effect of dietary crude protein content on growth performance and carcass characteristic variables for each of the three breeds of female pigs.

Parameter	Breed	Regression				MSE	R^2	Optimum
		X^3	X^2	X	Intercept			
ADG (g/d)	MC	-1.093	44.88	-591.4	2,829	13.5	0.84	14.45
	F_1	-0.794	33.04	-438.9	2,352	13.2	0.78	15.85
	F_2	-1.041	40.88	-500.7	2,457	12.0	0.95	16.41
ADFI (g/d)	MC	-	-2.282	67.86	845.2	39.6	0.22	14.89
	F_1	-1.450	61.73	-811.6	5,146	47.2	0.50	16.18
	F_2	-2.338	93.00	-1,151	6,169	61.2	0.83	16.65
FCR (kg/kg)	MC	0.011	-0.453	6.002	-21.49	0.15	0.79	16.30
	F_1	0.002	-0.095	1.263	-1.772	0.10	0.40	16.87
	F_2	0.001	-0.048	0.545	1.339	0.09	0.49	15.74
BF (%)	MC	0.024	-0.842	8.273	14.05	0.83	0.90	16.31
	F_1	0.025	-1.110	16.11	-52.66	0.34	0.70	14.47
	F_2	-0.015	0.730	-11.34	-74.80	0.63	0.87	14.12
Lean (%)	MC	0.013	-0.682	11.23	-16.46	0.33	0.91	13.82
	F_1	-	-0.112	3.296	21.63	0.09	0.99	15.54
	F_2	-0.016	0.614	-7.169	71.68	0.09	0.99	16.42

ADG=average daily gain, ADFI=average daily feed intake, FCR=feed conversion ratio, BF=backfat, Lean=percentage lean. All coefficients were significantly different from zero at $p<0.05$.

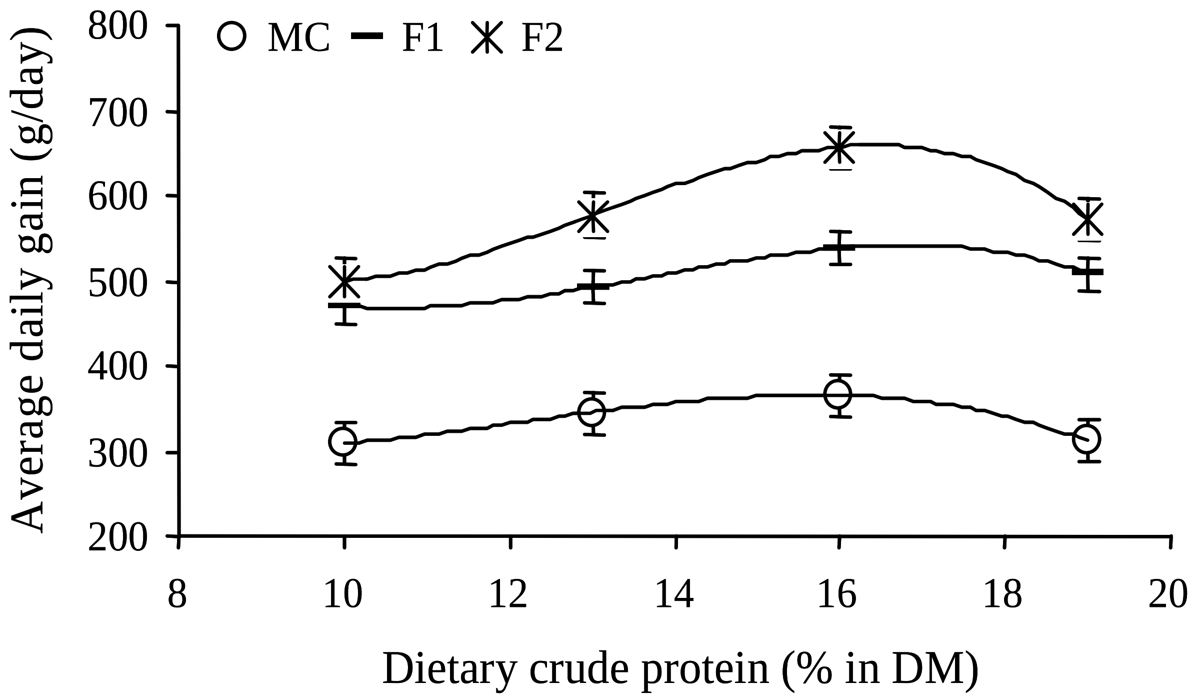

Figure 1. Effect of dietary crude protein content on average daily gain of the genotype (MC: Mong Cai, F_1: (LW×MC); F_2: (LD×MC)×LW) pigs.

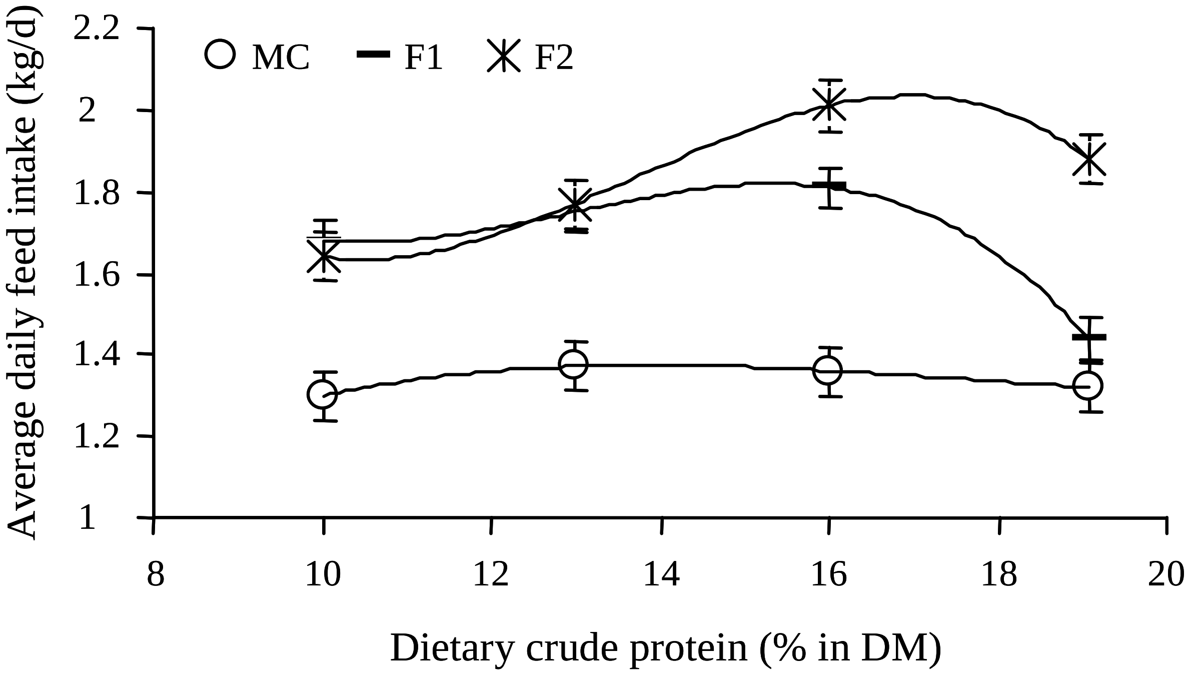

Figure 2. Effects of dietary crude protein content on feed intake of the different genotype (MC: Mong Cai, F_1: (LW×MC); F_2: (LD×MC)×LW) pigs.

The F_2 was the best performing genotype with the highest ADG, lowest FCR and lowest back fat thickness followed by the F_1 and MC. ADFI (Figure 2) increased for the F_2 and F_1 from 10.1 to 16.1 % dietary crude protein content and decreased at 18.9 % crude protein. The ADFI of MC was unaffected by the dietary crude protein content. The FCR of the MC showed a large increase at 18.9 % crude protein, reaching a similar level to the values recorded for 10.1 and 13.1 % crude protein. The back fat thickness for the MC ranged between 36.7 mm (10.1 % CP) and 30.1 mm (16.1 % CP) while the F_1 was relatively constant ranging from 22.5 to 23.1 mm. The back fat of the F_2 increased from 18.7 mm when the diet contained 13.1 % crude protein to 22.9 mm when the dietary crude protein content was 18.9 %. In all cases a cubic equation was found to best describe the relationship with the exception of ADFI of the MC pigs and lean percentage of the F_1 where a quadratic relationship was obtained. Table 3 also presents the dietary optimum crude protein levels as determined using the equations where ADG, ADFI, FCR, BF and lean percentage are either maximal or minimal. The optimal dietary crude protein content for maximum ADG was lowest for the MC (14.5 %, medium for the F_1 (15.9 %) and highest for the F_2 (16.4 %). The dietary crude protein content to minimize FCR was 15.7 % for the F_2, 16.9 % for the F_1 and 16.3 %

for MC. The maximum lean percentage for the F_2, F_1 and MC are obtained with a dietary crude protein content of 16.4, 15.5 and 13.8 %.

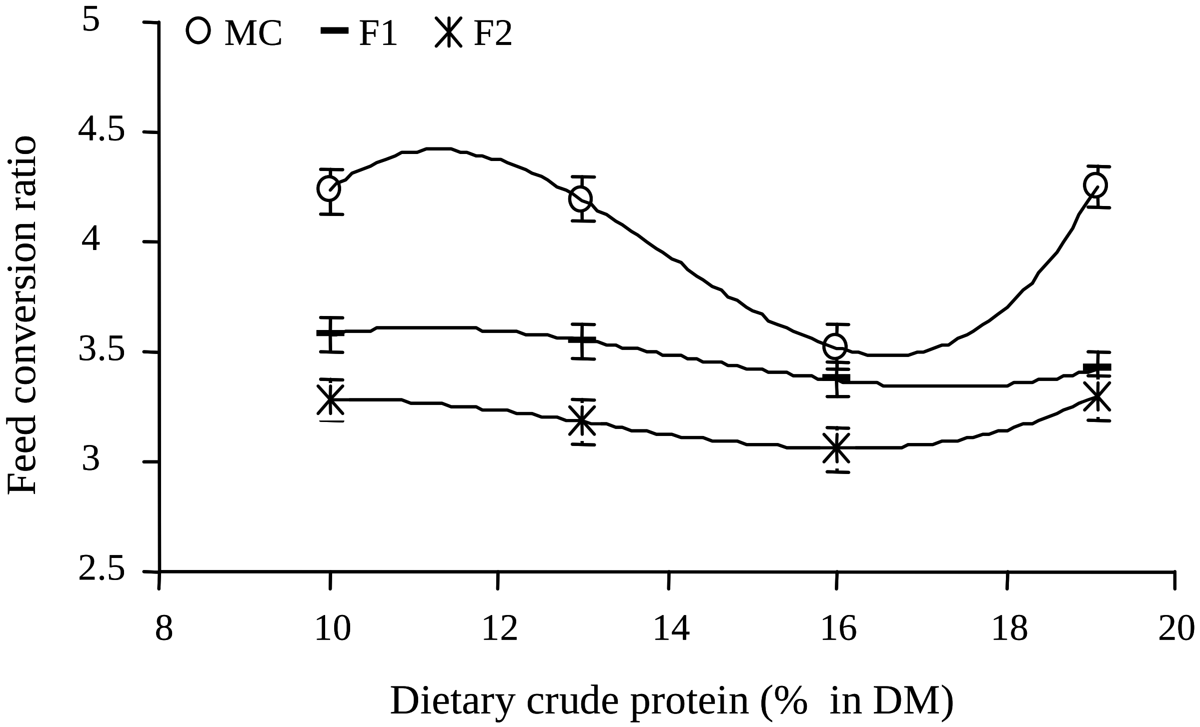

Figure 3. Effect of dietary crude protein content on FCR of the difference genotype (MC: Mong Cai, F_1: (LW×MC); F_2: (LD×MC)×LW) pigs.

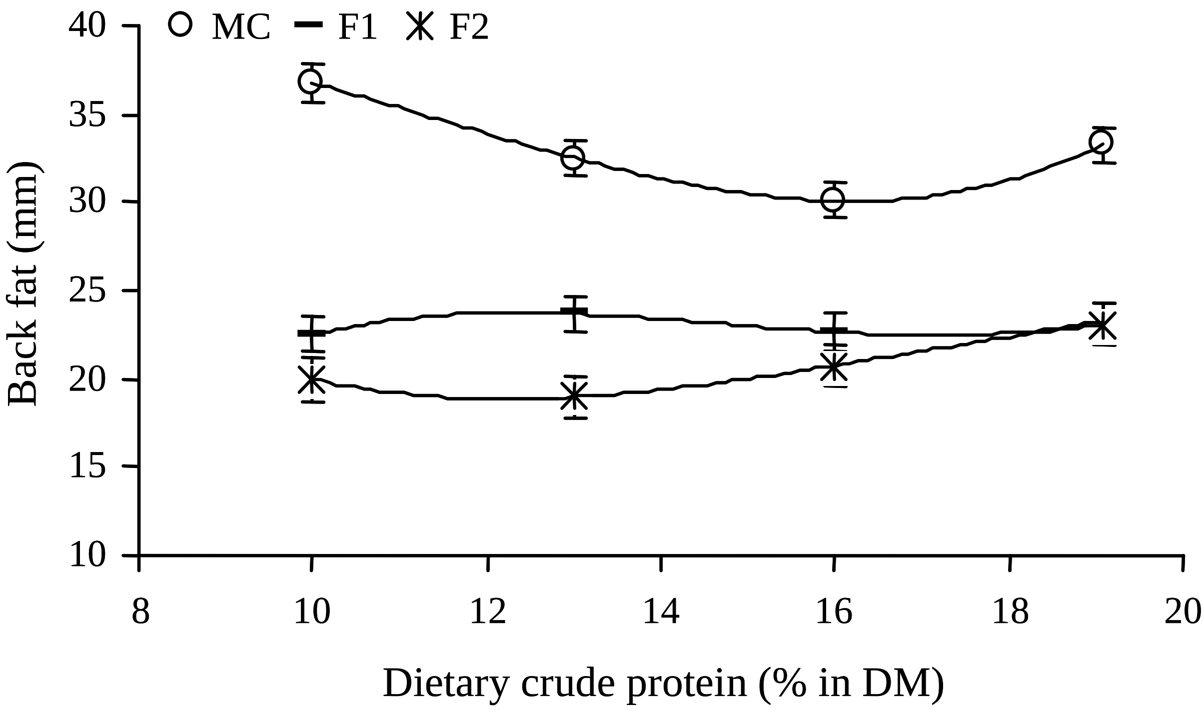

Figure 4. Effect of dietary crude protein content on back fat of the difference genotype (MC: Mong Cai, F_1: (LW×MC); F_2: (LD×MC)×LW) pigs.

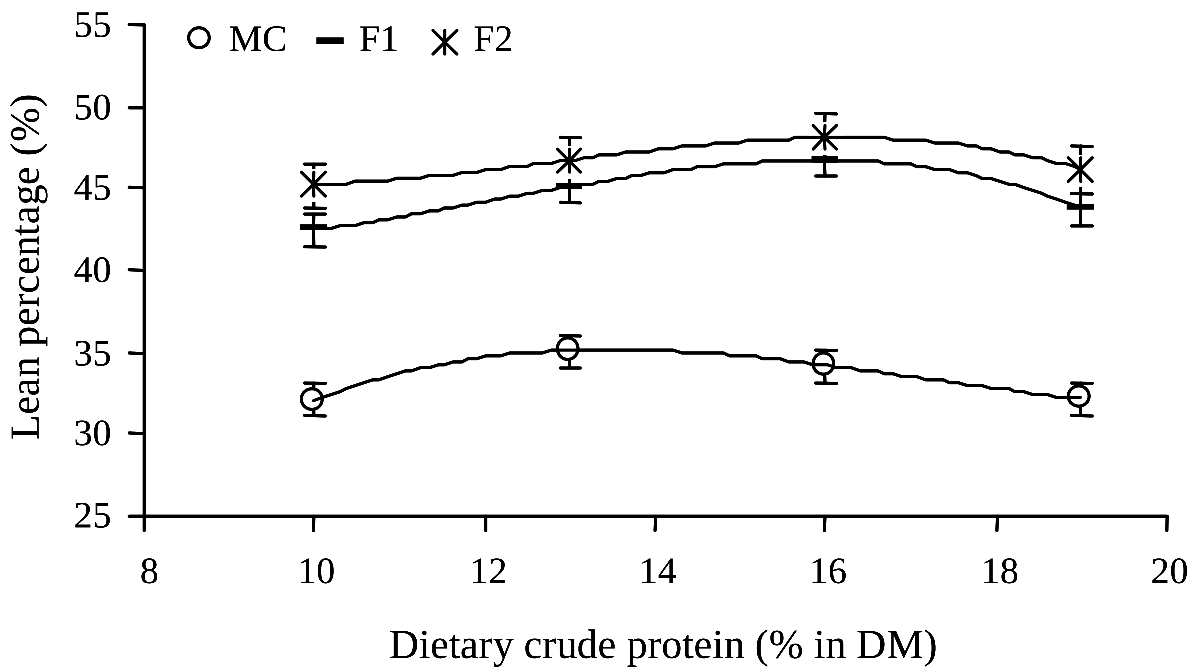

Figure 5. Effect of dietary protein content on lean percentage of the different genotype (MC: Mong Cai, F_1: (LW×MC); F_2: (LD×MC)×LW) pigs.

DISCUSSION

This study was conducted to determine the optimum dietary crude protein level for *ad libitum* fed fattening pigs commonly used in Central Vietnam under practical farming conditions. The main feed ingredients for pigs raised by smallholders are rice bran, cassava, sweet potato vine and corn meal while fish meal is used in smaller amounts. The dietary crude protein level in the diet of fattening pigs and sows is 8.5 to 10 % (Pham et al., 2010). The results of the present study show that crossbreds of Large White and Landrace with Mong Cai (F_1 and F_2) perform much better than MC pigs. The F_2 had the highest growth rate, and percentage of lean compared to the other genotypes. Different dietary crude protein concentrations were calculated to optimize specific growth performance parameters (Table 3) which can be used to optimize pig production of these 3 breeds in Vietnam.

In the present study, a reduced feed intake was observed at the highest dietary crude protein concentration (18.9 %) in all but especially the F_1 and F_2 pigs. A drop in feed intake and a concurrent reduction in growth performance was also observed in Duroc, Hampshire, Yorkshire in a studies by Tyler et al. (1983) and Holmes et al.

(1980) for boars and gilts of Landrace×Large White. Chen et al. (1999) recorded that ADG and ADG/ADFI decreased to a greater extent in Large White×Landrace and Duroc×Hampshire gilts compared to barrows when dietary protein concentration increased from 16 to 25 %.

These results are in agreement with those of Wagner et al. (1963). However, the results of Cromwell et al. (1990) indicate a greater reduction in performance by barrows when fed high-protein diets. The reason for the reduced feed intake when dietary crude protein content was 18.9 % in the present study could be related to the high level of fish meal used. The quality of the fish meal in terms of nutritional composition was typical for fish meal produced in Vietnam (NIAH, 2001). It cannot be excluded that the high inclusion level of fish meal in the high protein diet affected palatability of the diet causing a reduction in overall feed intake. Alternatively, the present study was conducted under practical conditions and the highest temperatures occurred towards the end of the fattening period. Average temperature and relative humidity recorded during the end of the study were >25°C and 87 %, respectively and these conditions may have affected daily feed intake. According to Quiniou et al. (2000), Renaudeau et al. (2004) and Huynh et al. (2005a,b), average daily food intake is strongly reduced when ambient temperatures are above 24°C and this negative effect of temperature is enhanced by a high relative humidity. Hansen and Lewis (1993) also found a reduced intake of high-protein diets by barrows and boars. Reductions in ADFI as CP concentrations were increased from inadequate to adequate levels have been noted by previous investigators (Baker et al., 1975; Irvin et al., 1975). It has been suggested that (Greeley et al., 1964) swine fed diets with low CP concentrations become hyperphagic in an attemp to sustain adequate protein (or amino acid) intakes. Hyperphagia results in a greater energy intake, enhancing the rate of fat accretion. When high protein diet are offered, animal become hyperphagic. Excess protein will be catabolised leading to the supply of energy and in the process leads to more heat per unit of digested energy compared to the heat generated from glucose/starch and fat. Besides the reduced voluntary feed intake, the growth-decreasing effect of high-protein diets may be partly due to a reduced energy value of diets with increased protein concentrations (Just, 1982; Henry et al., 1992)

In this experiment, a high protein level tended to increase water intake ($p<0.1$). Other studies have also shown an increase in drinking water associated with increasing dietary CP levels. Various environmental (Patience et al., 2005) and physiological factors (Mroz et al., 1995) affect water utilization although the impact of diet is not clear. Suzuki et al. (1998) and Pfeiffer et al. (1995) showed that water consumption increased in response to increasing dietary CP, whereas Albar and Granier (1996) found that barrows, but not gilts, offered a low CP diet had reduced water intake in one study, but differences were not significant in another**.**

Table 4. Calculated carcass protein and fat deposition rates based on energy intake, body weight and rate of gain of three breeds of female pigs.

Breed[1]	Dietary crude protein (%)							
	Protein deposition (g/d)				*Fat deposition (g/d)*			
	10	13	16	19	10	13	16	19
MC	35	41	48	36	93	109	130	99
F_1	69	70	75	71	190	195	208	196
F_2	79	92	99	82	220	252	273	225

[1] Pig genotypes: MC: Mong Cai, F_1: (LW×MC); F_2: (LD×MC)×LW).

The MC pig is an important breed in Vietnam, especially Central Vietnam, where it is used in approximately 10 % of the pig population, and the economic value of its net-income is approximately 20 % of the total output of pig production (Pham et al., 2010). In the present study, the protein deposition for all pig breeds but especially MC was low (Table 4). For practical purposes, the current results show that MC pigs, which have a similar voluntary feed intake at all dietary CP levels, have the largest reduction in lipid gain with a dietary CP of 13 %. In a previous report the lower capacity for lean tissue growth of growing MC pig compared with modern pig breeds was also shown (Drucker et al., 2006). These observations suggest that the MC pigs, which were in an earlier stage of growth than lean type pigs, approached maximum capacity for protein deposition with a dietary crude protein content of 13 to 14 % and therefore they require less protein per kg of feed than fast growing leaner breeds (Campbell et al., 1985; Bikker et al., 1994; present study). Due to differences in growth potential, muscle accretion, and maturation, the F_1 and F_2 pigs required a dietary crude protein content of 16 to 17 %, a concentration slightly greater than the recommended allowance of NRC (1998). Responses in protein synthesis for the MC pigs to increased dietary protein content were smaller than for the F_1 and F_2 breeds, but in MC pigs this is likely related to a reduced voluntary feed intake compared to the F_1 and F_2 pigs. The protein deposition on the 16 % CP diet for MC pigs appears close to the maximal deposition and as such provides little room for further improvement as provision of additional protein above 16 % had no benefit in terms of protein deposition. The constraint in protein synthesis might be imposed by the lower protein mass of MC pigs compared with F_1 and F_2 pigs. A relevant indication of this lower body protein mass is the 20 to 30 % smaller muscle size found in MC pigs compared with F_1 and F_2 of similar BW and fed the same balanced dietary protein pattern to those used in the present experiment.

This study confirmed the lower growth performance by MC compared to F_1 and F_2 pigs. ADFI and ADG in particular were much lower in MC than F_1 and F_2 pigs. Higher back fat thickness and lower carcass lean content in MC were related to a lower muscle growth potential. The MC pig deposit fat in a higher ratio to protein than the crossbreds. Similar results were reported when Iberian pigs (Morales et al., 2003) were compared to lean breeds of pigs. The low potential of MC pigs for growth and protein deposition results in a high ratio of feed to gain. But this feed conversion improves more with increased CP levels in the MC pigs than in crossbreds. So under practical conditions such as in Vietnam small holder farms, it is relatively more beneficial for MC to increase dietary CP to 13 % compared to F_1 and F_2. In the latter two breeds a higher dietary CP is needed. Thus from the data provided in the present study it is possible to predict optimum dietary CP content and these data allow construction of a growth profile for each genotype. The optimum dietary protein for ADG of the three genotypes would be approximately 16 % CP but for lean %, a distinct difference is noted with regard to optimal CP.

Table 3 and Figure 1 illustrate the effect of genotype and dietary protein and genotype on protein and fat deposition and on lean. Within breeds the MC pigs had the highest lean percentage with the diet at 13 to 14 % CP while F_1 and F_2 pigs need higher CP level for highest lean %. The lysine content is limiting in most local ingredients so the addition of lysine is essential for defining the protein value than the absolute protein level itself. The daily lysine requirement that were derived from maximum ADG is different for the three pig breeds. It should be noted that the formula for the calculation of fat and protein have been derived with data of moderately lean pigs (Kotarbinska and Kielanowski, 1969), which can be considered comparable to the F_1 and F_2 animals in our study. Bikker et al. (1996) showed that carcass fat deposition rate was more dependent on energy intake than on protein intake. Similarly, in our experiment, an increase in fat content and fat deposition rate was noted at the highest feed intake (energy intake). If the energy intake is above that needed for maintenance and maximum protein deposition, lipid deposition increases. In this respect De Greef et al. (1994) observed that energy intake above the maximum capacity of protein deposition caused an increase in the carcass lipid: protein ratio. The difference in capacity for protein deposition between the three genotypes used in this experiment shows that genotype and diets need to be considered together for feed composition of growing pigs in Vietnam.

When comparing the standard of nutrient requirements of swine (NRC, 1998; NIAH, 2001), the nutritive value of feedstuffs for fattening pigs in Central Vietnam is low due to insufficient amounts of amino acid in diets. On average, the crude protein content of a typical feed fed to pigs in small-holder farms is estimated to be approximately 10 % which results in a low average daily gain of F_1 and F_2 pigs (Pham et al., 2010). In previous studies, Ngoan et al. (2000) and Van An et al. (2005) found that the main protein feed sources in Central Vietnam are fish meal and seafood by-products like fish heads and shrimp heads. Fish meal is produced mostly from salt-water fish and typically contains between 33 and 45 % CP on a dry matter basis. By using fish meal and sea food by-products, the CP content in the diet can be raised to about 11 to 21 % CP (Ngo et al., 2004).

A number of opportunities have been identified for sustainable improvement in the production of small-holder pig farms. The formulation of appropriate and cost-effective diets from as much as possible locally available feedstuffs can improved the diets of fattening pigs. It is recommended from the investigations reported here that the CP content in diets for F_1 and F_2 pigs should be raised to 16 or 19 % in order to optimize pig production. In this respect, protein concentration should be adjusted in combination with the training courses on how to use and formulate diets based on local feed resources. The present results clearly show that large improvements in growth rate can be obtained by combining local feedstuffs with extra protein sources. It is possible to obtain these improvements also with locally grown protein rich feedstuffs (for example a local variety of pigeon peas) in addition to local sources rich in carbohydrate like cassava and sweet potato. This ensures an increased household food supply with an improved carcass quality. It is expected that improved feed quality by the supply of sufficient protein/lysine leads to increased performance and carcass quality of F_1 and F_2 fattening pigs.

In conclusion, genetically lean pigs have higher growth rates and give leaner carcasses compared to MC pigs at all dietary crude protein levels under practical conditions in Vietnam. At high dietary crude protein levels differences in gains increase. F_1 and F_2 pigs have faster growth rates, higher feed intake and lower back fat levels compared to the Mong Cai local breed. For Mong Cai local breed (MC), F_1 (Large White×Mong Cai) and F_2 crossbreds of (Landrace×Mong Cai)×Large White a dietary crude protein content of 14.0, 15.0, and 16.4 % appears optimal for overall growth performance and carcass characteristics.

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4

EFFECT OF DIETARY LYSINE SUPPLEMENT ON THE PERFORMANCE OF MONG CAI SOWS AND THEIR PIGLETS

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ABSTRACT

The objective of this study was to determine optimal lysine requirement of lactating Mong Cai sows with piglets. An experiment was conducted using 30 Mong Cai sows in a factorial randomized design with 5 dietary total lysine levels (0.60, 0.70, 0.85, 1.00 and 1.15 %) for one-week pre-partum and 5 dietary total lysine levels (0.60, 0.75, 0.90, 1.05 and 1.20 %) for the lactation diets. Mong Cai sows were 1.5 to 3 years old and had an initial body weight of 120 kg (sd=2.5) after farrowing. Sows were restrict-fed 1.7 kg feed during gestation and fed ad libitum during lactation. Diets contained about 12 % CP during pregnancy and about 14 % CP during the lactation period. The digestible energy content of the diets ranged from 13.2 to 13.3 MJ/kg DM. Water was supplied to allow the sow to drink ad libitum during lactation. Studied traits were related to both sows and their progeny. Sows were weighed at 107 days of gestation, after farrowing and at weaning of the piglets. Sow back-fat depth was measured at 110 days of gestation, after farrowing, at 21 days of lactation and at weaning. Number of piglets born, at 24 h after birth, at 21 days of age and at weaning were recorded. Piglets were weighed at birth, at 21 days and at weaning. Supplying lysine one week pre-partum had no effect on the number of piglets born (p=0.776) nor litter weight at birth (p=0.224). A positive effect of high dietary lysine level during lactation from 0.60 to 1.20 % with regard to sow weight loss, increased piglet weight at 21 days and weaning weight was observed. The level of lysine that resulted in the lowest sow weight loss and the highest weaned piglet weight was 1.02 %. The latter may be the optimum level of lysine for lactating Mong Cai sow diets. At this lysine level, the number of weaned piglets at weaning was also highest.

INTRODUCTION

Lactation is an important period in the life of sows. During a relatively short period, sows have to produce a large amount of milk and thus metabolic demands for nutrients and energy are high. Amino acids are important essential nutrients that may affect overall reproductive performance of breeding pigs. Lysine is the first limiting essential amino acid in most diets for lactating sows and daily lysine intake is a primary determinant of lactation performance (NRC, 1998; Yang et al., 2000b; Kim et al., 2001).

The amino acid requirement during lactation is closely related to the amount and composition of sow's milk. Several studies have shown that the quantity of maternal reserves, built up during gestation, can have an effect on subsequent litter growth and reproductive performance (Jones and Stahly, 1999; Clowes et al., 2003). Jones and Stahly (1999) and Yang et al. (2009) reported that sows fed diets with a low protein level (8.3 to 13.1 % CP) during lactation had a low milk production. Adequate dietary protein level (19.8 % CP) during lactation can increase fat milk output (Sinclair et al., 2001) and decrease body weight losses of the sows (Johnston et al., 1993; Sinclair et al., 2001). Dourmad et al. (1998) reported that a high producing sow requires at least 55 g of dietary lysine/d for minimum weight loss and for maximal mammary gland growth (Kim et al., 1999). The amount and composition of amino acids in the sow's diet can therefore be an indication of the optimal balance of amino acids ingested by the piglets (Verstegen et al., 1998). Touchette et al. (1998) found that lactating sows require 48 g of digestible lysine per day for an adjusted litter size of 9 to 11 piglets, in order to minimize her own protein mobilization. Tritton et al. (1996) and Yang et al. (2000b) reported no effect on litter size at birth when lysine intakes during the first pregnancy varied. Johnston et al. (1993), Touchette et al. (1998) and Sinclair et al. (2001) reported that protein/lysine levels in the lactation diets prevented sow weight loss but had no influence on sow backfat loss and did not improve daily litter weight gain. Yang et al. (2000a) found that a low amino acid intake during lactation impaired follicular development and maturation during the subsequent pro-estrus period. Bojcuková and Kratký (2006) noted that a higher litter weight at the age of 21 days in sows fed the highest dietary content of lysine (15.2 g compared to low level at

8.15 g of lysine/kg feed)

Mong Cai sows are a local, popular pig breed for smallholders throughout the entire country of Vietnam. Mong Cai sows are used as the major female line for crossing with exotic boars to produce hybrids (F_1= (Large White or Landrace×Mong Cai) and F_2= (Large White ×Mong Cai)×Landrace)) on smallholder pig farms. In rural areas of Central Vietnam, smallholder farmers feed their sows with locally available feed resources. Sows, however, do not receive sufficient amount of amino acids from these diets. A common lactation diet for Mong Cai sows in Vietnam contains from 0.4 to 0.5 % of lysine. The current study was conducted to find the optimal lysine requirements of lactating Mong Cai sows and their piglets. The hypothesis was that Mong Cai sows have the highest response at optimum lysine levels in the diets.

MATERIAL AND METHODS

ANIMALS

Thirty Mong Cai sows (six sows per treatment) aged 1.5 to 3 years with a weight after parturition of approximately 120 kg and a parity number of 2 to 3 were used. The treatments were designed according to dietary lysine level (0.60, 0.70, 0.90, 1.05 and 1.20 % lysine in the DM). The sows remained in the experimental pen from pregnancy onwards and during farrowing and lactation. Weaning occurred at day 45 of lactation. The experiment was conducted during the cool season from September 2004 to March 2005 at the farrowing house at Trieu Hai Farm of the Central Pig Breeding Company, Hue, Vietnam. Temperatures during this period ranged from 15 to 26°C.

HOUSING

The sows were housed individually in pens of 2.0 m length and 1.75 m wide. Pens were separated by brick walls, were 2.6 m height and had an insulated fibro-cement roof. The floor consisted of solid concrete except for a gutter (0.25 m wide ×1.50 m long × 0.40 m deep) which was protected with an iron lattice-covered floor at the back of the pen. Each pen was equipped with a feeder and water drinker for the sows and an infrared light from an electric heating bulb to provide additional warmth for the piglets. Bedding material was not used. The farrowing house was open so that the inside temperatures followed the outside ambient temperature.

FEEDING

A basal diet was fed from 107 days of pregnancy until farrowing which was formulated to contain 0.56 % lysine. Lysine HCl (78.8 % lysine) was supplemented to achieve dietary levels of 0.60, 0.70, 0.85, 1.00 and 1.15 % lysine from the 107th day of pregnancy onwards to farrowing. Dietary lysine level was modified with the aim to test if this has an effect on target backfat measurement of sows and piglet weights at farrowing.

Feed allowance at 107 days of gestation was formulated using the maintenance requirement estimates of to NIAH (2001). Feed allowance was constant from mating to the last week of gestation. Daily feed allowance during lactation was derived from the protein and energy requirement proposed by Pettigrew and Young (1997). Lysine HCl (78.8 % lysine) was supplemented to the basal diet to achieve a dietary level of 0.60 for basal, 0.75, 0.90, 1.05 and 1.20 % lysine for post-farrowing until weaning at 45 days. Sow received a high dietary lysine level before farrowing also received a high lysine level during lactation. Sows were restrict-fed during pregnancy with 1.7 kg of their gestation diet twice daily from mating until farrowing (Farrowing day = 0). Feed composition of the gestation diet contained about 12 % CP. Pigs were fed twice per day at 8 am and 4 pm. After farrowing sows were restrict-fed for three days at 2.0, 2.5 and 3.0 kg per day. After the third day of farrowing, sows were provided their lactation diets *ad litbitum* which contained 14 % CP. Digestible energy content for both the gestation and lactation diet was 13.2 to 13.3 MJ (Table 1). Water was supplied to allow the sow to drink *ad libitum* during lactation to maintain the feed intake and milk production.

TREATMENT

The diet was formulated using rice bran, cassava meal, corn meal, fish meal and sweet potato vines. Feed was formulated to meet the requirements of lactating sows in terms of energy, crude protein, minerals and vitamins. Lysine was added to reach the desired lysine levels. The amounts of digestible essential amino acids and digestible lysine in the experimental diet were based on an ideal CP content of 14 % as recommended by NIAH (2001) for lactating sows. The compositions calculated of the experimental diets are shown in Table 1.

Feed was offered to the sows after farrowing until weaning. Each morning, feed refusals were collected, and new feed was immediately provided. Feed consumption was determined as the difference between feed allowance and the refusals collected the next morning.

Table 1. Composition of diets fed during the lactation period.

Ingredients (%)	Digestible lysine level (%)				
	0.60	0.75	0.90	1.05	1.20
Synthetic lysine[1]	0	0.19	0.38	0.57	0.76
Rice bran	44	44	44	44	44
Corn meal	36	36	36	36	36
Cassava meal	8.50	8.31	8.12	7.93	7.74
Fish meal (55% CP)[2]	9.0	9.0	9.0	9.0	9.0
Sweet potato vine	1.0	1.0	1.0	1.0	1.0
Vitamin–premix[3]	0.5	0.5	0.5	0.5	0.5
Mineral–premix[4]	0.5	0.5	0.5	0.5	0.5
NaCl	0.5	0.5	0.5	0.5	0.5
Crude protein (g/kg DM)[5]	140.6	139.9	140.2	140.4	140.8
ME (MJ/kg)[6]	13.3	13.3	13.2	13.2	13.2

[1] Lysine HCL, manufactured by CJ CHEILJEDANG Cooperation, Seoul, Korea.
[2] Fish meal was supplied by Cargill, Minneapolis, MN, USA.
[3] Supplied per kg diet included: 0.24 mg folic acid, 1950 IU vitamin A, 1 mg vitamin B_1, 190 IU vitamin D_3, 40 IU vitamin E, 0.05 mg vitamin K.
[4] Supplied per kg diet: 52 mg Zn (as $ZnSO_4$), 47 mg Fe (as $Fe_2SO_45H_2O$), 60 mg Mn (as $MnSO_41H_2O$), 4 mg Cu (as $CuSO_45H_2O$), 0.96 mg I (as $Ca(IO_3)_2$), 0.11 mg Co (as $CoSO_47H_2O$), 0.07 mg Se (as Na_2SeO_3), 2 g dibasic calcium phosphate (as $CaHPO_42H_2O$).
[5] CP value analyzed by laboratory of Animal Nutrition of Hue University of Agriculture and Forestry.
[6] Calculated using digestibility values of individual ingredients from the NIAH (2001).

MEASUREMENTS

Sows were weighed at serving day, at 107 days of pregnancy, within 24 h after farrowing and at the 45th day of lactation (at weaning). Backfat thickness was measured by ultrasound at 107 day into gestation, 24 h after farrowing and at 21days of lactation using the Renco LEAN-METER® (Renco Corporation, Minneapolis, MN, USA). Two measurements were made at 6.5 cm from the dorsal midline on the right and left side of the animal at the level of the 10th rib (P2). Means obtained for the two sides were recorded for analyses. Ultrasonic evaluation was accomplished by using Vaseline oil and placing the probe directly on the skin of the pig. The outer layer thickness of fat was determined by measuring from the outer surface of the skin to the boundary of the outer and middle layer fat (Smith et al., 1992).

After farrowing, the number of live born, stillborn and mummified piglets as well as piglet weights were recorded. Needle teeth were clipped; ears were notched for identification, and piglets were given 1 ml of iron dextran (200 mg Fe/ml, Bomac Laboratory, New Zealand) and 1 ml penicillin G (Bayer Company, Germany) as scouring preventative medication. The piglets were weighed and handled (tooth cutting, umbilical cord treatment, labeling and antibiotic administration) up to 7-10 days after birth. Male piglets were castrated within 7 to 10 days. The piglets were weighed at the 7th, 14th and 21st day and at weaning. During the lactation period, piglets had no access to the sow's feed but water was available to them through a low-pressure nipple drinker. Piglets were weaned at the 45th days of age into a conventional nursery. At weaning, piglets were moved to the nursery of the farm, and sows were moved to a breeding facility and checked twice daily for signs of estrus using a mature boar to detect the onset of heat. Estrus was recorded when sows stood to be mounted by the boar.

STATISTICAL ANALYSIS

Data were analyzed by using General linear model (GLM) procedure of SPSS 11.5. The model was: $Y_{ik}= \mu+L_i+\varepsilon_{ik}$ (1)

where Y_{ik} is the observed independent variable, μ is the overall mean of the observations, L_i is the main effect of the dietary lysine level (i=0.60, 0.75, 0.90, 1.05 and 1.20 % lysine), ε_{ik} is the residual random component. If the treatment effect was significant ($p<0.05$), differences between treatments were compared with Tukey's procedure. Differences between means were tested by the Student–Newman–Keul's test. Differences were considered significant at $p<0.05$.

To predict the maximum litter weight at day 21 and at weaning, litter weight gain or minimum sow backfat losses, a curvilinear response curve was fitted using the following equation:

$Y = aX^2 + bX + c$ (2)

$Y = aX^3 + bX^2 + cX + d$ (3)

where Y is response criteria (sow backfat loss, sow weight loss, litter weight and litter weight gain,), X is dietary lysine and a, b, c, d represent components of quadratic equation (Urynek and Burazewsca, 2003).

Table 2. Effect of dietary lysine level on sow performance.

Sows traits	Dietary lysine level (%)					SEM	Significance
	0.60	0.75	0.90	1.05	1.20		p<
No of observations	6	6	6	6	6	–	–
Weight at mating (kg)	87.7	86.7	87.8	87.7	87.2	1.17	0.427
Weight on 107d (kg)	120.0	123.0	120.8	121.5	121.8	1.23	0.274
Weight at 24h after (kg)	96.8	95.5	95.6	96.8	96. 7	1.57	0.144
Weight at weaning (kg)	76.8[a]	78.8[a]	82.7[b]	86.3[c]	84.5[bc]	1.14	0.028
Weight loss (kg)	19.5[a]	13.4[b]	12.0[c]	11.5[c]	12.3[c]	0.34	0.012
Feed intake (kg/d)	3.63	3.75	3.80	3.82	3.75	0.12	0.054
ME intake(MJ of ME)	48.30	49.80	50.20	50.50	49.80	–	–
			Sow backfat measurement				
At farrowing (mm)	33.6	33.3	33.30	33.7	32.9	0.316	0.157
21d of lactation (mm)	30.4[a]	29.7[b]	29.9[c]	29.8[c]	29.9[c]	0.279	0.021
At weaning (mm)	28.0[a]	28.1[a]	28.5[b]	29.1[c]	27.8[a]	0.083	0.001
Backfat loss (%)	–5.6[a]	–5.2[b]	–4.7[c]	–4.6[c]	–5.1[b]	0.031	0.010
Weaning-estrus interval (d)	7.5[a]	6.3[b]	5.8[c]	5.5[d]	5.9[c]	0.091	0.010

[abcd] Means within rows with different superscripts differ ($p<0.05$).

RESULTS

In Table 2, the result of dietary lysine levels and the performance of the sows are presented. Average daily feed intake (ADFI) of sows during lactation was not affected by dietary lysine level (0.60 to 1.20 %) although a trend was observed ($p=0.054$). Dietary lysine level did not have an influence on body weight at 107 days of gestation. Sow body weight at 24 h after farrowing was not different between diets ($p>0.05$). Sow body weight loss during lactation decreased drastically when dietary lysine level was increased. There was a greater weight loss of the sows at the three lower levels of lysine (0.60, 0.75 and 0.90 %) than at the two higher levels (1.05 and

1.20 %). Weaning to estrus interval ranged between 5.5 and 7.5 days, and was influenced p<0.05) by dietary lysine and ME intake levels during the preceding lactation.

The number of piglets born per litter determined within 24 h after birth ranged between 10.8 and 11.5. Dietary lysine intake did not influence the total born and born alive piglets (p>0.05). Similarly, the number of piglets in groups did not differ within 7 days after birth (p>0.05). The number of piglets at the 21st days differed slightly between treatment groups (p<0.05), (Table 3). The average number of weaned piglets (at the 45th day) was highest with the 1.05 % lysine diet and lowest with the basal diet (Table 3). The differences in piglet numbers at weaning between groups were statistically significant (p<0.001).

Table 3. Effect of dietary protein level of sow's diet on litter performance.

Trait	Dietary lysine level (%)					SEM	Significance
	0.60	0.75	0.90	1.05	1.20		p<
			Litter size				
No. piglets born	11.4	11.3	11.8	11.7	11.5	0.297	0.766
No. piglets after 24 h	10.8	11.0	11.5	11.3	11.1	0.238	0.325
No. of piglets at 7 d	10.7	10.8	11.2	11.3	11.0	0.238	0.158
No. of piglets at 21 d	10.4^a	10.8^b	11.0^b	11.3^b	10.9^b	0.186	0.049
At weaning	9.9^a	10.7^b	10.9^b	11.2^c	10.9^b	0.175	0.001
			Total litter weight (kg)				
At birth	6.62	6.80	7.21	7.11	6.94	0.089	0.224
At 7 days	11.92	12.79	13.40	13.99	12.90	0.230	0.062
At 21 days	29.05^a	32.88^b	35.35^c	37.17^d	35.70^c	0.543	0.023
At weaning	76.37^a	90.25^b	99.25^c	104.76^d	95.94^c	1.860	0.001
			Average weight of piglets (kg)				
At birth	0.58	0.60	0.61	0.61	0.60	0.011	0.470
At 7 days	1.11	1.18	1.20	1.23	1.17	0.031	0.107
At 21 days	2.79^a	3.04^b	3.21^b	3.30^b	3.27^b	0.166	0.041
At weaning	7.71^a	8.43^b	9.11^c	9.35^c	8.53^b	0.320	0.001
Litter growth rate (kg/d)	1.59^a	1.85^b	2.05^c	2.17^c	1.97^b	0.050	0.001

^{abcd} Means within rows with different superscripts differ (p<0.05).

The average weight of piglets in the different groups was determined by weighing individual piglets immediately after farrowing and in the various weeks after birth. There was no significant difference in the average birth weight of piglets between the groups. The average weight in the different treatment groups at the 7th day postpartum also was not significantly ($p>0.05$) different. At the 21st day of age, the average weights of piglets in the individual groups differed significant between treatments ($p<0.001$). Similarly, the weaning weights of different groups were also statistically significant ($p<0.05$) at 21 days of age and at weaning. Dietary lysine level during lactation had an effect ($p<0.001$) on daily litter weight gains and was highest for the 1.05 % dietary lysine group.

Table 4. **Best fit models describing the effect of dietary lysine content on growth performance and carcass characteristic variables for Mong Cai sows in Central Vietnam.**

Variables	X^2	X	Intercept	SEM	R^2	Optimum (%)
Sow weight loss (kg)	46.667	-94.867	59.220	1.337	0.97	1.02
Sow BF[1] loss (mm)	6.9841	-13.638	11.343	0.130	0.93	1.01
Litter weight (kg)						
at 21 days	-6.079	74.376	-3.2797	0.543	0.99	1.06
at weaning	-155.21	315.14	-57.609	1.860	0.97	1.02
Litter growth rate (kg/d)	-3.3651	6.8305	-1.3543	0.050	0.97	1.02

[1] BF: Backfat.

Results of the quadratic and cubic regression equations that predict optimum dietary lysine concentration for maximum litter weaning weight, litter daily growth rate or minimum sow's weight and backfat loss during lactation are shown in Table 4. Optimum dietary lysine level for maximum litter weight at the 21st days was 1.06 % and optimum dietary lysine level at weaning was approximate 1.02 %. Optimum dietary lysine level for minimum weight loss of sows was 1.02 % and the optimum for backfat loss during lactation was 1.01 %.

Figures 1 to 5 present the minimal and maximal traits for sow weight loss (Figure 1), backfat loss (Figure 2), litter daily growth rate (Figure 3), litter weight at 21 days of lactation (Figure 4) and litter weight at weaning (Figure 5) at each lysine level and the best fit curve.

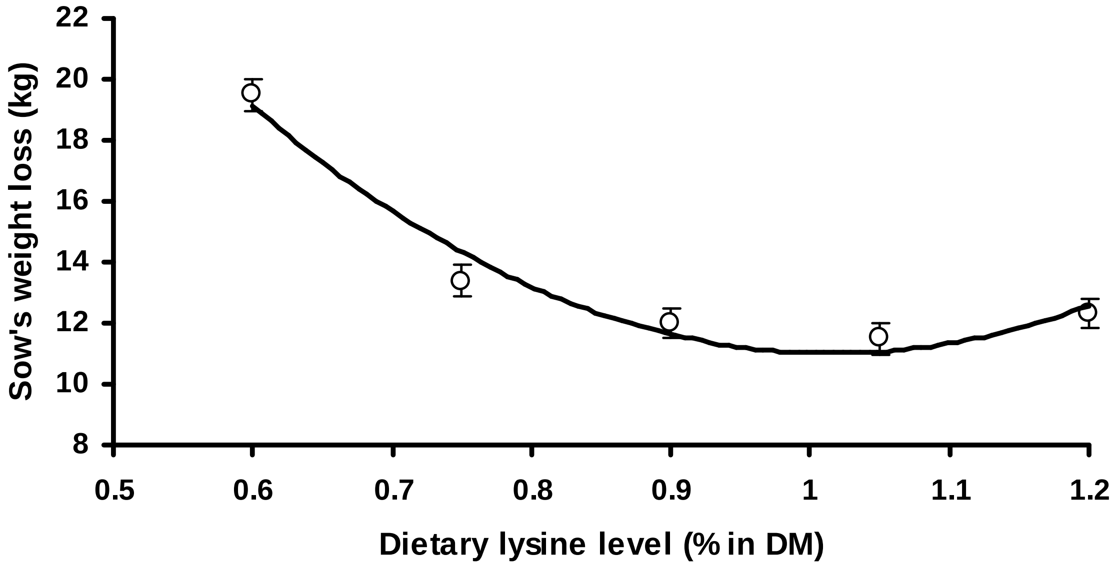

Figure 1. Effect of dietary lysine levels on sow weight loss during 45 days lactation.

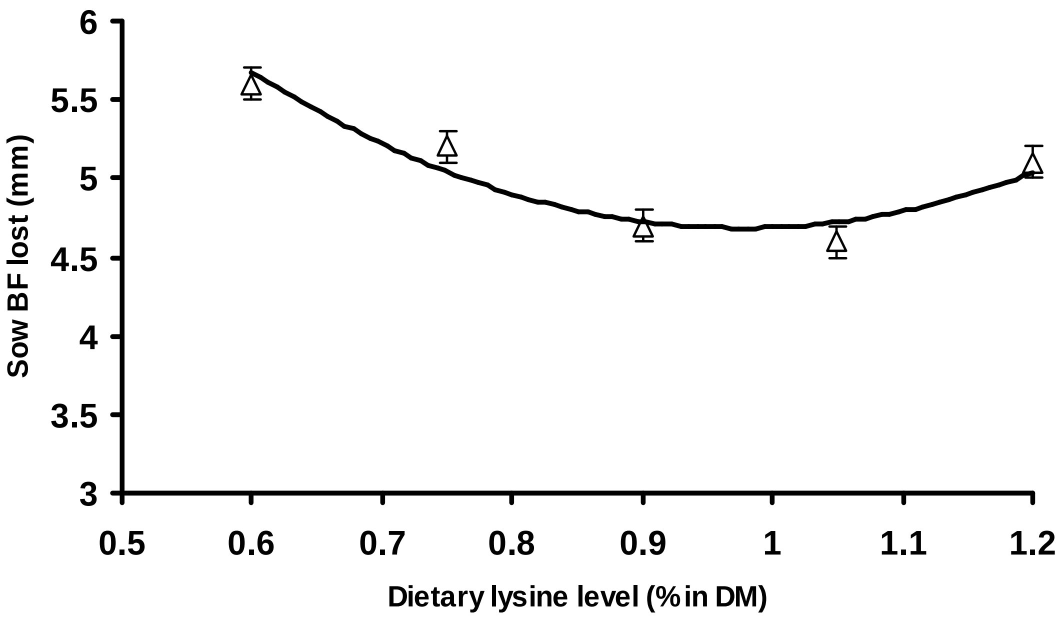

Figure 2. Effect of dietary lysine levels on sow backfat loss during 45 days lactation.

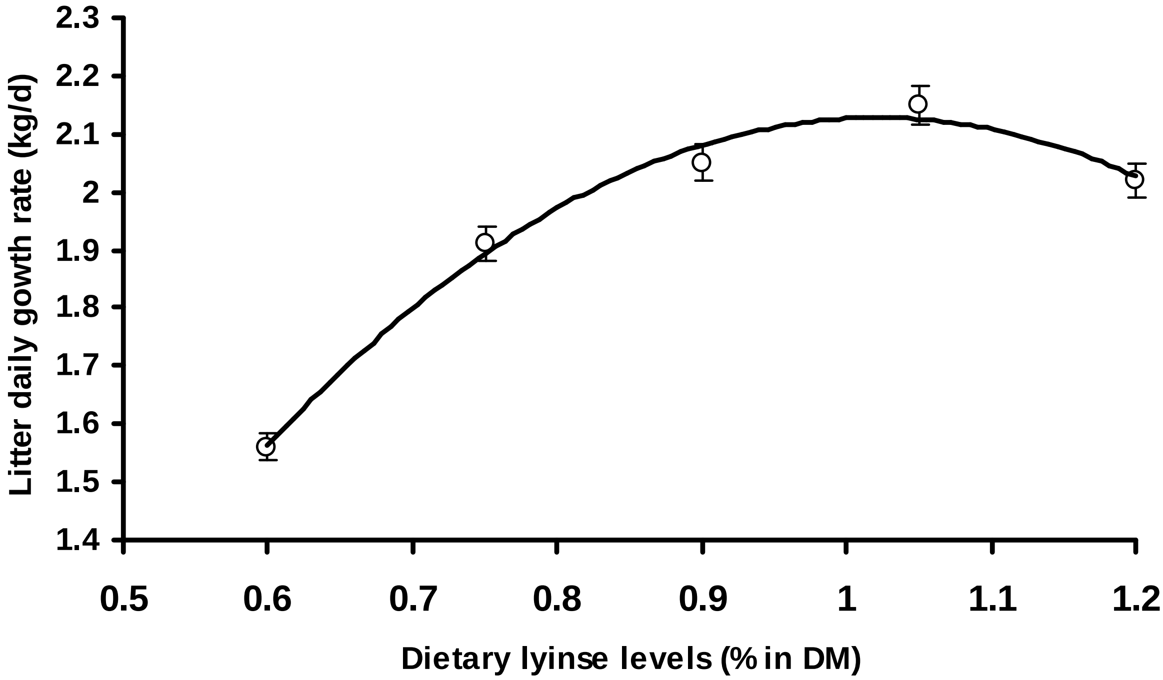

Figure 3. **Effect of dietary lysine levels on daily litter growth rate during 45 days lactation.**

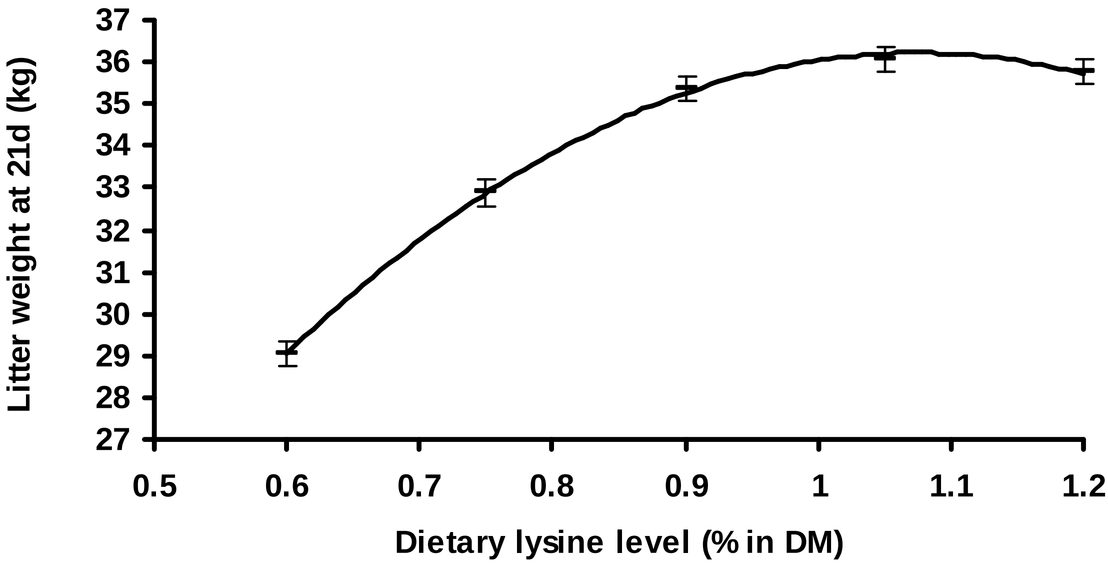

Figure 4. Effect of dietary lysine level on piglet weight at 21 days lactation.

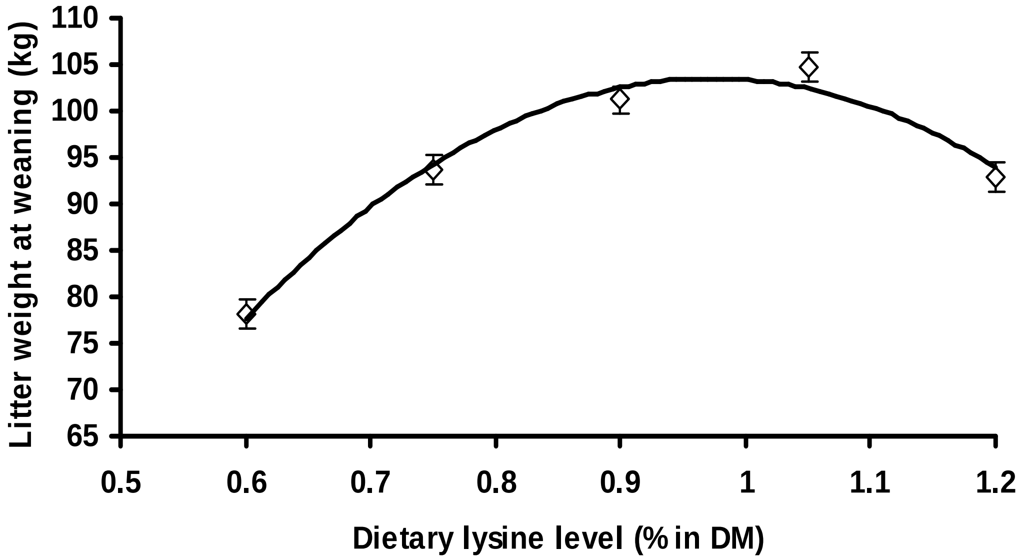

Figure 5. Effect of dietary lysine levels on total piglet weight at weaning of 45 days lactation.

DISCUSSION

The results of the present study indicate that increasing dietary lysine from 0.60 to 1.20 % did not affect feed intake significantly although a trend was observed during 45 days lactation. Sow weight loss, backfat thickness at weaning, the number of piglets at weaning and weight of litter at weaning were significantly affected by lysine content in diet. Sow feed intake was low when the lysine content was 0.60 % and 1.20 % in the diet and it was highest on the 1.05 % lysine diet. However, the differences of sow feed intake were not statistically significant between treatment groups ($p>0.05$). The feed intake of lactating sows is influenced by several factors e.g. feeding level during gestation, body weight, litter size, environmental temperature and the energy and protein concentration of feeds (Verstegen et al., 1998). In the literature, ADFI has not always been shown to be affected by increases in lysine from 0.62 to 1.05 % (Johnston et al., 1993), from 0.67 to 1.25 % (Touchette et al., 1998) and 0.80 to 1.06 % (Cooper et al., 2001). Yang et al. (2000b) recorded linear decreases ($p<0.01$) in ADFI during the first, second and third lactations as dietary protein (lysine) increased (from 0.4 to 1.5 %). The studies by Schneider et al. (2004), Lenehan et al. (2004) and Fu et al. (2003) recorded no changes in feed intake with increasing dietary lysine (0.9, 1.1 and 1.4 %). Feed intake by sows fed a high-protein diet during lactation may have been driven by high milk production, because these sows also produced more milk than sows fed the low-protein diet during lactation.

In contrast, Shields et al. (1985) reported a positive quadratic relationship between dietary protein concentration (5, 14, and 23 %) and lactational feed intake of first-litter sows. Several other workers (Mahan and Mangan, 1975; O'Grady et al., 1985) have observed this positive relationship between dietary protein concentration of lactation diets (12 to 20 % CP) and feed intake during lactation after the protein density of the gestation diets was low. José et al. (2006) recorded that increasing lysine from 0.75 % to 1.20 % resulted in higher feed intake at higher energy density in lactation diets (14.3 vs. 13.6 MJ ME/kg). In the present study, the ME content of the diets were almost the same 13.2 to 13.3 MJ ME/kg.

The present study demonstrates that increasing dietary lysine levels reduced the sow's weight loss and the weight loss was minimal at a lysine level of 1.02 %. Stahly et al. (1990), Johnston et al. (1993) and Kusina et al. (1999) found that increasing CP reduced lactation weight loss. Jones and Stahly (1999) and Yang et al. (2000c) recorded that losses in body weight during lactation were significantly reduced by lysine supplied to the sow's diets.

Several studies show that when the daily intake of lysine can be increased, body weight losses can be decreased (Sinclair et al., 2001). Eissen et al. (2003) found that an increase in intake of 1 kg per day reduced daily weight loss of sows by 0.13 kg (13 % of body weight loss/d) at a litter size of 10 piglets. Weight loss was reduced by 0.015 kg/d (1 %) at a litter size of 14 piglets. Yang et al. (2009) recorded that sows fed low lysine diets lost more body weight than sows fed high lysine diets. High lysine intake (64.9 g/d) during lactation increased the concentrations of total solids, protein and solids not-fat in colostrum and total solids, protein, fat and solids not-fat in milk (Yang et al., 2009).

According to Mullan and Williams, (1989), Dourmad (1991) and Meija et al. (2002) nutrient intake, body reserve losses, and absolute amount of maternal reserves at farrowing interact to influence reproductive performance. Yang et al. (1989), Dourmad (1991) and Charette et al. (1995) observed that the weaning-to-estrus interval after first lactation was closely related to body protein or body weight at weaning, with heavy primiparous sows having weaning-to-estrus intervals similar to that of multiparous sows. The mechanism which affects this interval seems to be associated with high LH concentrations during lactation (Shaw and Foxcroft, 1985). King and Martin (1989) found a lower mean LH concentration immediately prior to weaning and after weaning in sows on a low protein intake during lactation, as would have been the case with sows in the present experiment (Foxcroft et al., 1996). Tokach et al. (1992) and Yang et al. (2000c) recorded that increases in lysine intake are associated with increases in LH. Pulsatile secretion of LH is an important factor in stimulating follicular development and resumption of estrus postweaning (Shaw and Foxcroft, 1985; King and Martin, 1989; Yang et al., 2000c). Furthermore, LH pulse frequency during mid to late lactation was related to weaning-to-estrus interval (Tokach et al., 1992; Koketsu, 1996; Yang et al., 2000c). With relatively low numbers of sows in each treatment in the present study, subsequent litter size data are of limited importance. However, differences in subsequent litter size seemed to respond both directly to effects of dietary lysine level in the sow's lactation diets.

The current study showed that dietary lysine level has an effect on the backfat loss of sows. Stahly et al. (1990) recorded that backfat of sows at weaning were not affected by increases in lysine from 0.42 to 0.92 %. This is similar to Johnston et al. (1993) who increased lysine from, 0.62 to 1.05 %, Monegue et al. (1993) using a range of 0.60 to 0.90 % and Weeden et al. (1994) varying lysine from 0.60 to 0.70 %. José et al. (2006) recorded that increased dietary lysine from 0.75 to 1.20 % decreased backfat loss during lactation at two dietary energy levels (13.6 and 14.2 MJ ME/kg) and sows had the lowest backfat loss at 1.05 % lysine. When a sow does not receive adequate amounts of dietary amino acids, maternal tissue protein (particularly skeletal muscle proteins) is mobilized to support milk production (Kim et al., 2005). Excessive maternal protein mobilization often results in reproductive failure for the next parity (Jones and Stahly, 1999). Dourmad et al. (1998) reported that a high producing sow requires at least 55 g of dietary lysine/d for minimum weight loss as well as maximal mammary gland growth (55 g) as suggested by Kim et al. (1999). Backfat thickness at farrowing have been found to be negative relation to feed intake during lactation. Dourmad (1991) reported that reduction in feed intake was most pronounced during the first week of lactation and they estimated a relationship between backfat depth at farrowing and lactation feed intake. They found that regression coefficient of backfat loss on ADFI was decreased 95 g (per mm of backfat loss) during the first week of lactation and decreased 63 g/d during the entire lactation period.

The weight and backfat thickness changes observed in the sows during lactation are related to a reduced feed intake. When feed intake does not meet the nutritional demands for maintenance and milk production, there will be additional weight losses. The severity of weight and backfat thickness losses has been related to lactation period, litter size and weight gain, sow body composition at farrowing, parity order, and environmental conditions (Close and Cole, 2000). According to Close and Cole (2000), a high energy intake can minimize this variation in weight and backfat thickness. The results of the present study can not show the influence of feed energy density because only one density was used. The daily ME intake (50 MJ/d) observed for all diets were lower than the minimum level recommended by the NRC (1998). At current litter sizes, a higher feed intake during lactation would therefore reduce backfat and weight losses of primiparous sows and decrease the probability of a prolonged weaning-to-estrus interval (Eissen et al., 2003).

The difference between sow backfat loss on day 21 and at weaning was not significant among lysine levels from 0.60 to 1.01 %. High intake of lysine had a positive effect ($p<0.05$) on the weaning weight and backfat thickness, as well as on the weight and backfat thickness changes during lactation. In this study, the greater daily feed intake from 3.63 to 3.82 kg, this corresponded to 48.3 MJ ME/d and 50.5 MJ ME/d, respectively. Piglet weaning weight (ranging between 7.7 and 9.4 kg/pig) was influenced ($p<0.05$) by dietary lysine levels.

According to King et al. (1993), dietary protein/lysine levels not only affected milk composition but also affected total milk solid content. Lewis and Speer (1973) also reported that total solid and protein contents of milk decreased linearly and quadratically, respectively in response to reduced dietary lysine levels. Sows given low levels of dietary lysine (Chen et al., 1978) or protein (Elliott et al., 1971) produced milk with lower fat contents. Thus, low levels of dietary lysine not only affect sow milk yield but also reduces the content of protein and fat, therefore reducing total solids. Low dietary lysine levels have an effect on mobilization (Touchette et al., 1998) and an effect on backfat loss of sows (Yang et al., 2009). In addition, the lower feed intakes in the sows fed no supplemental lysine led to a lower energy intake which increased backfat loss compared to sows fed diets with supplemental lysine.

The data in the present study shows that increasing lysine level during lactation increased the piglet’s weight at day 21 and at weaning. Yang et al. (2000b) found that the dietary lysine intake were 44, 55 and 56 g/d in parities 1, 2 and 3 for maximal litter growth rate (2.06, 2.36 and 2.49 kg/d for parities 1, 2, and 3 respectively). Parity influences the lysine (protein) requirement of lactating sows and the response of subsequent litter size to previous lactation lysine (protein) intake (Yang et al., 2000b).

Result of Zhang et al. (2001) show that litter weight increases in piglets at an age of 20 and 35 days with increasing protein and lysine intake. Bojcuková and Kratký (2006) noted that litter weight at the age of 21days was highest in the sow group fed the highest dietary content of lysine. In contrast, Peters and Mahan (2001) concluded that feeding lysine levels above NRC (1998) recommendation did not affect litter performance.

Mullan and William (1989) found a linear relationship between backfat depth and fat content of primiparous sows. However, Johnston et al. (1993) and Toutchette et al. (1998) recorded that backfat change was not affected by lysine level in the diet. According to Yang et al. (2000b) increasing dietary lysine (protein) concentration tended to increase backfat loss linearly in parity 1 ($p<0.01$) but had no effect on sow backfat changes in parities 2 and 3 ($p>0.1$). A metabolic model of lactating sows was used by Pettigrew et al. (1992) and modified by Pettigrew et al. (1993). Lewis et al. (1981) found a quadratic response with regard to ADFI and gain when nursery pigs were fed 6 concentrations of lysine from 0.95 to 1.45 %, with a plateau at 1.25 % lysine. Martinez and Knabe (1990) also observed a quadratic ADFI response to lysine supplementation in the diets.

The present data show that increasing dietary lysine level from 0.60 to 1.20 % affect the interval between weaning and estrus ($p<0.001$). Johnston et al. (1993), Jones and Stahly (1999) reported that increasing protein/lysine levels for lactation sows had an effect on the interval between weaning and estrus. Yang et al. (2000b), Mejia et al.

(2002) and José et al. (2006) reported that post weaning interval to estrus was not influenced by dietary protein/lysine levels for sows. Here it is shown that Mong Cai sows fed lysine levels of 0.60 % had a longer weaning-to-estrus interval compared to Mong Cai sows with a higher dietary lysine level. The weaning-to-estrus interval is directly related to the preceding lactation period (lactation length, nutritional and feeding strategies, parity, litter number, weight and backfat thickness change), facilities, genetics and season (Koketsu et al., 1996; Zak et al., 1997; Boyd et al., 2002), as well as estrus detection and reproductive management.

From an economic perspective, increasing lysine concentration of the lactation diet increased size of the subsequent litter (Campbell, 1995). The present study shows that increasing dietary lysine level affected the number of piglets at 21 days of lactation and at weaning. Previous studies of Stahly et al. (1990), Johnston (1993) and Monegue (1993) recorded that increasing dietary lysine level resulted in an increase in the number of weaned piglets. Triton et al. (1996) reported that sows fed 60 to 80 g/d of total lysine during the first lactation had 10.6 and 11.1 total pigs born. In contrast, Touchette et al. (1998) recorded a decrease in body protein by increasing lysine intake from 32 to 59 g/d during the first lactation and an associated decrease in subsequent litter size (suggested that it was valine deficiency). Yang et al. (2000a) concluded that subsequent litter size of different parities had a different response to high lysine (protein) concentrations during the previous lactation. Cheng et al. (2001) reported that a corn-soybean meal diet containing 13 % crude protein and 0.6 % lysine did not significantly affect litter size and survival rate of weaning piglets compared with the 15 % crude protein and 0.75 % lysine diet.

Dietary lysine levels of 1.06 % in the lactation diet led to maximal litter weight at 21 days of lactation. Lactation diet of 1.02 % lysine led to maximal litter weight at weaning. These data are in agreement with the results of Zhang et al. (2001) that litter weight increases in piglets at the age of 20 and 35 days with increasing protein and lysine intake. Stahly (1990) and Jones and Stahly (1999) reported a positive effect of lysine/protein intake during lactation on litter weight gain. Yang et al. (2000a) recorded that litter weight gain responded quadratically ($p<0.05$) to increasing daily lysine intake during lactation in all three parities. In contrast, Johnston (1993), Touchette et al. (1998) and José et al. (2006) stated that there was no improvement in litter performance with greater lysine intake.

Cooper et al. (2001) also showed that there was no significant protein (lysine level) effect during the last week of pregnancy on piglet birth weight. In addition, sows fed dietary lysine from 0.60 to 1.06 % had better potential milk production, which is in accordance with Knabe et al. (1996). This author recorded that increasing dietary lysine during lactation resulted in increases in piglet weights at the 21st day. José et al. (2006) reported that the reproductive performance in the subsequent farrowing was not affected by the lysine levels and ME, hence, neither the total born nor the animals born alive differed among the treatments.

IMPLICATION

Increasing dietary lysine level has a positive effect on the performance of Mong Cai sows and their piglets. Increasing dietary lysine level from 0.75 to 1.20 % resulted in a decrease in sow weight loss compared to sows fed without supplying lysine. The results indicate that increasing dietary lysine levels led to an increase in the average piglet weight at 21 days (from 0.25 to 0.51 kg/piglet) and the average weaning weight (from 0.72 to 1.65 kg/piglet) compared to piglets born from sows fed without supplemental lysine in their diet. From these results, the optimum lysine level for the best performance of lactating Mong Cai sows and their piglets is 1.02 % of lysine in the sow's diet. Together with supplying lysine, it is suggested to study the effect of supplementing lysine combined with other limiting amino acids on the performance of Mong Cai sows and piglets.

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5

EFFECT OF DIETARY CRUDE PROTEIN CONTENT AND SEASON ON THE PERFORMANCE AND CARCASS QUALITY OF EXOTIC PIGS IN CENTRAL VIETNAM

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ABSTRACT

One hundred and forty four Landrace (LD) and Large White (LW) gilts were used to determine the effect of dietary crude protein level and genotype on growth and carcass characteristics both during the cool and the hot season in Central Vietnam. The initial weight of the Landrace and Large White gilts was 18.4 kg at 60 days of age. Trial pigs were fed one of three diets which contained crude protein (CP) levels of 10, 13 or 16 % and diets contained a digestible energy content (DE) of the 13.3 to 13.5 MJ per kg. Pigs were housed individually in pens with a floor area of 2.5 m^2 *and were provided ad libitum access to feed in a trough as well as water from bowls. Results showed that feed intake of Landrace and Large White pigs was lowest at 10 % CP with 1.68 and 1.70 kg/d and highest at 16 % CP with 2.20 and 2.14 kg/d. Daily gain was lowest on the diet with 10 % CP for both Landrace and Large White pigs (426 and 454 g/d, respectively) and highest at 16 % CP (650 and 636 g/d, respectively).* Backfat *thickness of Large White pigs was higher than Landrace pigs at 10 % (23.9 and 22.6 mm), at 13 % (22.5 and 21.5mm) and at 16 % CP (21.3 and 20.7 mm). No interaction was found between genotype, protein and season for backfat thickness (p>0.05). Pigs kept in the hot season fed 10 % of CP had a lower rate of gain (504 versus 540 g/d; p<0.001) and less feed intake (1.83 vs. 1.94 kg/d; p<0.001) than in the cool season. In both seasons, Large White performed better than Landrace at 10 % of CP but not at 13 % and CP 16 % CP. It was concluded that genotypes had different responses to dietary crude protein and to seasons with regard to feed intake, body weight and also protein and lipid gain. During the hot season, Large White and Landrace pigs had a reduced performance at all three CP levels.*

INTRODUCTION

Many studies have shown that dietary protein level and environmental temperature have clear effects on the growth performance and carcass quality of fattening pigs. Christian et al. (1980), Langlois and Minvielle (1989) and Cromwell et al. (1993) found that at optimal environmental conditions, a high content of dietary crude protein or lysine resulted in improved rates of gain and in increased carcass leanness in gilts. But Hansen and Lewis (1993a,b) showed that different genotypes reacted differently to dietary protein concentrations in different environments. Lopez et al. (1991a, b) found that thermal environment had a clear effect on average daily gain (ADG). According to Becker et al. (1993), hot and cool environments have a differential effect on the body composition of pigs caused by changes in feed intake. Increasing ambient temperature from 22 to 29°C resulted in a clear reduction in average daily feed intake (ADFI) and in ADG. Gentry et al. (2002) found that both ambient temperature and indoor or outdoor housing affected ADG and also the area of the longissimus dorsi muscle. Imports of Landrace and Large White pigs into Vietnam have been aimed to improve the lean meat content of pigs. However, these breeds need to be evaluated with regard to optimal dietary protein content in the hot season in Vietnam.

The objective of this study was to derive the optimum dietary crude protein content when local ingredients are used on performance and carcass quality in fattening pig of Landrace and Large White genotypes housed in individual pens during the hot and cool Vietnamese season.

MATERIALS AND METHODS

ANIMALS

Two breeds of pigs were used in this study: Landrace and Large White. Of each breed, 72 females were used and 36 animals per season. Animals originated from the Central Pig Breeding Company (National Dien Ban farm) in Central Vietnam. Two trials were conducted within on year with trial 1 preformed during the hot season: from March to August and trial 2 during the cool season, from September to February. Both Landrace and Large White were offspring of boars which had been imported from

Australia. The initial weight for both breeds was 18.4 kg (sd=1.4) at 60 days of age. After arriving at the experimental facilities, each pig was assigned to one of 3 levels of dietary protein. They were kept on that feed throughout the entire growth period of 150 days. The trials were planned as a 2 x 3 factorial design with 2 genotypes and 3 CP levels. Measurements were made on growth performance and carcass composition.

HOUSING AND FEEDING

Pigs were all housed in a naturally ventilated unit at the Dien Ban Farm in the same environmental conditions. The housing was open at two sides so that airflow could pass through the building. Thus the room temperature and light followed the outside environmental conditions. Each pig was individually housed in a pen of 2.5 m^2 on a solid concrete floor.

Pigs had *ad libitum* access to the feed from a bin which was weighed daily as well as *ad libitum* access to water from bowls. Daily water levels per bowl were measured and water in the bowls was replaced one time per day. Genotype and crude protein (CP) level were randomly assigned to pens. Animals were weighed once a month at about 07:00h.

DIETS

Three diets each with a different level of protein for all stages of production were composed. CP levels aimed at were 10 13 and 16 % in dry matter (DM of 88 %). Three diets were formulated with similar DE content and 3 different CP levels which were the same during the hot and the cool season. The diets were formulated using four major ingredients; rice bran, corn meal, cassava meal and fishmeal. These compounds constituted about 98.5 % of the diet with the remainer being 0.5 % premix-vitamins, 0.5 % premix-mineral and 0.5 % of sodium chloride. Protein levels were based on medium and high levels from the literature and the low value from common farming practice in Vietnam. A different protein level between diets was obtained by including different amounts of fishmeal at the expense of mainly rice bran. Lysine was added at a level of 5 g per kg in all diets. The diets were formulated using standard feeding values for the ingredients (NRC 1998) as recommended by the NIAH (2001).

Table 1. Ingredients and analyzed chemical composition of the three experimental diets.

Ingredients	Dietary protein (%)		
	10	13	16
Rice bran (%)	45.0	45.5	49.0
Corn meal (%)	33.0	30.0	27.0
Cassava meal (%)	17.5	12.5	5.5
Fish meal[1] (%)	2.5	10.0	16.5
Vitamin–premix [2] (%)	0.5	0.5	0.5
Mineral–premix [3] (%)	0.5	0.5	0.5
Salt	0.5	0.5	0.5
Synthetic lysine [4] (%)	0.5	0.5	0.5
Crude protein (g/kg) (analyzed value)[5]	101.8	132.6	160.4
DE (MJ/kg DM) (calculated value)[6]	13.5	13.4	13.3
ME (MJ/kg DM)[6]	13.0	12.9	12.8
Calcium (g/kg)[6]	1.13	4.10	7.20
Phosphorus (g/kg)[6]	0.69	2.50	4.45

[1] Fish meal (46 % CP) was supplied by Cargill Company (USA).
[2] Supplied per kg diet: 0.24 mg folic acid, 1380 IU vitamin A, 180 IU vitamin D_3, 11 IU vitamin E.
[3] Supplied per kg diet: 108 mg Zn (as ZnO), 108 mg Fe (as Fe_2SO_4), 60 mg Mn (as MnO), 65 mg Cu (as $CuSO_47H_2O$), 0.96 mg I (as $Ca(IO_3)_2$), 0.11 mg Co (as $CoSO_47H_2O$), 0.07 mg Se (as Na_2SeO_3), 2 g calcium phosphate (as $CaHPO_42H_2O$).
[4] Lysine HCL, manufactured by CJ CHEILJEDANG Cooperation, Seoul, Korea.
[5] CP value analyzed by laboratory of Animal Nutrition of Hue University of Agriculture and Forestry.
[6] Calculated using digestibility values of individual ingredients from the NIAH (2001).

Formulation of diets was the same in both seasons and the analyzed content in both seasons were similar (the DM value differed less than 2 %). Feed ingredients and diets were analyzed for DM and CP by the animal nutrition laboratory of the Department of Animal Nutrition of HUAF. For determination of the dry matter (DM) content, feed was freeze dried according to ISO 6496 (ISO 1998). Air–dried feed was dried in forced air oven at 103°C to constant weight. Crude protein concentration was determined as Kjeldahl N x 6.25 according to ISO 5983 (ISO 1997). All feed samples were analyzed in triplicate.

The determined CP levels were 10.2, 13.3 and 16.0 % for the two trials and were similar for the hot and the cool season. Diets were made fresh every two weeks during each trial. The mean chemical composition of the experimental diets, based on analysis of ingredients, is shown in Table 1.

THERMAL AND HUMIDITY MEASUREMENT

During the experiments, the temperature and humidity in the building were recorded every two hrs over 24h periods. Temperatures of a local weather station were taken as reference values. The temperature and relative humidity inside each pen was recorded at 5 points, one in each of the four corners in each pen and one point in the middle of the pen three times a day throughout the trial. Average results were used for analysis. The temperature was recorded about 5–10 cm above the floor and the mean of these 5 points was taken as a reading. The results were averaged per month.

CARCASS DATA

Food was withheld one day before each pig was slaughtered, 150 day after the start of the study. The pigs were electrically stunned and slaughtered according to normal commercial practice. Six pigs were random chosen from 12 pig of each treatment groups and used for carcass testing. The carcasses of six pigs within each treatment group were weighed and chilled at 4°C before physical dissection. Briefly, middle line backfat measurement was made at the fist rib, last rib and at the last lumbar vertebrae. Carcass measurements collected in the cooler included: dressing percentage, average backfat thickness (mm), (at first rib, last rib, and last lumbar vertebra) depths, and at a point 6.5 cm from the midline at the last rib (P2). Carcass length was measured from the anterior edge of first rib to anterior edge of pubic bone (in cm) immediately after slaughter. The longissimus loin eye area (in cm^2) was measured at a point ¾ the length of the muscle from the medial side at the 10^{th} rib ham yield in relation to pork/leg. One half of the carcass was subjected to physical dissection as described by Hansen and Lewis (1993b). The shoulder was separated from the loin and belly by a straight cut between the second and third rib and a straight cut 2.5 cm ventral to the ventral edge of the scapula. The ham was removed from the loin by a straight cut between the second and third sacral vertebrae approximately perpendicular to the shank bones. Each cut retained its corresponding skin and subcutaneous fat. The loin was separated from the belly by a cut that began just ventral to the ventral side of the scapula at the cranial end and followed the natural curvature of the vertebral column to the ventral edge of the psoas major at the caudal end of the loin. The weight of each cut was determined. After weighing, shoulder and ham were separated by knife into skin, subcutaneous fat, intermuscular fat, muscle (including blood vessels, ligaments, tendons and connective tissue) and bone. Carcass lean and fat ratio (%) was calculated from total weight half carcass (not included head and feet) and lean ratio in this half after dissection, included (%) lean, fat, bone and skin.

PROTEIN AND FAT DEPOSITION CALCULATIONS

The deposition rate of protein and fat in the empty body of the two genotypes were calculated assuming one gram of protein and fat contained 23.4 and 39.7 kJ of energy, respectively and ME intake = DE intake x 0.96 (NRC, 1998). The following equations were used:

ME intake = MEm + c* protein deposition + d* Fat deposition (1)

where:

MEm is the amount of ME required for maintenance (460 kJ of ME per kg of metabolic body size ($W^{0.75}$).

c* represents the amount of ME needed for deposition of 1 g of protein. Based on NRC (1998) the required amount of ME per g of protein deposition is 53 kJ.

d* represents the costs for deposition of 1 g lipid. Based on the NRC (1998) the amount of ME required for the deposition of 1 g of fat is about 53 kJ.

On the basis of literature (Kotarbinska and Kielanowski , 1969) 10 % of weight gain is gut fill and ash. So 0.9* ADG = Water + Protein + Fat. The deposition rate of protein and fat in the empty body of the three genotypes were calculated based on two following equations.

0.9ADG = F + P/0.21 (2)

where:

ADG is the average rate of gain (g/d)

0.21 is protein/(protein + water)

F is the amount of fat deposited (g/d)

P is the amount of protein deposited

Also ME for production = F* 53 + P* 53 (3) where:

MEp is the metabolizable energy used for fat and protein deposition.

F is the amount of fat deposited

P is the amount of protein deposited

From equation 2 and 3, protein and fat deposition can be calculated.

STATISTICAL ANALYSES

The data (initial weight, final weight, ADFI, ADG, FCR, backfat measurements) were statistically analyzed by the ANOVA procedure using GLM – multivariate analysis of SPSS software (Version 11.5). The experimental data were analyzed to include genotype, protein level and season as factors according to the following model:

$Y_{ijkl} = \mu + G_i + P_j + S_k + G_iP_j + G_iS_k + P_jS_k + B_l + G_iP_jS_k + e_{ijkl}$

where

Y_{ijk} is observed value of the dependent variation of individual k of genotype and dietary protein level j

μ is the overall mean of the observations

G_i is the effect of genotype $i = 1 \rightarrow 2$

P_j is the effect of dietary protein level $j = 1 \rightarrow 3$

S_k is the effect of season $k = 1 \rightarrow 2$

$G_i P_j$ is the interaction between G and P

G_iS_k is the interaction between G and S

P_jS_k is the interaction between P and S

$G_iP_jS_k$ is the interaction between G, P and S

e_{ijkl} is the random error $(0, \sigma^2)$, $l = 1 \rightarrow n$, and e_{ijkl} the random error associated with each observation.

A model with quadratic terms was fitted to the feed intake, ADG, FCR, backfat and lean percentage data with crude protein content as the independent variable. All statistical analyses were performed in SPSS version 11.5 with a probability level of 5 % regarded as significant.

RESULTS

TEMPERATURE DATA

The climate data during the 12 months during which the studies were performed is presented in Figure 1. The ambient temperature and relative humidity averaged 25.3°C and 86 %, respectively.

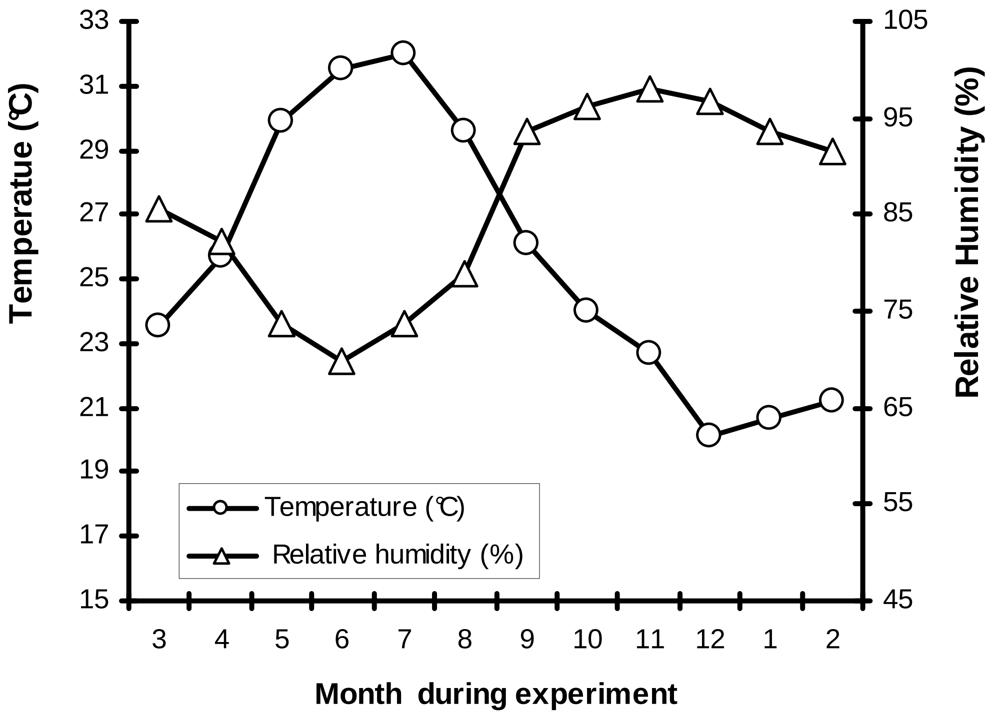

Figure 1. Mean ambient temperature and relative humidity during 12 months.

The mean daily ambient temperature and relative humidity inside building during 24 hrs are given in Figures 2 and 3. The lowest and highest mean temperature during entire experimental period were 20.0°C (in December) and 31.5°C (in June). Mean relative humidity was lowest during July (70 %) and highest in November (98 %). Data also shows a large difference in the mean temperature and relative humidity between the hot and cool season. In the hot season (March to August, the period in which the first pigs were followed), the average temperature was 29.9°C and the mean relative humidity was 81 %. The minimum temperature was 18.2°C, maximum temperature 38.5°C, maximum humidity 90 % and minimum humidity 60 % (at noon).

In the cool season (September–February), the average temperature was 24.2°C and the mean relative humidity was 89 %. The maximum temperature was 35°C, minimum temperature 15.3°C, maximum humidity 96.5 % and minimum humidity 70 %.

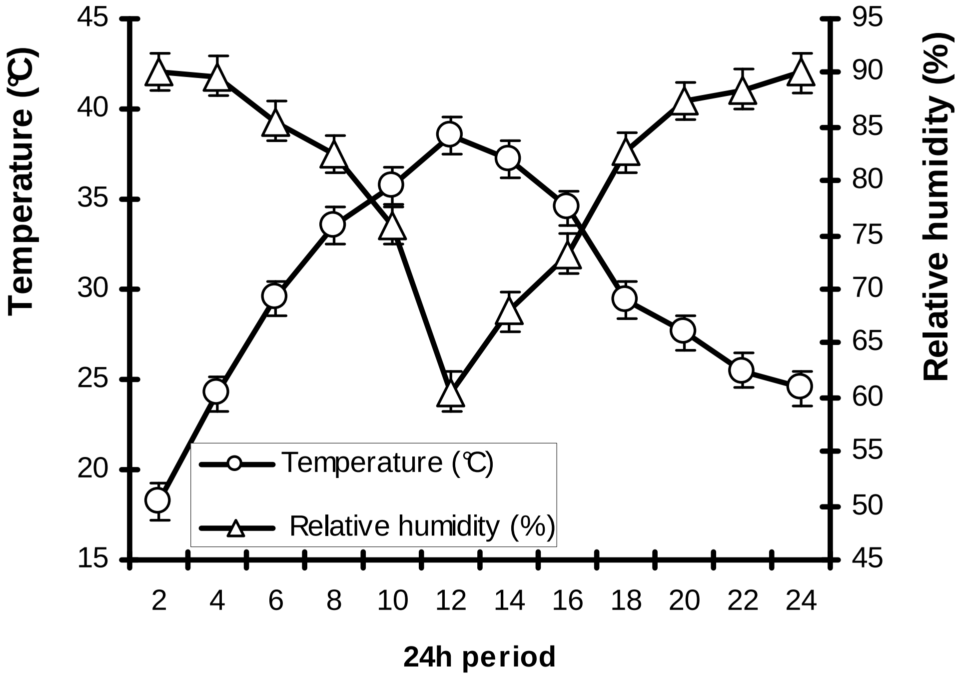

Figure 2. The mean temperature and humidity at each two hrs of the day starting with 2 am in the hot season inside the housing.

The lowest mean temperature of the day during the hot season was recorded at 4 am (20°C) while the highest mean temperature was observed at noon (38.5°C). The relative humidity during the day was highest at 24:00 hrs and lowest at noon (60.5 %). During the cool season the range in mean temperatures and related humidity was lowest at 02:00 hrs (15°C; 80 %) and highest at 14:00 hrs (26°C, 97 %).

PERFORMANCE

The effect of genotypes and dietary protein level on growth performance of the animals is presented in Table 2. At slaughter after 150 fattening days, the Landrace pigs had higher final live weights and average daily gain (ADG) compared to Large White pigs ($p<0.001$). The daily feed intake and feed conversion ratio were not affected by breed. The carcass length, dressing percentage and muscle longissimus area were not significantly influenced by breed ($p>0.05$). Backfat thickness was higher in Large White than in the Landrace pigs (22.6 vs. 21.1 mm; $p<0.001$).

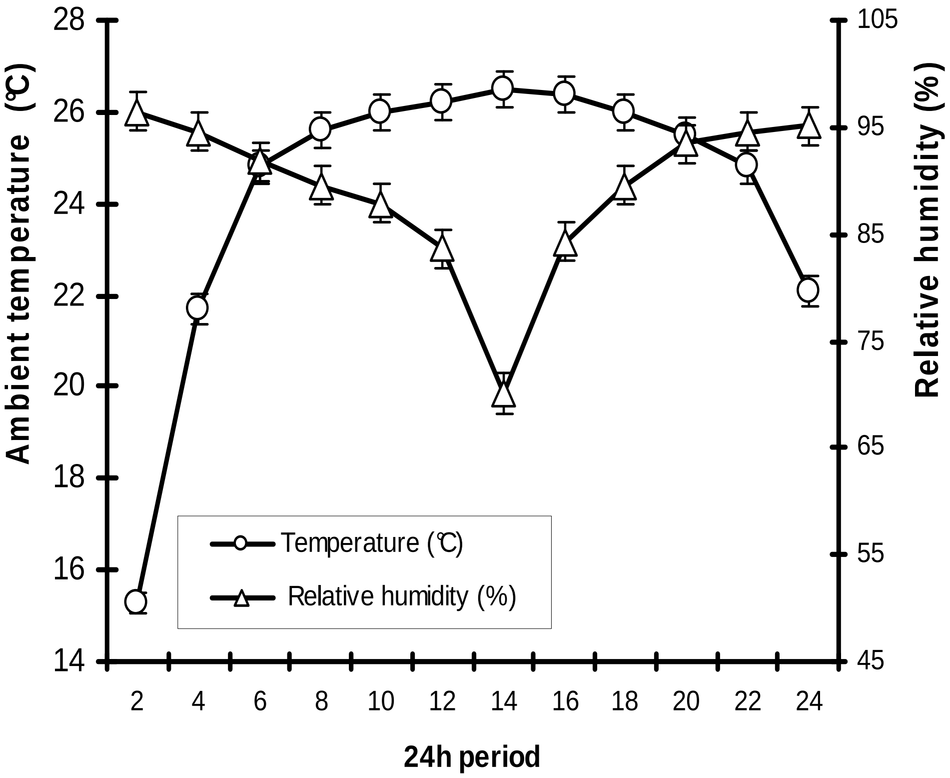

Figure 3. **The mean temperature and humidity at two hourly intervals during the day starting at 2 am in the cool season inside the housing.**

The data in Table 2 shows that dietary protein level influenced final weight, average daily gain, average daily feed intake and feed conversion ratio ($p<0.001$). The results show negative effects of low dietary protein level on intake and ADG ($p<0.001$). Season had a significant effect on final weight, average daily gain and feed intake in both genotypes ($p<0.001$). Between trials, the hot season showed lower ADFI and ADG. At the same protein level (10, 13 or 16 % CP) in the hot season, ADG was 30–50 g/d less (about 10 %) than in the cool season. There was an interaction between genotype, dietary protein level and season on final weight, and average daily gain.

Genotypes affected backfat thickness, lean percentage and fat percentage ($p<0.05$). Data in Table 2 shows that lean percentage was higher and backfat thickness was lower in Landrace than that in Large White pigs. The increasing dietary protein level affected dressing percentage, lean percentage and backfat measurement. At the two low protein levels (10 and 13 % CP), there were similar values for carcass length. At 16 % CP, Landrace pigs had less backfat compared to Large White pigs. Lean percentage in both Landrace and Large White were increased with increased dietary protein level. Lean content in the carcass was similar in both breeds and was lowest after fattening with 10 % CP and highest after fattening at 16 % CP.

Table 3 presents the response of LW and LD pigs to dietary protein levels and season in Central Vietnam. The data in Table 3 shows that both LW and LD responded positively to dietary crude protein level ($p<0.001$). Season had an effect on only some traits such as FI, ADG and final weight of LW and LD pigs but not on carcass traits such as carcass length, BF and lean percentage of the two breeds.

Table 4 shows the best fit models describing the effect of dietary crude protein content and season on growth performance and carcass characteristic variables for each of two breeds of female pigs. Only linear effects of CP were found. High dietary protein levels increased ADFI in all treatment groups. Average feed intake for Landrace pig and also for Large White pigs at three protein levels in the cool season were higher than in the hot season. There was an interaction between breed and dietary protein level for final weight, average daily gain, feed intake ($p<0.001$) and FCR ($p<0.05$). Dietary CP increased the 10th rib backfat measurement in both genotypes. Both in the hot season and in the cool season feed intake increased with CP content in both breeds. Also increases in ADG with CP content were similar in both breeds.

Season had no effect on carcass traits in both Landrace and Large White pigs. An interaction was found between genotype, dietary protein and season for final body weight and ADG. No interaction was found between genotype, dietary protein and season for carcass traits in this trial. Weight at slaughter ranged from 84 to 120 kg. Calculated protein and fat deposition data are presented in Table 5. Lipid and protein deposition were affected by genotypes and by dietary protein level. Landrace pigs had a somewhat higher calculated lipid and protein deposition rate than Large White pigs.

Table 2. Growth performance and carcass characteristics of two exotic breeds (Landrace (LD) and Large White (LW)) of pigs as affected by genotype, dietary crude protein content and season in Central Vietnam.

Parameter	Genotype (G)		Dietary protein level (P)			Season (S)		GxPxS	
	LW	LD	10 %	13 %	16 %	HS	CS	SEM	Significance
Initial weight (kg)	18.4	18.5	18.4	18.5	18.3	18.4	18.4	0.07	0.343
Final weight (kg)	96.5	96.8	84.5[a]	90.7[b]	115.1[c]	94.0[a]	99.4[b]	1.3	0.001
ADG (g/d)	521	524	441[a]	482[b]	644[c]	504[a]	540[b]	16.0	0.001
ADFI (kg/d)	1.87	1.89	1.71[a]	1.77[a]	2.17[b]	1.83[a]	1.94[b]	0.011	0.096
FCR (g/g)	2.78	2.76	2.96[a]	2.81[b]	2.54[c]	2.80	2.73	0.020	0.358
Water consumption (L/d)	5.6	5.7	5.1[a]	5.8[b]	6.1[c]	6.5[a]	4.8[b]	0.252	0.269
Dress percentage (%)	70.5	70.6	69.8[a]	70.5[a]	71.4[b]	70.5	70.6	0.72	0.146
Backfat (mm)	22.6[a]	21.6[b]	23.3[a]	22.0[b]	20.8[c]	22.1	22.0	0.07	0.183
Longissimus muscle (cm)	29.7	30.0	28.4[a]	29.5[b]	31.6[c]	29.6	29.8	0.05	0.460
Lean percentage (%)	53.6	53.9	52.1[a]	53.6[b]	55.8[c]	54.1	54.1	0.19	0.072
Fat percentage (%)	22.5	22.4	24.4[a]	22.4[b]	20.5[c]	22.5	22.4	0.05	0.058

[abc] Means within rows for genotype, dietary crude protein level and season with different superscripts differ ($p<0.05$).

LW=Large White, LD=Landrace; HS=Hot season and CS=Cool season, ADG=Average daily gain, ADFI=Average daily feed intake, FCR=feed conversion ratio.

Table 3. Comparative response of Large White and Landrace pigs to dietary protein and season in Central Vietnam.

Parameter	Dietary crude protein effect								Season effect					
	Large White				Landrace				Large White			Landrace		
	10 %	13 %	16 %	SEM	10 %	13 %	16	SEM	HS	CS	SEM	HS	CS	SEM
Initial weight (kg)	18.2	18.3	18.2	0.14	18.3	18.3	18.4	0.16	18.2	18.3	0.13	18.4	18.3	0.17
Final weight (kg)	86.0^{a}	89.5^{b}	113.2^{c}	1.15	82.2^{a}	92.1^{b}	115.9^{c}	1.27	93.5^{a}	98.9^{b}	1.08	93.8	99.8	1.26
ADG (g/d)	454^{a}	472^{b}	636^{c}	13.4	426^{a}	493^{b}	650^{c}	14.7	503^{a}	538^{b}	15.5	504^{a}	542^{b}	16.2
ADFI (kg/d)	1.70^{a}	1.78^{b}	2.14^{c}	0.03	1.68^{a}	1.79^{b}	2.20^{c}	0.04	1.82^{a}	1.92^{b}	0.04	1.84^{a}	1.94^{b}	0.04
FCR (g/g)	2.96	2.84	2.52	0.36	2.98	2.87	2.49	0.34	2.83	2.72	0.39	2.80	2.70	0.41
Water intake (L/d)	5.1^{a}	5.8^{b}	6.1^{c}	0.3	5.0^{a}	5.9^{b}	6.2^{c}	0.4	6.6^{a}	4.7^{b}	0.4	6.6^{a}	4.6^{b}	0.4
Dress percent. (%)	69.7^{a}	70.6^{a}	71.4^{b}	1.18	70.2^{a}	70.6^{a}	71.1^{b}	1.18	70.4	70.7	1.25	70.5	70.7	1.07
Backfat (mm)	23.9^{a}	22.5^{b}	21.3^{c}	0.12	22.6^{a}	21.5^{b}	20.7^{c}	0.15	22.2	22.0	0.18	20.9	21.0	0.19
Longissimus (cm^2)	28.8^{a}	29.2^{b}	31.1^{c}	0.31	29.1^{a}	29.5^{a}	31.4^{b}	0.34	70.4	70.6	0.33	30.0	30.0	0.34
Lean percent (%)	51.8^{a}	53.7^{b}	55.5^{c}	0.61	51.6^{a}	54.2^{b}	56.3^{c}	0.63	53.6	53.8	0.67	53.8	54.3	0.49
Fat percentage (%)	24.4^{a}	22.4^{b}	20.6^{c}	0.32	24.5^{a}	22.4^{b}	20.3^{c}	0.06	22.5	22.4	0.33	22.4	22.3	0.27

^{abc} Means within rows for genotype, dietary crude protein level and season with different superscripts differ ($p<0.05$).

LW=Large White, LD=Landrace; HS=Hot season and CS=Cool season, ADG=Average daily gain, ADFI=Average daily feed intake, FCR=feed conversion ratio.

Table 4. **Best fit models describing the effect of dietary crude protein content and season on growth performance and carcass characteristic variables for each of two breeds of female pigs.**

Parameter	Genotype	Hot season					Cool season				
		X^2	X	Intercept	MSE	R^2	X^2	X	Intercept	MSE	R^2
ADFI (g/d)	LW	0.0144	- 0.3089	3.3244	0.020	0.99	0.0156	0.3378	3.5722	0.020	0.99
	LD	0.0189	- 0.4011	3.8522	0.018	0.99	0.0189	-0.4044	3.7956	0.19	0.94
ADG (g/d)	LW	8.2778	-186.72	1481.4	4.86	0.82	8.0000	-175.67	1421.7	4.86	0.87
	LD	6.3333	-129	1072.7	5.25	0.88	3.5556	-53.444	613.89	5.25	0.94
FCR (g/g)	LW	-	–0.0617	3.6283	0.36	0.96	-	–0.0583	3.525	0.36	0.96
	LD	-	–0.075	3.3775	0.31	0.93	-	–0.0733	3.6567	0.31	0.96
BF (mm)	LW	-	–1.655	25.53	0.133	0.99	-	-1.95	26.053	0.133	0.99
	LD	0.0872	-2.7028	40.766	0.082	1.00	0.0522	-1.9044	36.062	0.082	1.00
Lean (%)	LW	-	0.9933	41.20	0.078	0.96	-	0.6667	45.133	0.078	0.97
	LD	-0.0222	1.3778	39.774	0.071	1.00	-0.0411	1.8056	38.036	0.071	1.00

ADG=average daily gain, ADFI=average daily feed intake, FCR=feed conversion ratio, BF=backfat, Lean=Lean percentage, LW=Large White, LD=Landrace, MSE=Mean square error. All coefficients were significantly different from zero at $p<0.05$.

Table 5. **Calculated carcass protein and lipid deposition rate in exotic pigs in Central Vietnam during the hot and cold season.**

Pig breed	Protein deposition (g/d)			Fat deposition (g/d)		
	10 % CP	13 % CP	16 % CP	10 % CP	13 % CP	16 % CP
				Hot season		
Landrace	56	62	94	152	170	259
Large White	58	69	87	159	191	239
				Cool season		
Landrace	53	67	103	147	186	285
Large White	59	73	91	163	202	251

CP = Crude protein.

DISCUSSION

This study was conducted to test the response of lean type of pigs to different CP levels both during the hot and cool season in Central Vietnam. In the literature various studies on pigs in hot environments have been reported, but no data are available on the combination of breeds, CP level, and season with results on ADG lean and protein and fat gain. In that respect this study is unique. Both breeds are lean type of pigs but they may react differently to conditions of high temperature and high relative humidity. This study showed that Landrace and Large White pigs had a different growth rate during the period of 150 days. ADFI and feed conversion were not influenced by breed ($p>0.05$). This is in accordance with previous studies in the literature (Renaudeau et al., 2005). Fan et al. (2006) showed that Landrace had better growth rates than Large Whites (862 vs. 790 g/d) and more longissimus muscle area (40.2 vs. 35.6 cm^2) compared to Large Whites. However, Johnson et al. (2002) recorded that at 177 days of age and at 114 kg, Large White had better growth rates (870 vs. 850 g/d) and lower backfat thickness (16.6 vs. 17.1 mm) compared to Landrace.

The results of studies in literature on the impact of dietary CP on carcass composition are variable. Smith et al. (1999) reported that pigs fed the low–CP, AA–supplemented diets produced carcasses with a slightly less lean percentage. Noblet et al. (1987) and Tuitoek et al. (1997) also reported minor effects of dietary CP on carcass lean percentage, with slightly higher lean yields in pigs fed diets more CP. The present results are similar to previous studies of Baker et al. (1975) and Hansen and Lewis (1993a,b) with a lean type of pigs. The growth performance varied with dietary protein level, genotype and also differed somewhat between seasonal periods. As a result body weight after a certain period differed. The feed intake varied between diets and it increased with increasing crude protein content in the diet. Renaudeau et al. (2006) and Hansen and Lewis (1993a, b) found similar effects of dietary CP content on feed intake with lean type of pigs.

Result in Tables 2 and 3 show that at low protein levels (10 to 13 % CP), Large White pigs have a better response with regard to ADG, ADFI and FCR. Several studies have reported higher carcass fatness after feeding a low dietary protein level (Chiba et al., 2002) and/or low lysine level (Cromwell et al., 1993; Witte et al., 2000) compared to a high supply. Szabo et al. (2001) report a decrease in fat content with increasing lysine to energy ratio during restricted feeding. An increase in nitrogen (protein) deposition rate is often accompanied by a decrease in lipid deposition rate and in fat depth measurements (Rao and McCracken, 1990). Cline et al. (2000) and Witte et al. (2000) also found that when feeding protein or lysine deficient diets, fat content increased and loin eye area and carcass lean content decreased.

The desirable temperature ranges for growing (25 to 55 kg) and finishing (55 to 110 kg) pigs reared in groups and provided feed *ad libitum*, respectively, are 16 to 27°C and 10 to 24°C at a relative humidity of 50 % (Pond and Maner, 1984). Since pigs in the present study were housed individually, they may be less affected during the hot season as the maximum temperatures for individually housed pigs can be expected to be higher compared to group housed pigs. The mean temperature encountered during the cool season was higher than the above-mentioned ranges for group housed pigs. The 24h mean temperature was 29°C during the summer and 21°C during the fall trial. The relative humidity as an average was 86 % (pen level) and the 24h summer mean temperature rose to 38.5°C. The optimum temperature for growing–finishing pigs has been reported to be between 18 and 21°C (NRC, 1981). During the summer trial, air temperature regularly exceeded these ranges. The environmental temperature clearly affected ADFI and thus daily ME intake. According to Quiniou et al. (2000), average daily gain and also feed intake is strongly reduced when ambient temperature is about 24°C and higher. Similarly, Renaudeau et al. (2004) and Huynh et al. (2005) found that this negative effect of temperature on intake can be augmented by high relative humidity. It should be noted that all the studies in the literature were conducted with group housed pigs unlike the present study where pigs were individually housed. The latter will reduce the effects of high ambient temperature on feed intake. The lysine content in protein needs to be sufficiently high for growth performance and thus for lean growth in lean type pigs (Rao and McCracken, 1990). In the present study, different dietary protein levels had the same effects on both breeds. However, Landrace and Large White fattening pigs responded differently with regard to final weight, ADG, and backfat thickness. Generally it is assumed (Le et al., 1999) that Large White pigs can cope better with stressful environments compared to Landrace pigs. In addition genetic lines that have been selected for increased leanness and low feed intake have been found to be more sensitive to heat stress (Nienaber et al., 1997). Myer et al. (1998) recorded that average backfat thickness was not influenced by rearing environment/season, but average longissimus muscle area was affected in the pigs in the fall trial which had larger longissimus areas than pigs in the summer trial. These results are in agreement with Myer et al. (1998) that longissimus area, and lean percentage of both Landrace and Large White pigs were higher in the cool season.

The wet tropics are characterized by two phenomena; high humidity and high ambient temperatures (Berbigier, 1998). Pigs do dissipate heat by panting, especially if they can not wallow in mud or water (Mount, 1968). So they are not dependent on skin evaporation compared to other species (e.g. humans). In the present study, animals were housed individually and could not wallow. Curtis (1983) in his book "Environmental management in animal Agriculture" (pages 79–132) describes how a combination of high temperature and high humidity can be represented in a temperature–humidity index (THI) if animals can not wallow. For pigs THI index is defined as:

TH I= 0.65 ambient temperature + 0.35 wet bulb temperature.

The impact of the wet bulb temperature is about half that of the ambient temperature (=dry bulb temperature). For this reason characterization of the environmental temperature rather than humidity was chosen here. It is well documented that ambient temperature is the predominant component of climatic conditions for pigs (Curtis, 1983; Verstegen and Close, 1994). The result showed that climatic conditions in the present trial were representative of the tropical humid climate in Central Vietnam (Le et al., 2007), (GSO, 2001, 2002), (Figures 1, 2 and 3). At high temperatures, pigs decreased their feed intake and increased water intake (Tables 3, 4). Increased water intake is needed for evaporative cooling from the respiratory tract. This evaporation is increased at high temperatures and at a high humidity (Huynh et al., 2005). However, humidity and temperature can not be completely separated. Myer et al. (1998) showed a negative effect of hot (and humid) environment on the performance of pig raised under farm–like conditions. In their research, pigs reared during the summer grew 11 % slower and required 5 % more feed per unit of weight gain than a comparable group of pig raised during the fall when the environmental temperatures were lower. Previous studies on short–term heat stress showed that at each degree Celsius above about 24°C caused less daily gain by about 36 to 60 g/d (Steinbach, 1987). Mount (1979) mentioned a decrease of 30 g/d in ADG of pigs for each 1°C above optimal temperature. According to Huynh et al. (2005), changes included increased body temperature, increased respiration rate. Results of studies by Gentry et al. (2002) indicated that temperatures from 22° to 29°C do not have a major affect on carcass measurements and meat quality. Similarly the results found here showed only minor differences in carcass characteristics of pigs fattened during the hot and cool season.

Differences in quality traits between the respective genetics were all statistically significant. Animals of both breeds performed best at the highest CP level with regard to longissimus loin eye area and average backfat thickness as well as lean and fat percentage. There were only small differences for carcass characteristics (backfat thickness, longissimus eye loin area, lean and fat percentage) between the hot and cool season.

Feed intake (or energy/protein intake) was the most limiting factor to pig production under tropical humid climatic conditions. This is in agreement with Le Bellego (2002), who demonstrated that the pig is susceptible to heat stress caused by temperature and mainly reacts by a reduction in energy intake. Since pigs decrease their feed intake at high environmental temperatures, a more nutrient dense diet with also high protein content may help to minimize production losses at high temperatures under the conditions that protein is not abundant. According to Sugahaea et al. (1970), the increased fat and decreased protein content of the longissimus dossi muscle after fattening at high temperature (33°C) may be a result of an amino acid deficiency in the diet. Calculated fat and protein deposition in Table 4 agree with previous studies that total body fat gain can vary considerably between genotypes of pigs (Bikker et al., 1995, 1996a). The differences in calculated fat deposition agree with differences in the fat percentages. Variation in energy intake is an important determinant of variation in body fat content, within pig genotypes (De Greef et al., 1994; Bikker et al., 1995, 1996 a, b). The increasing dietary protein level and increased feed intake, increased protein and fat deposition and increased lean production agree with the study of Hansen (1993a,b). Also Dierick et al. (1989) have reported a reduction in 10th rib backfat thickness and body fat and an increase in muscle mass production. Increased ME intake was associated with increased BW, protein, lipid gain and this slope of increase differed between breeds (Renaudeau et al., 2006).

The different responses in protein and lipid deposition with extra feed intake of the two breeds may result in variation in body weight. In smallholder production systems of Central Vietnam, farmers often sell their pigs at much lower body weights (60 to 80 kg). Therefore it would be interesting to repeat this study with animals at a lower final body weight to predict voluntary feed intake from potential protein deposition. Campbell and Tavener (1985) carried out experiments with very small piglets (1.8 to 6.5 kg) and Mohn et al. (2000) with pigs weighing 75 to 90 kg. Their results taken as whole agree with the view that marginal response of protein retention on energy limiting feed do not vary much with live weight. So this would mean that our results are applicable to pigs with lower final weights also.

It can be concluded that there are only very small differences in performance between the Large White and Landrace pigs at the two low protein levels (10 and 13 % CP) used in the present study. At a higher protein level (16 % CP), Landrace have a faster growth rate, final weight and less backfat. Negative effects of the hot season on performance of pigs for final live weight, ADG and ADFI were found when compared to the cool season. At high ambient temperatures and at high humidity, pigs decreased feed intake and resulted in reduced daily gains. The results show that a high performance in lean type pigs can be reached if dietary crude protein level is raised to 16 % or higher. In current study, dietary lysine level was about 0.9 to 1.0 %, higher than the NRC recommendations of 0.75 % lysine for growing (50 to 80 kg) pigs.

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6

EFFECT OF DIETARY PROTEIN LEVELS AND FLOOR TYPES ON PERFORMMANCE OF MONG CAI SOWS AND PIGLETS

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ABSTRACT

The objective of this study was to determine the effect of dietary crude protein level and floor type on the performance of Mong Cai sows. An experiment was conducted with 36 Mong Cai sows in a 3x3 factorial completely randomized arrangement with 9 treatment combinations and 4 animals per treatment. There were 3 dietary crude protein levels (10, 13 and 16 %) and 3 floor types (ground clay floor, concrete floor and raised wooden floor). Sows were from 1 to 2 years old and had an initial body weight of 120 kg (sd=2.5) after farrowing. Response criteria for growth performance of sows and their piglets included sows and offspring performance. Studied sow traits included body weight at 107 days of gestation, after farrowing and at weaning as well as back–fat depth at 110 days of gestation, after farrowing, at 21 days of lactation and at weaning (45 days). In addition, interval from weaning–to–estrus was determined. Studied progeny traits included number of piglets born, at 24 hours after birth, at 21 days of age and at weaning as well as body weight at birth, at 21 days and at weaning. Dietary crude protein level of 16 % decreased sow weight loss during lactation but did not influence back–fat loss determined at parturition and at weaning. High dietary crude protein level resulted in a higher number of piglets at weaning ($p<0.01$) and heavier piglet body weight both at 21 days of age ($p<0.05$) and at weaning ($p<0.001$). Floor types did not affect traits of sows but it affected piglets. Using raised wooden floors resulted in a higher number of piglets at weaning ($p<0.01$) compared to piglets on ground clay and concrete floor ($p<0.001$). The daily litter weight gain, piglet weight at 21 day and weaning and total weight gain during lactation on the raised wooden floor were significantly higher than on the other floor types. No interaction between dietary crude protein level and floor type on studied sow and progeny traits were found, except for body weight of piglets at weaning. The present study showed that the performance of Mong Cai sows and their piglets can be improved by increasing the dietary crude protein level up to 16 % and using a raised wooden floor rather than concrete and clay ground floor to house the animals.

INTRODUCTION

Dietary protein level can influence milk production capacity of sows. The NRC (1998) indicated that the protein requirement of a sow during lactation is about 12 to 14 % at a feed intake of 6.5 to 7.0 kg. Effects of dietary crude protein level on the productivity of lactating sows have been reported by numerous authors such as Elliot et al. (1971), Greenhalgh et al. (1980) and King et al. (1993).

According to Touchette et al. (1998), an increase in litter size and milk production has a great impact on the sow's amino acids requirements. An insufficient protein or amino acid supply causes a decrease in milk production and can affect the subsequent reproductive performance (King and Dunkin, 1986; King et al., 1993). In addition, King (1987) found that loss of body protein during lactation may have a greater influence on the subsequent reproductive performance than loss of body fat. King et al. (1993) showed that a dietary protein level (13.3 and 16.8 %) resulted in higher milk yield and in the content of fat and total milk solids. Kusina et al. (1999) showed that high protein intake during lactation reduced sow weight loss at 21 days after farrowing.

There are numerous studies which show that the metabolism of animals and their health can be affected by housing conditions and floor types. This has been shown for growing pigs housed on asphalt/straw and on concrete slats (Verstegen et al., 1974). On concrete slats, body weight gain was reduced due to an increased heat production. For sows, Silva et al. (2009) reported that in warm climatic conditions, the daily feed intake was increased in sows kept on cooled floors. Sows exposed to a cooled floor showed higher body weight (+8.5 kg) and backfat (+0.75 mm) at weaning compared to animals kept on a non cooled floor. Piglets of sows housed on a cooled floor had the highest weight at weaning, which is probably the result of an increased feed intake of the sows. Thus, the housing effect on sows during lactation is mediated via feed intake.

Mong Cai is the name of a local swine breed which are typically raised by smallholders in Central Vietnam. Sows are normally fed local feed sources which have a low nutritive value, especially low dietary crude protein (8 to 11 %) content (Pham et al., 2010). Central Vietnam has a tropical humid climate where the annual average temperature is about 25.9°C and relative humidity is about 83.4 %. During winter time, the lowest temperature sometimes falls below 15°C with more than 95 % humidity. Flooding often occurs causing additional difficulties for pig production in lowland areas. During summer time, temperatures can go up to 39°C with relative humidity of less than 60 %.

There are limited data on the effects of housing condition on the performance of Mong Cai pigs in the hot–humid climate of Central Vietnam. The objective of this study was to evaluate the effects of floor type and level of dietary protein content on lactation performance and the subsequent reproduction of Mong Cai sows in Central Vietnam.

MATERIALS AND METHODS

ANIMALS

Thirty six Mong Cai sows, 1 to 2 years of age and with an initial weight after farrowing of 120 kg (sd=2.5) from the Central Pig Breeding Company (Hue, Vietnam) were used in this study. The sows in the three dietary protein groups had similar weights at day 110 and were in parity 1 to 3. Sows remained in the experimental pen from the start of pregnancy until weaning of the piglets at 45 days of age. The experiment was conducted from June to December during which time the ambient outside temperature was between 20° and 29°C.

TREATMENTS

The treatments consisted of three floor types to house the sows and piglets: 1. wooden floor (WF), 2. concrete floor (CF) and 3. ground clay floor (traditional floor system in Vietnam). Pig houses were constructed from locally available materials such as bamboo and Eucalyptus wood. The floor and wall were made from Eucalyptus timber while the thatched roof was made from bamboo and *imperata* grass. The raised wooden floor and concrete floor were both situated 50 cm above ground level while the low clay floor was at the ground level. The WF was fully slatted and covered with eucalyptus boards. Each slat had an area of 270x30x4 cm with each slat fitted on the wooden support (300x20x20 cm) and a space between slats of 1 cm. The bars in the wooden floor and under neath the concrete floor pens were constructed of eucalyptus wood. The surface of two pens (a pig house) was fenced by bamboo and the roof consisted of thatch from bamboo and *imperata* grass. Pig houses were built between two weeks and three weeks before the start of the experiments. The surface area of each house was 3.75 m^2 (2.5x1.5 m). Each house was divided into two pens by a gate such that each pen had a surface area of 1.85 m^2. A feeder was placed in each pen. Temperatures were recorded daily at about 10 cm above the floor in four corners and the centre of each pen using a thermo–humidity meter. The temperature and relative humidity were recorded every two hours over 24 hour periods. Temperature and relative humidity of each period were measured three times in each pen and used average values for analysis.

FEED AND FEEDING

Three diets were formulated to contain approximately 10, 13 and 16 % crude protein (CP) with the aim to test CP level on the performance of sows and piglets. The ratios between digestible essential amino acids and digestible lysine were calculated to ensure that they were not below that of the ideal protein as recommended by NRC (1998) and in the specific diets for Mong Cai sows as recommended by NIAH (2001).

Feed allowance at 107 day of gestation was set to meet maintenance requirement estimates of the NIAH (2001). Daily feed allowance during lactation was set according to protein and energy requirement estimates proposed by Pettigrew and Young (1997). From day 1 to day 110 of gestation, all sows were fed the same gestation diet (composed out of 98 %.) containing 12 % CP at a rate of 1.6 kg/d. The diets were formulated using four major ingredients; rice bran, corn meal, cassava meal and fish meal which constituted approximately 98 % of the diet (Table 1). Each diet contained 0.5 % of a vitamin premix, mineral premix, NaCl and lysine.

From day 110 of gestation until weaning, sows were fed the lactation diets containing 10, 13 or 16 % CP. Before farrowing sows were fed 1.7 kg/d. After farrowing sows were fed limited for three days at 2.0, 2.5 and 3.0 kg per day. After the third day of farrowing, sows were provided the lactation diets *ad litbitum*. The calculated digestible energy content for both gestation and lactation diets was 12.5 and 13.0 MJ DE, respectively. Every morning, feed refusals were collected, and new feed was immediately provided. Feed consumption was determined as the difference between feed allowance and the refusals collected on the next morning. The refusal feed was dried at 60°C and weighed for later analyses in a pooled sample per CP level. Water was supplied *ad libitum* during lactation to maintain the feed intake and milk production of sows. Water intake was recorded using individual water meters installed on each pen.

Table 1. Dietary composition of the lactation diets.

Ingredients	Dietary crude protein content (%)		
	10	13	16
Rice bran (%)	46	40.0	36.0
Cassava meal (%)	15	15	11
Corn meal (%)	35	34	34
Fish meal (%)[1]	2	9	15
L–Lysine[2] (%)	0.5	0.5	0.5
Vitamin–Premix[3] (%)	0.5	0.5	0.5
Mineral– Premix[4] (%)	0.5	0.5	0.5
NaCl (%)	0.5	0.5	0.5
Crude protein (g/kg DM) (analyzed value)[5]	103.3	131.8	162.7
Total lysine (g/kg)[6]	9.0	12	15
DE (MJ/kg DM)[6]	13.3	13.5	13.6
ME (MJ/kg DM)[6]	12.7	13.0	13.1

[1] Fish meal (55% CP) was supplied by Cargill, Minneapolis, MN, USA.
[2] Lysine HCL, manufactured by CJ CHEILJEDANG Cooperation, Seoul, Korea.
[3] Supplied per kg diet: diet 0.24 mg folic acid, 1950 IU vitamin A, 1 mg vitamin B_1, 190 IU vitamin D_3, 40 IU vitamin E, 0.05 mg vitamin K.
[4] Supplied per kg diet: 52 mg Zn (as $ZnSO_4$), 47 mg Fe (as $Fe_2SO_45H_2O$), 60 mg Mn (as $MnSO_4H_2O$), 3.4 mg Cu (as $CuSO_45H_2O$), 0.96 mg I, 0.11 mg Co (as $CoSO_47H_2O$), 0.07 mg Se (as Na_2SeO_3) and 2 g calcium phosphate (as $CaHPO_42H_2O$).
[5] CP value analyzed by laboratory of Animal Nutrition of Hue University of Agriculture and Forestry.
[6] Calculated using compositional data of the NRC (1998) and digestibility values of ingredients from the NIAH (2001).

MEASUREMENTS

Sows were weighed on the day of insemination, at 110 days of pregnancy, within 24 hrs after farrowing and at 45 days of lactation when piglets were weaned. Back–fat thickness was measured by ultrasound at 24 hrs after farrowing and at

21days of lactation using the Renco LEAN–METER® (Renco Corporation, Minneapolis, MN, USA). Two measurements were made at 6.5 cm from the dorsal midline on the right and left side of the animal at the level of the 10th rib (P2). The mean value obtained for the two sides was used for analyses. Ultrasonic evaluation was accomplished by using Vaseline oil and placing the probe directly on the surface of the pig. The outer layer backfat thickness was determined by measuring from the outer surface of the skin to the boundary of the outer and middle layer fat (Smith et al., 1992).

Within 24hrs after birth, number of live born, stillborn and number of mummified piglets and piglet weights were recorded. Piglets were weighed and handled (tooth cutting, umbilical cord treatment, labelling and antibiotic administration) up to 24 hrs after birth. Piglets were weighed again on days 7, 14 and 21 after birth and also at weaning at 45 (± 3) days. During the lactation period, piglets had no access to the sows feed but water was available continuously through a low–pressure nipple drinker. Diarrhoea and mortality of piglets from 4 to 45 days after farrowing were recorded. Piglets with diarrhea were marked (in yellow colour) to be sure that they were not be counted twice. For analysis, diahrrea scores were expressed as an incidence density, i.e., a percentage of the number of piglets in the litter with diarrhoea morbidity or mortality to the total number of piglets being at risk of diarrhoea in the litter.

At weaning, the piglets were moved to a nursery on the farm, and sows were moved to a breeding facility and checked twice daily for signs of oestrus using a mature boar. Oestrus was recorded when sows stood to be mounted by the boar.

STATISTICAL ANALYSES

Effects of dietary crude protein level and floor types on dependent variables such as sow weight, sow back–fat measurements, litter size, piglet weight were analyzed by the ANOVA procedure using GLM–multivariate analysis of SPSS software (Version 11.5). The following model was used:

$$Y_{ijk} = \mu + P_i + F_j + PF_{ij} + e_{ijk}$$

where Y_{ijk} is the dependent variable of k^{th} animal within i^{th} protein level and j^{th} floor type, μ is the overall mean, P_i is the effect of i^{th} protein level ($i = 1 \rightarrow 3$), F_j is the effect of j^{th} floor type ($j = 1 \rightarrow 3$), $(PF)_{ij}$ is the correlation between i^{th} crude protein level and the j^{th} floor type, and e_{ijk} is the residual error associated with y_{ijk}. Effects were considered significant at $p<0.05$.

RESULTS

The climatic data during the trial period are presented in Figure 1. The average ambient temperature was 25.3°C and relative humidity was 83.7 %. The highest average monthly temperature recorded was 29.0°C and the lowest 20.0°C. The average relative humidity during 24 hr periods was lowest in June (70.7 %) and highest in November (94.5 %).

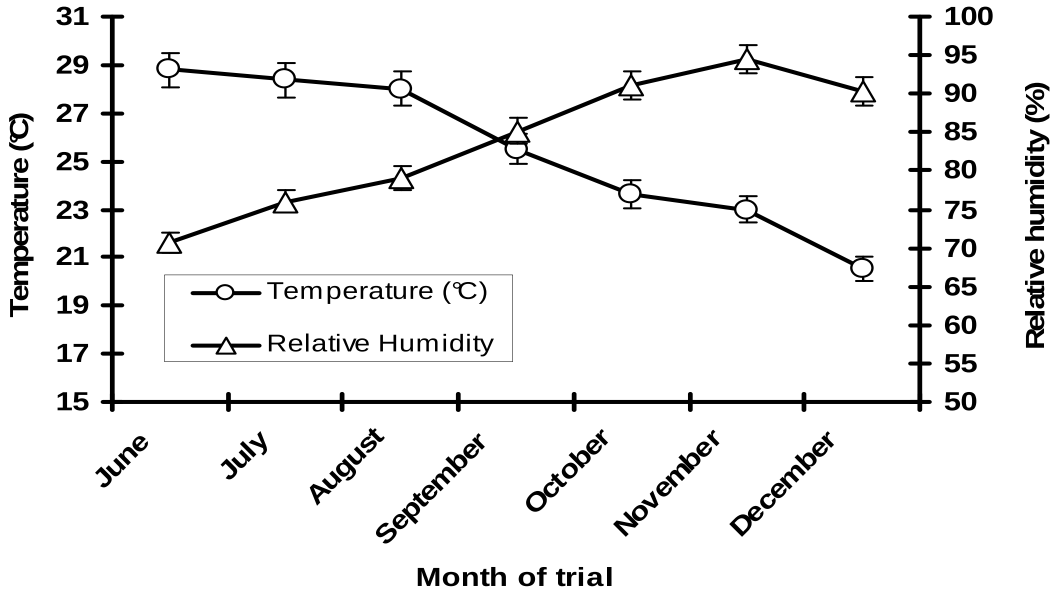

Figure 1. Mean monthly ambient temperature and relative humidity values of trial months, from June to December.

The mean values for ambient temperature and relative humidity inside the building during the day over the experimental period on the different floor types are presented in Figure 2.

The lowest mean temperatures on the ground clay floor, the concrete floor and raised wooden floor were 17.4°, 17.7° and 18.5°C and the highest temperatures were 27.8°, 28.3° and 26.5°C, respectively. Relative humidity was comparable in three floor types. The minimum relative humidity on the 3 floors were 83.9, 77.7, 72.0 % respectively and the maximum relative humidifies were 95.4, 92.5 and 85.1 %, respectively.

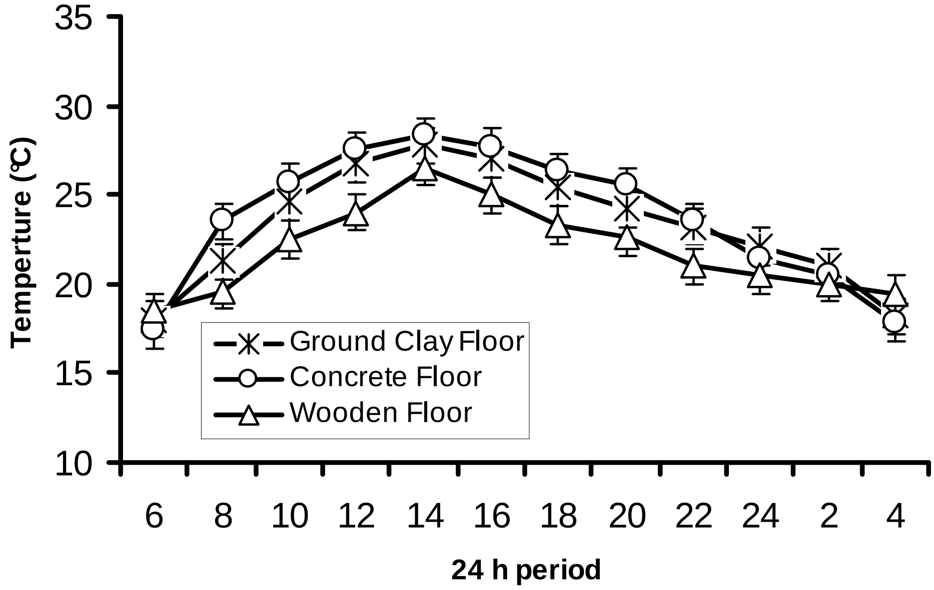

Figure 2. Mean temperature inside the animal house of the three floor type pens at two hr intervals during the day (each mean is an average of 30 individual determinations).

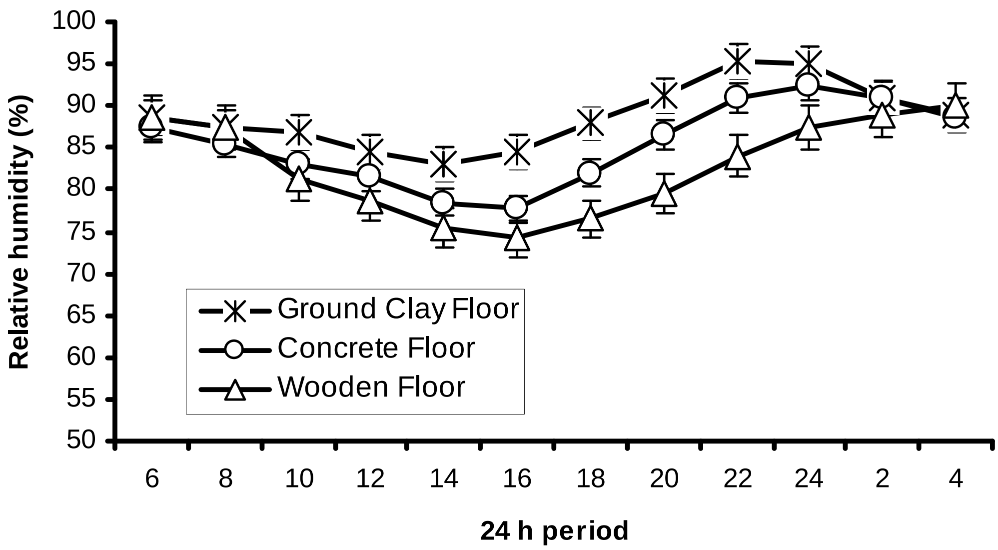

Figure 3. **Mean relative humidity inside the animal house of the three floor type pens every two hours during the day (each mean is an average 30 individual measurements)**

Table 2. Main characteristics of inside climatic values recorded during the experiment[1].

Criteria	Floor type			SEM
	GF	CF	WF	
Temperature (°C)				
Minimum	18.0^{a}	17.4^{b}	18.5^{c}	0.09
Maximum	27.8^{a}	28.3^{b}	26.5^{c}	0.17
Mean	23.3^{a}	23.8^{b}	21.9^{c}	0.15
Relative humidity (%)				
Minimum	83.9^{a}	77.7^{b}	72.0^{c}	0.33
Maximum	95.3^{a}	92.5^{b}	90.0^{c}	0.45
Mean	88.7^{a}	85.4^{b}	82.7^{c}	0.39

[1] 24h period corresponds to the means of the daily values of ambient temperature and relative humidity from each 2hour of 24 hour period record

[abc] Values within a row without a common superscript differ p<0.05,.

Floor type: WF=wooden floor, CF=concrete floor, GF=clay ground floor.

Results in Table 2 and Figures 2 and 3 show that clay ground floor and concrete floor pens had lower temperatures (at 14 pm) and higher relative humidifies (at 2h am) compared to wooden floor pens.

Table 3 shows the effects of dietary crude protein level on sow performance. Dietary crude protein levels did not affect average daily feed intake (ADFI) of sows during lactation (p>0.05). However, floor type affected sow ADFI and was 3.71 kg/d for sows housed on the ground floor, 3.86 kg/d for the concrete floor and 3.96 kg/d for the raised wooden floor.

Dietary CP level during the gestation period did not affect (p>0.05) the sow's body weight from day 110 of the gestation period until 24h after farrowing. Body weight loss of sows during lactation was highest at 10 % CP and lowest at 16 % of CP (p<0.05). Increasing dietary CP level during lactation had no influence on back–fat thickness at day 21 of lactation and at weaning. Sows fed the 10 % CP diet had a higher body weight losses and more backfat losses than sows fed dietary CP levels of 13 and 16 %.

The post weaning interval to oestrus was influenced by dietary CP level with the weaning–to–oestrus interval ranging from 6.0 to 10.4 days, and was the longest at a 10 % dietary CP content ($p<0.001$).

Floor types had a significant ($p<0.05$) influence on the daily feed intake of sows, but did not affect back–fat thickness or sow body weight changes during lactation. None of the other measured parameters were affected by the type of floor.

Litter size at birth and at day 21 after farrowing was not influenced by dietary CP levels (Table 4). Litter size at weaning was different between sows fed 10 % CP diet and sows fed 13 and 16 % CP diets while litter weight at birth was similar between treatments. Increasing dietary CP during lactation resulted in an increase in the average weight of piglets and the litter at day 21 and also at weaning.

The results show that floor type affected piglet body weight at weaning (GF: 8.46 CF: 8.96 and WF: 9.24 kg, respectively). Floor type also affected daily litter gain with the highest gain recorded for the raised wooden floor. Floor type affected the number of piglets with diarrhoea, the duration when piglets had diarrhoea and the mortality rate of piglets due to diarrhoea (Table 5). Interaction between dietary crude protein level and floor type was not observed ($p>0.05$) for feed intake of sows, body weight and back–fat changes, litter size and piglets performance on day 21. An interaction was found between dietary crude protein level and floor type for piglet weight at weaning ($p<0.001$).

DISCUSSION

The present study aimed to test effects of dietary crude protein level and floor type on the performance of Mong Cai sows and their piglets. Results showed that crude protein level in the lactation diet had a marked effect on sow body weight changes and back–fat thickness during lactation. The ADFI of sows was not significantly different between the three dietary crude protein levels. Johnston et al. (1993) also found that dietary crude protein had no effect on the voluntary feed intake. Studies of Schneider et al. (2004), Lenehan et al. (2004) and Fu et al. (2003) showed similar feed intakes with different levels of dietary lysine content (0.9, 1.1 and 1.4 %).

Table 3. Effect of dietary crude protein level and floor type on the performance of Mong Cai sows.

Parameter	Dietary crude protein (%)			Floor type			Pooled	Significance		
	10	13	16	GF	CF	WF	SEM	CP	FL	CPxFL
Feed intake (kg/d)	3.81	3.92	3.89	3.71[a]	3.86[b]	3.96[c]	0.13	0.130	0.034	0.691
Total lysine intake (g/d)	34.3[a]	47.0[b]	58.4[c]	45.7	46.3	47.5	1.45	0.048	0.123	0.667
Drinking water intake (L/d)	11.2[a]	13.7[b]	14.8[c]	13.4	13.5	13.7	0.87	0.046	0.764	0.897
Sow weight at 107 d gestation (kg)	123.1	123.3	124.2	123.0	123.9	123.7	1.76	0.773	0.877	0.964
Sow weight after farrowing (kg)	102.9	103.7	104.1	103.4	103.1	104.2	1.62	0.513	0.813	0.959
Sow weight at weaning (kg)	81.4[a]	83.8[b]	84.9[b]	83.1	83.4	83.6	1.73	0.040	0.151	0.294
Weight loss during lactation (kg)	21.2[a]	19.9[b]	19.2[b]	20.2	19.9	20.2	2.36	0.013	0.598	0.507
Back–fat at 110d gestation (mm)	35.5	34.6	34.9	34.9	35.3	34.8	1.27	0.168	0.325	0.193
24h after farrowing	33.9	32.9	33.0	32.9	33.6	33.3	1.23	0.068	0.757	0.443
at day 21 of lactation	28.5	29.8	29.5	29.2	29.1	29.5	2.16	0.157	0.463	0.575
at weaning	27.0	27.2	27.3	27.3	27.2	27.0	3.13	0.150	0.405	0.345
Back–fat loss during lactation (mm)	6.9	5.9	5.5	6.2	6.1	6.0	0.14	0.061	0.325	0.261
Weaning to oestrus interval (d)	10.4[a]	6.7[b]	6.0[c]	7.9	7.6	7.5	0.65	0.001	0.447	0.212

CP=crude protein, WF=wooden floor, CF=concrete floor, GF=clay ground floor.
[abc], Values with different superscript differ significantly within effect (crude protein level or floor type).

Table 4. Effect of dietary crude protein level and floor type on the performance of Mong Cai piglets.

Parameter	Dietary crude protein (%)			Floor type			Pooled	Significance		
	10	13	16	GF	CF	WF	SEM	CP	FL	CPxFL
Number of piglets born	12.0	12.5	12.4	12.3	12.2	12.3	0.16	0.169	0.718	0.154
at 24 h	10.6	11.6	12.1	11.9	11.8	11.6	0.23	0.126	0.622	0.980
at 21 days	10.0[a]	10.5[b]	10.4[ab]	10.0	10.5	10.5	0.40	0.046	0.571	0.909
At weaning	9.3[a]	10.1[b]	10.5[b]	9.2[a]	10.2[a]	10.5[b]	0.59	0.033	0.041	0.589
Litter weight at birth (kg)	7.32	7.63	7.67	7.38	7.68	7.56	0.39	0.082	0.605	0.499
at 21 days	26.2[a]	29.1[b]	29.6[c]	26.1	29.2	29.9	0.72	0.016	0.067	0.458
at weaning	78.7[a]	90.6[b]	97.2[c]	79.9[a]	90.1[b]	96.4[c]	3.18	0.001	0.003	0.123
Daily litter gain (kg/d)	1.61[a]	1.87[b]	1.94[c]	1.70[b]	1.78[ab]	1.94[b]	0.08	0.001	0.005	0.080
Piglet weight at birth (kg)	0.63	0.61	0.62	0.61	0.62	0.60	0.07	0.189	0.253	0.307
at 21 days	2.62[a]	2.77[b]	2.88[c]	2.61[a]	2.78[b]	2.85[c]	0.04	0.038	0.023	0.263
at weaning	8.46[a]	8.97[b]	9.24[c]	8.68[a]	8.83[b]	9.18[c]	0.08	0.001	0.013	0.032

CP=crude protein, WF=wooden floor, CF=concrete floor, GF=clay ground floor.
[abc], value with different superscript differ significantly within effect (crude protein level or floor type).

Table 5. Effect of dietary crude protein level and floor type on piglet health.

Parameter	Dietary crude protein (%)			Floor type			Pooled	Significance		
	10	13	16	GF	CF	WF	SEM	CP	FL	CPxFL
Total tested litters	12	12	12	12	12	12	–	–	–	–
No. diarrhoea piglets/sow	5.8	5.6	5.1	7.3[a]	6.7[b]	2.4[c]	0.198	0.255	0.001	0.718
No. of days with diarrhoea	5.1	5.0	4.8	6.9[a]	4.8[b]	3.2[c]	0.136	0.774	0.001	0.827
No. of dead piglets/sow	2.1[a]	1.6[b]	1.7[b]	2.1[a]	1.9[b]	1.4[c]	0.093	0.035	0.015	0.061
Mortality rate/litter/sow (%)	19.69	13.87	14.20	19.49	15.80	12.75	–	–	–	–

CP=crude protein, WF=raised wooden floor, CF=concrete floor, GF=clay ground floor.
[abc,] value with different superscript differ significantly within effect (crude protein level or floor type).

The current study shows that an increase in the dietary lysine by increasing the protein content had clear effects on performance of sows and piglets. Increasing dietary protein increased sow dietary lysine intake to 34, 47and 58 g lysine/d in the diets with 10, 13 and 16 % CP respectively. Feed intake by sows fed a high–protein/lysine diet during lactation may have been driven by the high requirements for milk production, because the sows on 16 % CP had more litter weight gain and probably produced more milk than sows fed the low–protein diet during lactation. Renaudeau et al. (2001) reported also a poor litter performance when sows were fed a low protein diet. Sows need a high lysine intake (65 g/d) for milk production (Yang et al., 2009) especially modern breeds of sows to achieve litter growth rates of >2,500 g/d (Stahly et al., 1990; Monegue et al., 1993).

The data indicate that floor type did influence the sow's ADFI ($p<0.05$). With regard to the farrowing house, the challenge lies in providing housing where the animal is maintained within their comfort limits throughout the day. A previous study of Quiniou and Noblet (1999) showed that ambient temperatures for lactating sows of between 16° to 22°C are optimal. However piglets prefer a higher ambient temperature between 30° to 32°C, at least directly after birth (Black et al., 1993). Sows housed on wooden floor during lactation had greater feed intake than sow housed on ground floor and concrete floor. Sows fed low dietary crude protein during lactation consumed less feed than sows receiving high protein diets (3.92, 3.89 vs. 3.81 kg/d). Jones et al. (1983) stated that if temperatures remain above 29°C for a short period of time, performance and reproductive efficiency are adversely affected. The increased feed intake of sows housed on the wooden floor may be attributable to greater feeling of comfort by the animals. This may be because wooden floors have more ventilation compared to ground floors and concrete floors. Evaporative and zone cooling are thus more optimal for the sow. The possibility of increased conductive heat loss may keep sows cooler compared to animals housed on ground floors and concrete floors. An increase in the ambient temperature (from 22° to 29°C) of the farrowing house, may lead to greater heat stress and reduced feed intake in the lactating sow and may compromise the final performance of the litter (Renaudeau et al., 2001). Heat stressed pigs have accelerated respiration, reduced feed intake, and increase water intake in order to maintain a constant body temperature (Messias de Bragança et al., 1998). Thus, the lack of thermal comfort may result in consequences for the productivity of the sows, compromising their reproductive cycle and piglet performance (Martins et al., 2004).

In the present study, body weight between day 110 of pregnancy and 24 hrs after farrowing were not differentially affected by the dietary crude protein concentration of the feed provided during the last week of the gestation period. Johnston et al. (1993) treated pregnant sows with low (13.6 %), medium (15.5 %), high (17.5 %) and very high (19.2 %) dietary protein concentrations and recorded that body weight of sows at day 110 of gestation and 24 h postpartum was negatively related to crude protein concentration of the previous gestation diets. In the present study, sows only received their respective CP pregnancy diets from day 107 to day 114.

High dietary crude protein in the lactation diet had a positive effect on live weight loss of sows during lactation. Johnston et al. (1993) and Weeden et al. (1994) found that increasing dietary CP concentration reduced lactational weight loss. Stahly et al. (1992) and Touchette et al. (1998) reported that losses of body weight during lactation were significantly less if high lysine levels (up to 1.25 % digestible lysine on an as fed basis) were supplied in the diet. Extra body weight loss of sows fed the 10 % CP diet in the present study was highest and this is probably caused by a lack of amino acid intake for milk protein production.

The present study showed that sows fed the lowest dietary crude protein levels had a somewhat lower feed intake. McNamara and Pettigrew (2002) found that lactating sows consuming high amounts of lysine had less body weight loss than sows eating low amounts. Yang et al, (2009) reported that sow fed low lysine (0.1 %) lost more body weight and backfat thickness from post farrowing to weaning than sow fed high lysine diets (2.4 %). Sows will have partly compensated the lack of amino acid intake by using extra body protein for milk protein synthesis. The latter can be especially detrimental for sows with a small body weight and a large litter size as the Mong Cai local breed. Sow back–fat change during lactation was not significantly affected by dietary crude protein level. These results are in agreement with Johnson et al. (1993). Moreover, Dourmad et al. (1998) found that increasing dietary protein level had no effect on back–fat thickness.

Hancock et al. (1983) and Johnston et al. (1987) reported sow back fat depth at weaning was not affected by floor materials. In the present study, floor type did not influence back–fat changes of the sows during lactation. Floor type had a significant effect on the temperature and relative humidity but did not affect sow back fat change. These results follow the same trend as found by Derno et al. (1995) and also by Quiniou et al. (2000). They found no influence of ambient temperature on backfat thickness.

Sows fed diets with a very low dietary protein content have a longer post weaning to oestrus interval. In the literature, the duration of post weaning to oestrus interval was not influenced by dietary protein treatment for sows that displayed oestrus (Brendemuhl et al., 1987) but the protein levels used in the literature were higher than in the present study. Johnston et al. (1993) noted that increasing CP in the lactation diet above an already high level (13.6, 15.5, 17.5 and 19.2 % CP) has little or no effect on the interval weaning–to–oestrus. If there are large deviations in nutrient intake (61.5 vs. 51.8 g lysine/d and ME: 78.2 vs. 65.9 MJ/d intakes), body reserve losses during lactation will also show a large fluctuation and this may influence reproductive performance (Yang et al., 1989; Dourmad, 1991). This is also in agreement with the results of King (1987) and Charette et al. (1995), who observed that the weaning–to–oestrus interval after first lactation was closely related to the amount of body protein or body weight at weaning, with heavy primiparous sows having weaning–to–oestrus intervals similar to that of multiparous sows.

Dietary crude protein level from day 110 of pregnancy onwards did not affect litter weight at birth. But lactation diets affected litter weight at 21 days and at weaning. According to King et al. (1993), dietary protein/lysine levels not only affected milk composition but also affected total solid content, thus influencing growth performance of piglets. There is a direct correlation of nutrient intake and piglet performance. Stahly et al. (1990) and Johnston et al. (1993) reported a positive effect of not only lysine but also protein intake during lactation on litter weight gain. Jones and Stahly (1999) reported that high protein and/or lysine intake increased milk nutrient output and hence overall litter growth. As nutrient intake increases, milk production rises, increasing piglet growth rates (Eissen et al. 2000). According to Brendemuhl et al. (1987), a severely restricting protein intake (380 and 760 g protein/d) during lactation significantly reduced litter size at weaning. King and Williams (1984) and King and Dunkin (1986) imposed similar dietary protein restriction in lactation diets and found no influence on litter size at weaning. The results presented here indicate that the sows fed the 10 % CP diet receive insufficient protein for maximum lactational performance and this resulted in lower piglets weights. According to Richert et al. (1997), a sow nursing 10.5 pigs responded to dietary lysine in excess of 0.8 % whereas those nursing 8.5 pigs per litter did not respond with additional pig weaning weight. Johnston et al. (1993) reported sows fed low (13.5 % CP), medium (15.5 %) and high (17.5 % CP) level had a lysine intake of 36, 48 and 55 g/d respectively. Litter weight of sows fed low, medium and high protein level were 64.4, 66.4 and 67.2 kg, respectively. Similarly, the litter weights and piglet weaning weights were highest for the sows fed 13 % CP (lysine intake 47 g/d) and 16 % CP (lysine intake 58 g/d) and lowest in sows fed 10 % CP (lysine intake 34 g/d) diets.

From the inside air temperature variation observed during the present study (18^o to 27.8°C for clay ground floor, 17.4^o to 28.3°C for concrete floor and 18.5^o to 26.5°C for raised wooden floor), the sows were exposed almost continuously to long periods of high temperatures which may have influenced their productive performance. Floor type did not influence the interval weaning–to–oestrus. Our results differ from those found by Shaw and Foxcroft (1985), Koketsu et al. (1997), they observed a negative effect of high temperature on the return to oestrus of sows after weaning. Probably this difference may be explained by breed differences and that Mong Cai pigs can cope better with the daily variation in ambient temperature. The present study also showed that sows housed on the wooden floor produced a higher piglet and litter weight gain at 21 days of lactating and also at weaning. This probably means that also milk production of the sows was higher and may be explained by a higher feed intake of these sows. Silva et al. (2009) recorded that sows exposed to periods of heat had piglets which gained less and they had a lower average weight at weaning. Total weight gain during lactation was highest ($p<0.01$) for sows raised on cooled floors (17°C) as compared to animals housed on a control floor (range 21.5° to 29.5°C). These results are agreement with Van Wagenberg et al. (2006) that cooling the floor using a farrowing crate increased piglet performance (22 g/day $^{-1}$ per piglet, which was 9 % higher than in the ordinary system). A wooden floor as used in our experiment remained cleaner and drier compared to the concrete and traditional clay ground floors and this may affect the performance and health of sows and piglets. Renaudeau (2009) reported that pigs housed in a clean environment consumed more feed and grew faster than those housed in a dirty environment. Probably the higher position of the wooden floor and consequently the air flow distribution between wooden slats had a positive effect on the animals during the gestation and lactation period.

Specific pre–weaning housing and certain floor system such as used in the present study may be beneficial for preventing the occurrence of diarrhoea of piglets which is an economic problem (Munsterhjelm et al., 2009). Mortality was highest for piglets on the clay ground floor (17.5 %) and lowest for those on raised wooden floor (12.8 %). In previous studies, Leonard et al. (1996) and Hoofs (1996) showed that mortality was lower in farrowing crates with plastic slats than metal slats. Warmer temperature conditions during the day on the concrete and on the clay ground floor as well as wet and dirty conditions of the pens is probably the main reason for high incidence of diarrhoea and mortality compared to animals on the raised wooden floor.

IMPLICATIONS

The present experiments demonstrate that dietary crude protein content affect sow and piglet performance. Because of the risk of flooding during the raining season in Lowland area of Central Vietnam, wooden floor may provide better conditions for piglets, reduces diarrhoea and mortality and may result in a higher number weaned piglets and litter weight on 21 days of age and at weaning.

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7

GENERAL DISCUSSION

INTRODUCTION

Pig production is very important for many areas of Vietnam even it performance is not always optimal yet. Growth performance of pigs, carcass composition and quality of pork depend on genetic potential, rearing conditions (feed composition, feeding level, housing) and environmental conditions (Sellier, 1998; Lebret, 2008). The nutritional value of feeds (e.g. protein: energy ratio) and amounts of feed provided to the animals are tools to influence growth rate and body composition. For these reasons, the present studies were aimed to investigate the importance of different feeding regimes to local Mong Cai growing pigs in comparison with other breeds and Mong Cai sows. The Mong Cai pig breed originates from Mong Cai in the Quang Ninh province and is nowadays widely raised in all regions of Vietnam. Characteristics of Mong Cai pigs include large litters (10 to 11 piglets per litter), average birth weight of 0.5 to 0.6 kg per piglet, weaning weight between 5 to 6 kg and slaughter weight ranging from 55 to 60 kg. Mong Cai pigs have much lower lean meat percentages (30 to 32 %) than exotic breeds and also much higher backfat percentages (33 to 35 %) (Thien et al., 1996).

For science reason, Mong Cai is a breed with low mature weight which needs only small amounts of feed for maintenance. It is a slow growing animal but can be kept in conditions where feed supply is scarce (Pham et al. 2007). In addition, it can survive on feeds with a low energy and nutrient density like diets with high fiber content (Khieu et al., 2005). It is an animal which does not have high demand of nutrition (Pham et al. 2010).For meat quality Mong Cai breed has a far superior intra and inter muscular fat content compared to the extreme lean pigs. So for these reasons, it is important to maintain the breed characteristics. The breed has important characteristics with regard to keeping and meat quality. In the literature, no comparisons of Mong Cai with other breeds are available. Therefore, the studies described here are the first which investigated the latter.

The traditional farming in Vietnam is an integrated system of rice, root crops, fruit trees, vegetables and livestock. Normally, in Central Vietnam two or three rice crops per year are produced. Cash crops such as maize, soybeans, cassava, sweet potatoes, groundnuts and vegetables are grown in the winter or summer season and harvested within three months. Rice bran is an important feed source and it contains about 11 % ether extractables, 11 % of crude protein and 8 to 9 % of crude fibre. It is used mostly for feeding pigs and dairy cows but also used as a supplementary feed source for buffalo and cattle when they are used for heavy work.

NUTRITIONAL CONSTRAINT OF PIG PRODUCTION IN CENTRAL VIETNAM

The survey (Chapter 2) explored the major reasons for the low production output of pigs in Central Vietnam. The survey showed that pigs held by smallholders are sometimes fed the same feed ingredients as people and are in direct competition with humans for food (Chapter 2). The main feed ingredients used for pigs being raised in smallholder farms in Central Vietnam are rice bran, rice, cassava meal, sweet potato vines and small amounts of salted fish. The difference between high and low quality–feeds is mainly determined by the concentration of digestible energy and amounts of crude protein i.c. amino acids. When low amounts of energy are consumed, only a small amount of energy can be deposited in body weight gain as the majority is used for maintenance processes. From the survey conducted (Chapter 2), it was found that the amounts of feed supplied to both growing pigs and sows by small-holder farmers in Central Vietnam is inadequate with regard to energy and protein supply for optimal production. These results were found for all three different zones in Central Vietnam. Comparing the standard nutritional requirements of swine (NRC, 1998; NIAH, 2001) with the nutritive value of feedstuffs supplied to fattening pigs in Central Vietnam, showed an insufficient amount of protein/amino acid in diets. On average, the crude protein content of a typical feed fed to pigs by small–holder farms is estimated to be approximately 10 % which results in a low average daily gain (Pham et al., 2010). The crude protein content fed to the growing and fattening pigs was deficient for all three regions in Vietnam with the major deficiencies occurring in Upland areas. Compared to the recommendations by the NRC (1998) and NIAH (2001), the shortage of crude protein in the growing diets was 62.1 % in Lowland, 66.4 % in Coastal and 69.7 % in Upland areas. The shortage in dietary crude protein in the fattening diets in comparison with recommendations of NIAH (2001) in the three zones was 68.2, 71.9 and 74.6 %, respectively. The shortage of crude protein in the diets of pregnant sows in the three zones were for the Lowland, Coastal and Upland areas: 31.6, 42.7 and 61.3 %, and in the diets of lactating sows in these areas 63.4, 65.0 and 78.9 %, respectively. The common factor for the low production is the insufficient supply of nutrients (especially protein) which makes it impossible to reach a high production level.

Strategies to improve pig production should therefore focus on the increase of feed supply to ensure a sufficient level of protein and energy in the diet and find ways to implement this on farms. Therefore, it is important that not only studies on research institutes are done but also investigations on farms need to be conducted. The strategies to promote pig production are focussed on using feedstuffs which are more rich in nutrients and energy than the feedstuffs given until now. In addition to providing better feedstuffs, improvements can be made by providing farmers a nutrition education programme. Interventions in Central Vietnam now focus firstly on increasing the knowledge and on changing attitudes of farmers. With this knowledge a better nutrient intake should be practiced. The important aspects are good nutritional quality, good health care, and sufficient nutrient intake. Swine nutrition education can stimulate farmers to use certain feedstuffs, but the farmer must have the means and opportunities to do this.

Data in Table 1 presents the mean composition of analyzed feed ingredients often used in diets of pigs on smallholder farms and the composition of feeds used in the present study.

Table 1. Chemical composition (as is) of main feedstuffs fed to pigs in Central Vietnam.

Ingredients	DM (%)	CP (%)	EE (%)	Ash (%)	CF (%)	ME (MJ)
Rice bran	88.2 ± 1.1	11.5 ± 0.7	11.5 ± 0.1	7.4 ± 0.03	8.8 ± 0.1	12.71 ± 0.85
Cassava meal	89.0 ± 1.2	2.6 ± 0.2	2.8 ± 0.2	1.9 ± 0.09	3.5 ± 0.03	15.12 ± 1.29
Maize meal	89.2 ± 3.6	8.3 ± 0.6	9.4 ± 0.6	1.5 ± 0.1	3.5 ± 0.02	15.06 ± 1.20
Fish meal	88.6 ± 0.8	46.3 ± 3.9	8.4 ± 0.8	16.3 ± 1.2	–	13.69 ± 1.12
Sweet potato vine	13.5 ± 1.3	16.7 ± 1.3	5.0 ± 0.3	10.3 ± 0.6	9.2 ± 1.0	9.39 ± 0.71

Values are means ± sd, the number of analyses per ingredient was between 7 and 10. DM=dry matter, CP=crude protein, EE=ether extractables, CF=Crude fibre, ME=Metabolisable energy.
Feedstuffs were analyzed by the Animal Nutrition Lab. of HUAF.

Cassava has a higher DM content than rice bran and corn meal. In addition, the data indicates that the four main feedstuffs can complement each other in supplying adequate crude protein and energy to pigs in Central Vietnam. There is a considerable amount of fibre in ingredients such as rice bran and sweet potato vine which may limit intake and digestibility (Van Soest et al., 1987). It is well-known that local pigs are able to utilize diets with a higher fibre content somewhat better than exotic breeds, such as the Large White (Kanengoni et al., 2002; 2004). In the current study, diets were mainly formulated from four ingredients so there was within the different diets a nice similarity in some properties like the type of protein and energy.

In Table 2, the composition of feeds used in the present study is presented. Fish meal can be a very good protein source but the batches should be of similar good quality. In addition, quality decay should be avoided. In the present studies, the growing animals were provided feed *ad libitum*. The reason for this is that voluntary feed intake is an important criterion in pig production and different breeds exhibit differences in voluntary feed intake.

Table 2. **Average crude protein of the analyzed batches of diets (6 batches between March and June) used for trials and calculated DE.**

Composition	Dietary crude protein level (%)					
	10	12	13	14	16	19
Dry matter	88.5 ± 0.4	88.8 ± 0.4	88.6 ± 0.4	88.8 ± 0.4	88.8 ± 0.4	88.8 ± 0.4
Crude protein (g/kg DM)	102.3 ± 0.8	123.4 ± 1.5	131.3 ± 1.2	143.8 ± 0.8	161.5 ± 0.8	189.8 ± 1.3
DE (MJ/kg DM)	13.57 ± 0.40	13.75 ± 0.27	13.51 ± 0.39	13.57 ± 0.13	13.46 ± 0.48	13.50 ± 0.12

Mean values ± standard deviation. DE=Digestible energy.

Figure 1 shows the *ad libitum* feed intake of the 5 genotypes of pigs studied in the present work (Chapters 3 and 5) at 16 % CP. Landrace, Large White and F_2 (LDxMC)xLW have a higher feed intake compared to F_1 and Mong Cai pigs. The present results show that F_2 pigs require a higher protein level and also perform better than the other breeds. This is important information to formulate practical diets for improved genotype as F_2 and lean type pigs (LW and LD) who should have at least 16% CP to have an optimal performance.

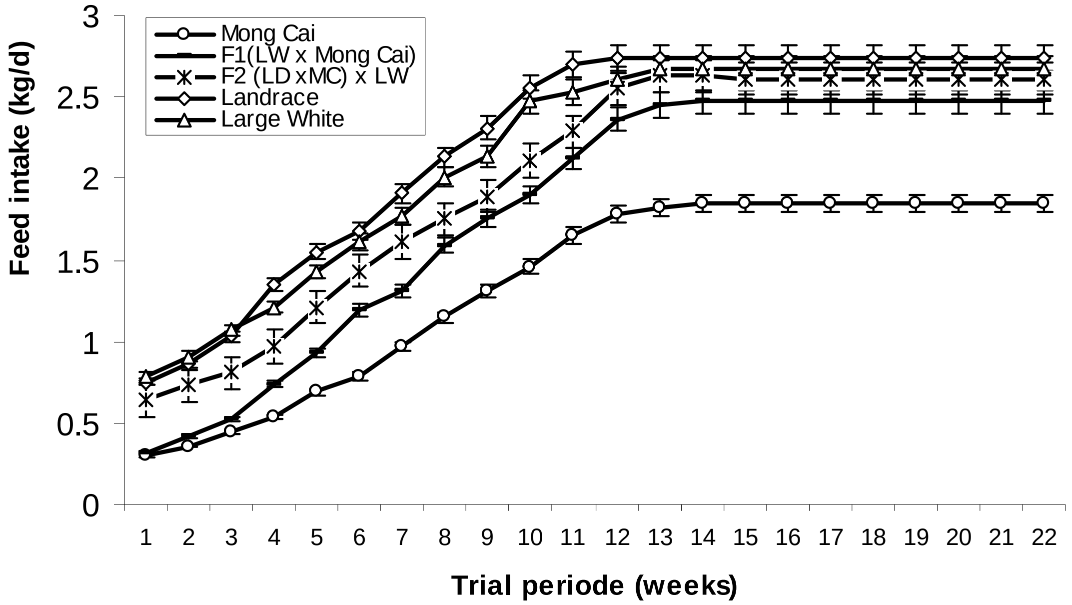

Figure 1. Feed intake during trial period at 16 % CP of five genotypes (from Chapters 3 & 5).

In Chapter 1 it was discussed that lysine is the most limiting amino acid in the protein sources commonly used to feed pigs. Therefore, the amount of lysine determines the growth of the animal when energy is not limiting. Protein requirements are generally defined as the required amount of ileal digestible ideal protein in relation to the digestible energy content (Whittemore, 1983). The dietary intake of ileal digestible ideal protein should be sufficiently high in order to support maximal protein deposition. At this point, ADG is maximal and F/G is optimal. Whittemore (1983) noted that if the amount of protein in the diet is larger than the amount required by the pig, extra energy is required to excrete the excessive N from this protein. This will reduce the amount of energy in the diet that is available for growth. In addition, it will increase body heat production to some extent and may reduce voluntary feed intake (especially if pigs are under heat stress).

The data in Table 3 show that at a low dietary crude protein level (10 % CP), all genotypes had the lowest feed intake, protein and fat gain. Within breeds, MC had the highest intake and carcass lean percentage at a dietary protein level of 13 % CP. At 16 % CP the other genotypes had the highest daily feed intake, and calculated protein and fat gain. From the results in Chapter 3 and partly summarised in Table 3, it was derived that 16 % CP was about the optimum level for crossbreds but for Mong Cai the optimum was closer to 13 %.

Table 3. Effect of dietary crude protein level on average daily feed intake (ADFI), protein and fat gain of five genotypes of pigs.

Parameter	Crude protein content (%)														
	10					13					16				
	MC[1]	F_1	F_2	LD	LW	MC	F_1	F_2	LD	LW	MC	F_1	F_2	LD	LW
ADFI[2]	1.30	1.67	1.64	1.68	1.73	1.37	1.75	1.79	1.79	1.75	1.36	1.81	2.01	2.21	2.14
Prot.dep[3]	35	69	79	54	59	41	70	92	65	71	48	75	99	99	89
Fat dep[4]	93	190	220	150	161	99	195	252	178	197	130	208	273	272	245
Backfat[5]	36.5	22,5	20.7	22.6	24.3	32.5	23.6	19.0	20.5	22.3	30.0	23.2	19.9	19.6	21.1
Lean[6]	31.1	43.5	45.2	51.5	51.8	33.6	45.5	46.7	54.0	53.6	31.1	45.6	47.7	56.6	55.1

[1] MC= Mong Cai; F_1= (LW or LDxMC); F_2=(LDxMC)xLW, LW=Large White; LD=Landrace.
[2] Feed intake (kg/d).
[3] Protein deposition (g/d).
[4] Fat deposition (g/d).
[5] Backfat measurement (mm).
[6] Carcass lean percentage (%).

EFFECT OF GENOTYPE ON PERFORMANCE AND CARCASS

The genetic potential of the pig, the nutritional level and the environmental conditions will set the maximum level of lean growth that a pig can achieve. It is important to have a good knowledge of the genetic capability of the pig because it is related primarily to the amount of dietary protein (amino acid) needed by the animal. Compared to pigs with a low genetic potential for lean growth (like Mong Cai), high lean type pigs have a high mature weight and also a high muscle growth rate. They have the ability to deposit more muscle at heavier weights than Mong Cai. In this respect it should be noted that Mong Cai pigs which have mature weights of about 120 kg are at slaughter closer to maturity than the lean types of pigs. It has been found (Richard et al., 2000) that at later stages, the same gain in muscle growth may require somewhat more amino acids compared to the early phases of the growing period because of the needs for turnover of the increased body protein mass. Thus the dietary protein content needs to be sufficient high because they still need the same amount of amino acids for the same protein gain. So pigs with different rates of protein (lean tissue) gain will have different amino acid requirements per day. Therefore, an important question is what are the protein/lysine requirements in pigs with different high lean growth rates (crossbred and exotic pigs) and in pigs with a low lean growth rates (Mong Cai).

The studies in this thesis were designed to determine which CP levels given to pigs fed with local ingredients would provide optimum results with regard to gain, feed intake and carcass composition. The focus was firstly on the optimum CP content and then on differences between genotypes. Because the same ingredients were used it can be assumed that ileal digestibility values of AA's in the CP were similar between diets. For diets composed with other ingredients, different optimums in CP can be expected. The results show that Crossbreds of Large White and Landrace with Mong Cai (F_1 and F_2) perform better than pure Mong Cai pigs even under hot conditions. This means that when dietary energy and protein is sufficiently available, the crossbreds can use it well. The results here also reveal that crossbred pigs of F_1 (LW or LDxMC) and F_2 (LDxMC)xLW have the highest rate of gain and lean percentage in their body compared to Mong Cai. The data show that the three genotypes used in the present work require a dietary protein level of 13.7 % CP for MC, 14.5 % CP for F_1 and 16.4 % for $F_{2,}$ respectively for optimal growth. These CP levels at the chosen energy level will be close to the optimum dietary protein levels for protein deposition also. The calculated fat deposition and protein deposition here are calculated with the method developed by Close (1970). It should be noted that the methods used by Close (1970) has several inherent assumptions on the ratio of protein to water as well as this regards to ash. Also gut fill is assumed to be a certain level and because in the present work the same ingredients were used, this is justifiable. The results are in accordance with the results of various studies reported in the literature that body fat gain can vary considerably between genotypes of pigs (De Greef et al., 1994; Bikker et al., 1995, 1996a, Thomke et al., 1995). It should be emphasized that the studies described here were conducted in the spring and summer with the highest temperature towards the end of the fattening period of about 25°C as an average. Obviously, the climatic conditions, particularly the environmental temperature can affect daily feed intake. According to Quiniou et al. (2000), Renaudeau et al. (2004) and Huynh et al. (2005a,b), the average daily food intake is strongly reduced when ambient temperatures are above 24°C. The data here shows that the temperatures are often above this value (Chapter 5) and so the results are influenced by high temperatures.

Fetuga et al. (1976) and Anugwa and Okwori (2008) have shown also that growth performance and muscle development proceeded at a slower rate in indigenous pig compared to the Large White and Landrace pigs. Especially in local pigs, the ratio of fat to lean increases rapidly with increases in live weight. As a result, their dietary protein requirement will be lower at higher weights than for lean type of pigs.

EFFECT OF DIETARY CRUDE PROTEIN ON THE PERFORMANCE AND CARCASS OF FATTENING PIGS

Dietary composition, particularly the protein: energy ratio can be used to modify body composition during growth and also to modify protein and/or fat deposition. Growth rate is reduced as a consequence of limited dietary CP (or lysine) levels in the pig's diet. An increased dietary CP level increased ADG, but will not increase mature weight (Lee et al., 1967). So more meat can be produced in a shorter period of time and because of the increased ADG, the higher final weight can be reached sooner (after 180 days). The results here clearly indicate the need to re–evaluate nutritional requirement of different genotypes under the environmental conditions in Central Vietnam (see also Chapter 2).

The average feed intake increases when CP increased from 10 to 16 %, but decreases when CP level is as high as 19 % (Chapter 3). These results are similar to those in previous studies in the literature such as studies from Baker et al. (1975), Reinhard et al. (1976) and Hansen and Lewis (1993a, b) with lean type of pigs. Similarly to their findings, here a curvilinear response was found for ADG and FCR to the CP level in the diet (from low to adequate to excess). Wagner et al. (1963), Reinhard et al. (1976) and Tyler et al. (1983) suggested that the decreased performance of pigs fed high–CP diets can be attributed to the low energy content of high–CP diets. Here diets with a similar digestible energy contents were used. In addition, feedstuffs from local crops often have a high level of fermentable carbohydrates which provides extra heat per unit of DE ingested (Just 1982). If a high level of protein in diets is accompanied by insufficient energy, growth will be less

(Just 1982, Henry et al., 1992). If, on the other hand, protein is limiting in the diet, it is worth increasing the CP level to enable maximal protein gain at that energy intake (Bikker 1995). The results here show that at optimum protein levels with regard to ADG, pigs also show the highest feed intake. The optimal requirements can be derived from the curvilinear relationship between CP level and ADG (see Chapter 3).

Intake and ADG was different between CP % and reached their highest level at a similar levels for dietary CP. For a low backfat level, a somewhat higher CP content is needed. Therefore, different parameters need a different optimum CP value and these optimums can be different for different breeds. Dhudapker et al. (1971) reported that growing Middle White Yorkshire pigs required 18 % CP in the diet. Reddy et al. (1981) indicated that Large White Yorkshire pigs weighing between 20 to 35 kg under Indian conditions required also about 18 % CP. On the other hand, Sharda et al. (1982) suggested that crossbred pigs (Middle White Yorkshire x Indian indigenous pig) between 14 to 25 kg BW require about 16 % CP in the growing phase and 14 % CP in the finishing phase (25 to 71 kg BW) for optimum growth and feed efficiency. So comparisons have only limited value. However, a correct comparison between CP % can only be made if AA content and digestibility (ileal) is known. If the pigs need to produce extra lean carcass meat, they may require up 18 % CP in the growing phase and up to 16 % CP in the finishing phase. It should be noted that comparison of CP % between different experiments without knowledge of the (ileal) digestibility of AA’s and AA composition of the diets makes comparison difficult. Only if feedstuffs are similar these comparisons can be made and conclusions be drawn.

Devendra and Clyde (1970) derived similar levels for optimum crude protein content for growing and finishing pigs in a tropical environment as found here. They suggested an optimum of about 16 % CP while 18 CP % was too high. So in order to have an optimum ADG and lean percentage for lean type pigs, the optimum dietary crude protein level for crossbreds between Mong Cai and Landrace and Large White in the hot season should probably be between 16 and 18 %.

Table 4 presents the effect of dietary crude protein levels on economic benefit of different genotype pigs in Vietnam. It should be emphasized that the CP content of local diets (composed of local feedstuffs) in Central Vietnam should be adjusted to the genotype of the pig, with a CP of around 16 % for crossbreds and 13.7 % for Mong Cai pigs (Chapter 3 and 4). Although lean pig types like Large White, Landrace, and Pietrain breeds have a higher yield of lean meat Vietnamese people remain to have a preference for the Mong Cai pig breed. In terms of meat quality, Mong Cai pig meat has a good water holding capacity, good taste and a superior level of intramuscular fat. Pure Mong Cai females are common used as the mother line for cross-breeding with exotic boars and is used in approximately 10 % of the pig population. The meat of crossbreds F_1 (LW or LD x MC) was judged more tender, juicy and tasty than meat from LW and LD pure breed (Pham et al. 2007).

Table 4. Average feed cost per kg gain and benefit per kg gain from each genotype.

Genotype	Dietary protein level (%)			
	10	13	16	19
	Average cost per kg gain of each genotype			
MC[1]	9,037	9,172	10,826	7,746
F_1	12,301	12,240	12,587	12,484
F_2	13,656	13,790	14,757	12,746
	Net income of each genotype when sold [2]			
MC	313,011	351,308	512,777	250,913
F_1	770,942	799,760	917,036	838,818
F_2	921,532	1,087,326	1,335,869	980,942

[1] MC=Mong Cai; F_1= (LW or LDxMC); F_2=(LD x MC)xLW.
[2] Calculated in Vietnamese Dong (VND). Costs included are animal cost, feed cost, veterinary and housing cost. Net income was calculated per pig.

Table 5. Effect of genotype on feed intake of pigs during 150 days of growth under *ad libitum* feeding conditions.

Variable	MC	F_1	F_2	LW	LD
Initial weight (kg)	12.2	12.3	12.4	18.4	18.5
Final weight (kg)	61.5	87.2	98.2	96.2	96.7
Viscera mass[2] (kg)	8.31	5.59	5.24	4.51	4.56
Daily feed intake (kg/d)	1.32	1.75	1.85	1.98	2.10
Daily feed intake (g/d/kgBW$^{0.75}$)	88.2	90.8	91.6	95.1	100.0

[1] MC=Mong Cai; F_1=(LW or LDxMC); F_2= (LDxMC)xLW; LW=Large White; LD=Landrace.
[2] Consisted of heart, liver, kidney, lung and empty intestines.
Mean crude protein content was 16 %.

The data in Table 5 shows that Mong Cai pigs have a higher viscera weight compared to crossbred and exotic pigs. Some of the factors that are known to influence visceral organ size are body weight, feeding level, diet composition, and pig genotype (Koong et al., 1983; Bikker et al., 1996a; Coudenys, 1998). Since the same diets were fed and the pigs were housed identically, the differences in performance can be assumed to be directly related to genotype.

RELATIONSHIP BETWEEN GENOTYPE, PROTEIN AND ENERGY

The utilization of dietary protein must be placed into the context of the available energy supply as this is the main driving force of metabolism. If energy is limiting, part of the dietary amino acid supply may be used for energy. In the present studies, a dietary energy content of 13.5 to 14 MJ DE per kg as used. The results show that protein deposition rate was clearly increased for all breeds of pigs if CP level increased up to 16 %. Protein and fat deposition differed between genotypes with F_2 pigs having the highest fat and protein deposition rates and Mong Cai the lowest rates. In the diets used here, the optimum calculated lysine content was 9.3, 10.0 and 10.5 g per kg diet for MC, F_1 and F_2, respectively. This is somewhat higher compared to the NRC (1998) estimates, probably because of the differences in AA digestibility of the ingredients used here with ingredients on which the NRC tables are based.

Since most animals eat to meet their energy requirements, an alternative method of expressing the protein needs is in relation to the energy concentration expressed as g/MJ of DE, as energy in protein (kJ) or as energy from protein/MJ DE. In general, differences in energy metabolism are related to feed intake level (Verstegen et al., 1982). If the protein is in excess, the pig utilizes this for energy (fat deposition) making the animal less efficient in terms of protein utilisation compared to when lipid and starch are used. Some of the factors that are known to influence intake are BW, feeding level, diet composition, and pig genotype (Koong et al., 1983; Bikker et al., 1996a; Quiniou et al., 1995; Coudenys, 1998). Variation in energy intake is an important determinant for variation in body fat distribution, as well as the total content, within pig genotypes (Campbell et al., 1985; Campbell and Taverner, 1988; De Greef et al., 1994; Bikker et al., 1995, 1996a,b; Quiniou et al., 1995, Coudenys, 1998). The current study shows that MC achieves a higher body fat percentage compared to F_1, F_2 and lean pigs.

It should be noted that the formulae for the calculation of fat and protein have been derived with data of moderately lean pigs (Kotarbinska and Kielanowski, 1969), which can be considered comparable to the F_1 and F_2 animals in our study. Bikker et al. (1996a) showed that carcass fat deposition rate was more dependent on energy intake than on protein intake. Similarly, in the experiments reported here, the highest fat content and fat deposition rate was observed at the highest feed intake (energy intake). If the energy intake is above that needed for maximal protein deposition, lipid deposition increases. De Greef et al. (1994) observed in this respect that energy intake above the maximum capacity of protein deposition, caused an increase in the carcass lipid: protein ratio. My results and review of the literature shows differences in the capacity for protein deposition between the genotypes. So genotype and diets need to be considered together for optimal feed composition of growing pigs in Vietnam.

IMPACTS OF CLIMATIC CONDITIONS

The growth performance of pigs reared in tropical areas is mostly low even when balanced diets and improved breeds are used (Egbunike, 1986). This low level of performance is due to a range of factors associated with tropical climatic conditions. In Central Vietnam, the two typical characteristics of the tropical climate are a high air temperature and high relative humidity.

Numerous studies have shown that ambient temperature has a direct effect on voluntary feed intake and therefore on the performance of pigs (Verstegen et al., 1978; Close, 1989.) In the literature, various studies on pigs in hot environments have been reported, but no data are available in terms of a combination with breeds, CP level, and season which results in ADG, protein and fat gain. Until now the feeding strategies under these conditions are determined by practice and by some derivations from scientific data obtained with other types of pigs and pigs kept under different conditions. The present studies are unique because both local and imported breeds of pigs are compared and exposed to a range of different dietary CP levels derived by using mostly local feedstuffs which were fed during different seasons. LW and LD breeds are lean type of pigs but they may react differently to high temperatures and relative humidity. The climatic conditions, particularly the environmental temperature, clearly affected daily DE intake in the studies here. According to Quiniou et al. (2000), average daily gain and feed intake are both strongly reduced when ambient temperature is about 24°C or higher. Similarly, Renaudeau et al. (2004) and Huynh (2005b) found that this negative effect of temperature on intake can be worsened by high relative humidity.

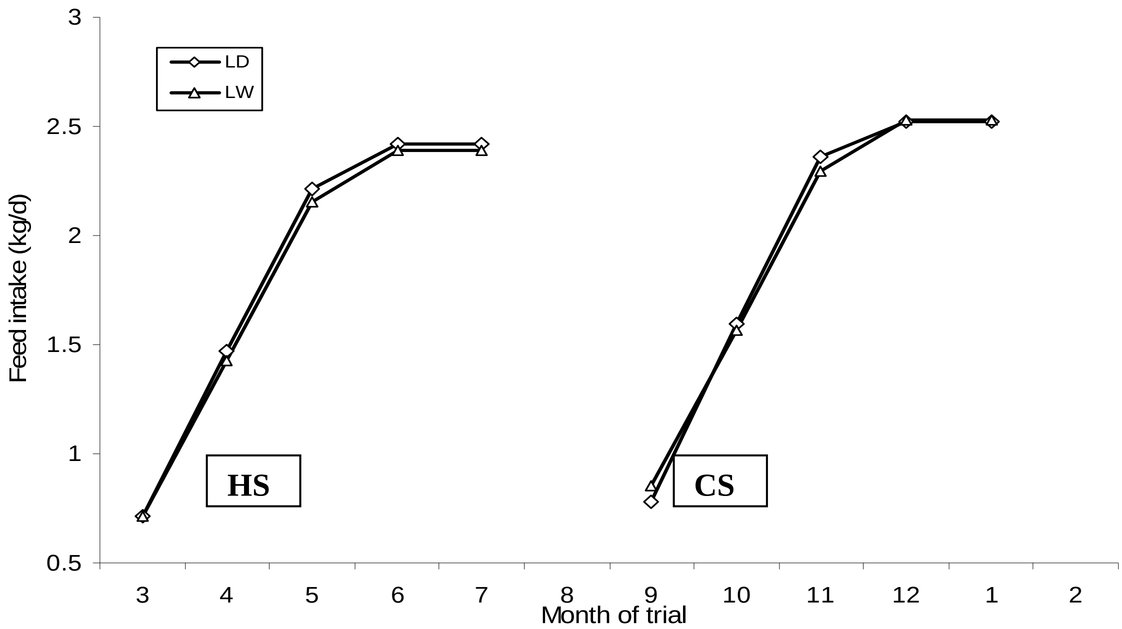

Figure 2. **Average daily feed intake (kg/d) of Large White (LW) and Landrace (LD) pigs per month during the hot (HS) and cool (CS) seasons in Central Vietnam**.

It is clear that lean type pig (LW and LD) have a lower feed intake, ADG and lean content in hot conditions compared to thermo–neutrality conditions (see Chapter 5). In addition, lean pigs are more sensitive to heat stress than obese lines (Nienaber et al., 1987). It is also well documented that ambient temperature is the predominant component of climatic condition for pigs (Curtis, 1983; Le Dividich and Herpin, 1994; Verstegen and Close, 1994). The results here showed the response of pigs to tropical humid climate in Central Vietnam (Figures 2, 3 and 4). In the hot season, both genotypes (LW and LD) have a lower feed intake (g per kg body weight$^{0.75}$) than in the cool season (Figure 3 and 4). At high temperatures, pigs decrease their feed intake and increase water intake. Observations here indicate that average water intake in the hot season is higher than that in the cool season (4.5 vs. 3.5 kg/d) and water/feed ratio is 2.47 in the hot season instead of 1.80 in the cool season. High water intake is a response of the animals to provide water for evaporative cooling from the respiratory tract. In previous studies on short–term heat stress, it was shown that each degree Celsius above 24°C causes less daily gain of about 36 to 60 g/d (Steinbach, 1987). Mount (1979) also suggested that there is a decrease of 30 g/d in the ADG of pigs for every 1°C above the optimal temperature.

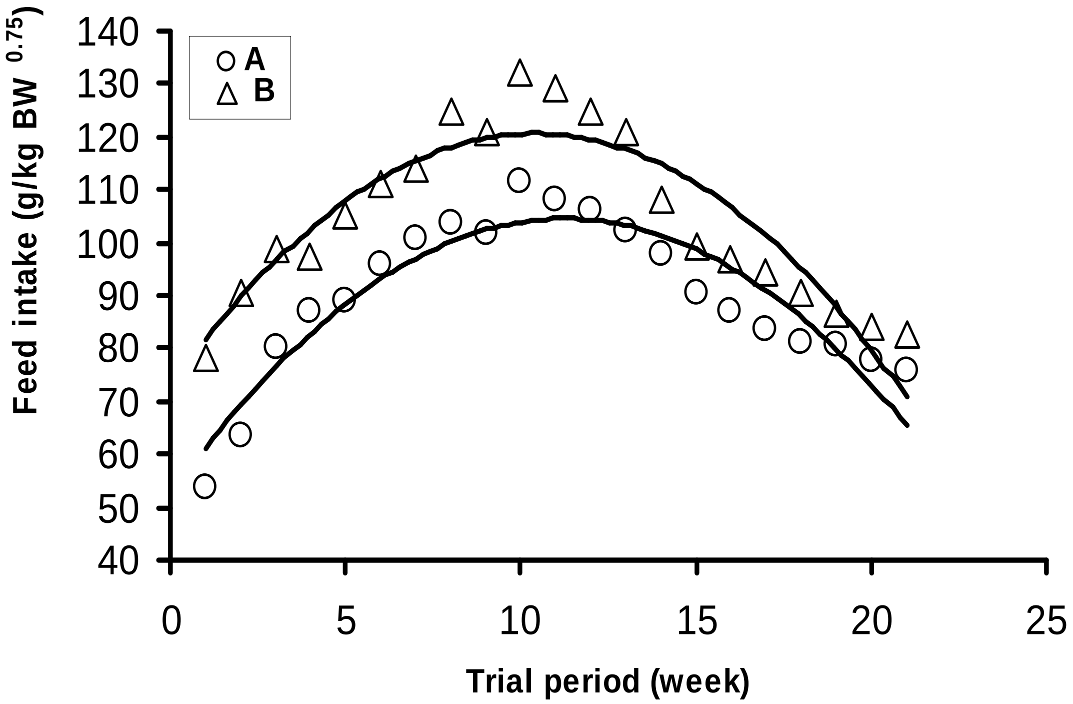

Figure 3. **Effect of season on feed intake (g per kg body weight $^{0.75}$) of Large White pigs during the hot (A) and cool seasons (B) in Central Vietnam.**

The results show that pigs raised during the hot season have a lower ADFI and ADG compared to when the same animals are raised during the cool season. At the same protein level (10, 13 or 16 % CP), the ADG is 30–50 g/d (about 10 %) less in the hot season compared to the cool season with ADFI being about 110 g/d less. The average weight gain per day decreased by 10 g/d for each 1°C above the optimal temperature (20° to 25°C, Huynh et al. 2005b) for growing finishing pigs. From week

1 to week 3 of the trial period, feed intake (g/kg body weight $^{0.75}$) for both lean type pigs were not different between the hot and cool season. Huynh et al. (2005a,b) noted that temperature has a strong effect on pig behaviour whereas humidity has less effect. However, the effect of humidity, as revealed in their study, was that the lowest ADG was at 80 % relative humidity and highest at 50 %. The latter authors found that respiration rate increased in high ambient temperatures and even more with additional high humidity. Huynh et al. (2005b) also noticed that feed intake decreased in both high temperature and relative humidity. Results of studies by Le Bellego et al. (2002) and Gentry et al. (2002a, b) indicate that with temperatures from 22° to 29°C, carcass measurement and meat quality were not much affected. Similarly, the studies here also showed that there are only minor differences in carcass characteristics of pigs fattened during the hot and cool season. It should be noted that pigs here are housed individually while most studies in the literature report data on group housed pigs.

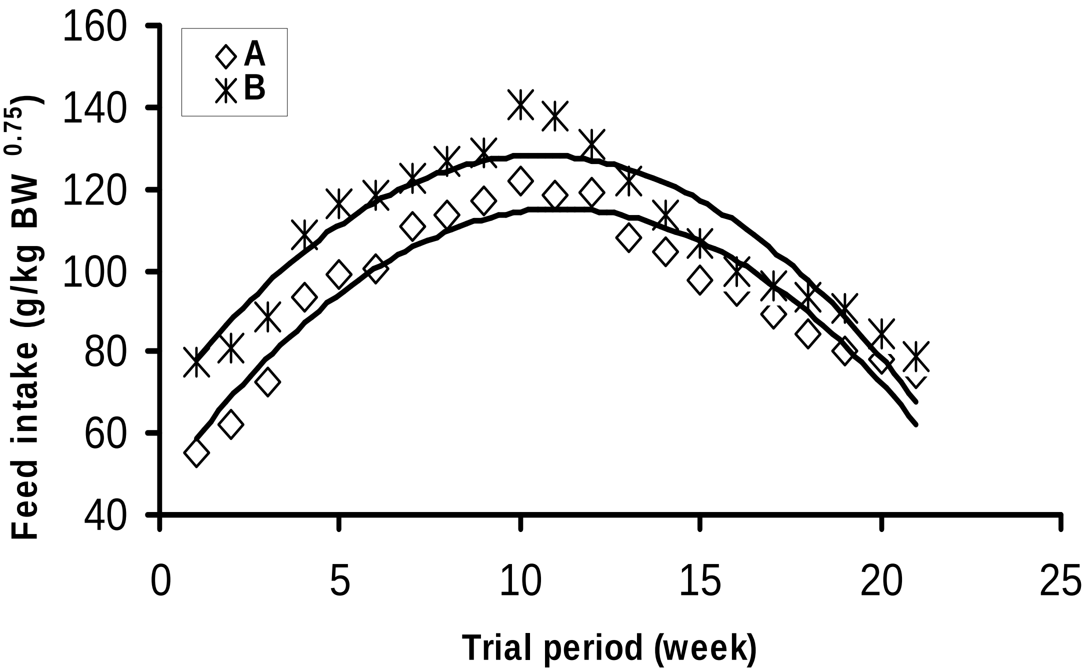

Figure 4. **Effect of season on feed intake (g per kg body weight $^{0.75}$) of Landrace pigs during the hot (A) and cool seasons (B) in Central Vietnam.**

Since pigs have a lower feed intake at high environmental temperatures, a nutrient dense diet (with extra fat) which does not yield much additional heat may help to minimize production losses at high temperatures. This can only be obtained by including highly digestible feedstuffs with a high starch and lipid content. With a low level of heat produced, energy intake during time of high temperatures can be maintained better. Thus, high dense diets can assist in maintaining feed intake provided that they do not yield extra energy in the form of heat. Also an ideal amino acid composition of the protein may be beneficial since Friesen et al. (1991) observed improved rates of gain when diets for finishing pigs were supplemented with crystalline L–lysine at conditions where daily temperature exceeded 32°C.

Farmers in smallholder production systems in Central Vietnam often sell their pigs at a lower body weight (60 to 80 kg) compared to the final fattening weight employed here. Campbell et al. (1985) carried out experiments with very small piglets (1.8 to 6.5 kg) while Möhn et al. (2000) studied pigs from 75 to 90 kg. Overall their results showed that the marginal response in protein gain to dietary protein with extra energy did not vary much with variation in live weight. Transposing these result to the work conducted here indicates that the data in the present work may be representative for pigs with a lower final weight.

EFFECT OF DIETARY PROTEIN/LYSINE LEVEL ON PERFORMANCES OF SOWS AND PIGLETS

The feed intake of lactating sows is influenced by several factors e.g. feeding during gestation, body weight, litter size, environment temperature as well as energy and protein concentration of the feed (Verstegen et al., 1998). Sow feed intake and litter size at weaning are affected by lysine content in the sow's diet. Monegue et al. (1993), Weeden et al. (1994) and Johnston et al. (1993) observed that losses of body weight during lactation were significantly affected by dietary lysine level (low level 0.62 % and very high level of 1.05 % lysine). Sow weight loss during lactation decreased considerably with an increase in the lysine content (Touchette et al., 1998). The weight and backfat thickness changes observed in sows during lactation are a consequence of changed feed intake, composition of the feed and amounts of milk produced. Duration lactation, the number of piglets, parity and environmental condition are of influence. According to Close and Cole (2000), a high level of dietary energy intake can minimize the variation in weight and backfat thickness between sows. The results of the present study show that for Mong Cai pigs feed CP is important for the level of weight loss and backfat thickness during lactation. Daily DE intake of lactating sows observed on all diets is lower the minimum recommended by NRC (1998) of about 73.2 MJ DE per day.

Dourmad (1991) reported that a low feed intake occurred during the first week of lactation. This author estimated that the loss in body fat during lactation was 95 g/d per mm of backfat during the first week of lactation and 63 g/d per mm of backfat over the entire lactation period. Mullan and Williams (1989) derived a regression equation for backfat losses and fat content losses of primarous sows as affected by amount of feed intake. Lewis and Speer (1973) and Johnston et al. (1993) recorded that backfat change was not affected by lysine level in the diet. King et al. (1993) recorded a low fat mobilization in sows when daily lysine supply was about 25.5 g. In present study, Mong Cai sows had the least back fat loss when daily lysine intake was 40.1 g/d (1.05 % lysine, Chapter 4).

Johnston et al. (1993) reported that the increase in protein intake for sows had little effect on the interval to post weaning oestrus. According to Stahly et al. (1990) and Monegue et al. (1993), intake level during lactation can affect the weaning to estrus interval. In the present study, it was found that at dietary lysine levels of 0.6 %, sows have a longer interval of weaning to estrus than at a high dietary lysine level. Lee and Mitchell (1989) showed that there is no effect of protein level during pregnancy on piglet birth weight. Here, sows only had a few days (from day 107 onwards) with different CP levels so an effect on birth weight cannot be expected. Litter growth rate was unaffected by pregnancy treatment during 7 to 10 days of pregnancy. Cooper et al. (2001) also recorded that the numbers of piglets born and piglets born alive was not affected by dietary lysine level during gestation.

Yang et al. (1989) reported that lactation diets with concentrations of total lysine ranging from 0.6 to 1.60 % yielded litter sizes of 11.2 to 13.6 piglets born in the next litter. Here a smaller difference was found compared to the study of Yang et al. (1989). Stahly et al. (1990) and Johnston et al. (1993) reported a positive effect of protein intake during lactation on litter weight gain. Mong Cai sows fed a dietary lysine content of 1.05 % had a litter with a higher weight at day 21 and at weaning at 45 days compared to litters of control sows who received 0.6 % lysine. Litter weight gain was not improved at the highest lysine level (1.20 %) compared to 1.05 %. Mahan and Mangan (1975) reported that voluntary feed intake during both lactations was reduced in sows fed a diet low in protein during gestation and lactation but intake during lactation was not reduced. The data of Mong Cai pigs in the present study agree with the result of Mahan and Mangan (1975) since body weight loss was highest when sows were fed 10 % CP. Johnston (1993) found that increasing CP above the adequate level for sows has little effect on the interval weaning to estrus. The results of the study here indicate that sows fed diets with a very low crude protein content have a longer post weaning interval to estrus. This is a direct effect of low protein in the diet which results in large losses in body protein mass during lactation. According to Brendemuhl et al. (1987), it is not desirable to severely restrict lactational protein intake because it may reduce litter size at weaning.

EFFECT OF HOUSING ON PERFORMANCE OF SOWS AND PIGLETS

The microclimate in a pig pen depends on floor type. Relative humidity and inside temperature were numerically highest in the pens with wooden floors and lowest in the pens with a clay floor (Chapter 6). This may be related to more evaporation due to floor fouling (Voermans and Hendriks, 1995). In their literature review, Gonyou et al. (2006) showed a significant effect of space allowance on ADG. The results of Guingand and Granier (2001) and of Spoolder et al. (2000) show that floor type does not influence growth performance very much if animals are in their thermal comfort zone and if they have the same feed intake. However, in the current study, floor type was associated with differences in growth performance and small differences in feed intake. Pigs reared on wooden floor pens reached a higher final weight and had a higher ADG than pigs on the concrete and clay floor. This can be partly explained by the fact that microclimatic conditions in the wooden floor pens under the tropical climatic conditions are superior compared to other floor types (Chapter 6). Pigs reared on wooden floor pens grew slightly faster than those on other floor types. These growing pigs also ate slightly more when housed on wooden floors, a finding in accordance with the Hansen et al. (1982).

The situation in the farrowing pens is complicated since suckling piglets have higher temperature requirements than lactating sows. The upper limit of the zone of thermal comfort (i.e. above the higher critical temperature) is around 22°C for the sow, whereas the lower limit is around 30°C for suckling piglets (Black et al., 1993). When the environmental temperature rises above the evaporative critical temperature of the sow, the sow can only control body temperature by increasing heat loss through evaporation or by reducing its heat production by eating less. Black et al. (1993) and Messias de Bragança et al. (1998) report a decrease in voluntary feed intake of 40 % and 43 % in lactating sows when the temperature is raised from 18° to 28°C and 20° to 30°C, respectively.

Piglet mortality within the first three days of life remains a problem in intensive swine farms (Spicer et al., 1986). Mortality rates vary between 10 and 20 % (Tuchscherer et al., 2000) depending on the housing system. In an earlier study with data obtained over 5 years on 761 farrowings of sows, Grissom et al. (1990) found an overall pre–weaning death loss ranging from 12.2 to 24.2 %. This mortality level is higher in pens than in crate systems. Preweaning mortality may be associated with stress and this may explain the lower risk for influenza A infections according to Ewald et al. (1994). Less stomach and intestinal disorders were found by Christensen et al. (1995) in pigs on straw systems compared to slatted floors. The studies here indicate that nursing piglets kept with the sows may best be housed on wooden floors as this results in less diarrhoea and mortality compared to concrete clay floors. The present study however did not measure welfare parameters of lactating sow which may be compromised on wooden slatted floors. The piglets raised on the concrete floor and clay ground floor had a higher frequency of diarrhea and higher mortality.

CONCLUSIONS

1. Diets used for both fattening pigs and sows in three ecological zones – Upland, Lowland and Coastal areas in Central Vietnam have poor overall nutritive

value, especially diets in Upland areas. Intake in nutrients and energy is considerably below requirements.

2. Pigs on smallholder farms can improve production if the pigs are fed a higher protein level in their diet. This can not only supply more pig meat for the farmer and a higher profitability and as such increase the rural economy in Central Vietnam.

3. Genotypes such as F_1 and F_2 show better growth performance and carcass quality compared to local Mong Cai pigs under typical Vietnamese climatic conditions. Animals with the highest protein gain like F_2 require the highest dietary protein (amino acid) levels to support their higher rate of protein deposition. Because the innate fat level in the body of Mong Cai pigs is high, it can not be expected that this can be changed considerably by a high dietary crude protein content. An increase above the optimum will not change growth rates and backfat measurement considerably.

4. Increasing dietary crude protein levels in pig diets increases protein deposition rate in all pig genotypes commonly held in Vietnam. Genetically lean pigs have higher growth rates and give leaner carcasses compared to Mon Cai pigs at all dietary crude protein levels under practical conditions in Vietnam. The present results confirm previous data with regard to breed in relation to energy partitioning between protein and lipid deposition.

5. Increasing the dietary lysine level from 0.75 to 1.20 % showed a possitive effect on performance of Mong Cai sows during lactation and piglets. The sows fed the diet supplemented with lysine decrease weight loss compared to sows without supplemental lysine in their feed. In these studies, the optimum level based of Mong Cai lactating sows was approximately 1.02 % lysine. The level during lactation has no effect on the number of piglets in the beginning of lactation but can affect the number of weaned piglets providing opportunities to increase pig performance in Vietnam.

6. High dietary lysine level in the sow diets increases piglet weight of Mong Cai sows at 21d (from 0.20–0.52 kg/piglet) and weaning weight (from 0.3–1.95 kg/piglet) compared to piglets born from sows fed no supplemental dietary lysine. Again pig performance in Vietnam can be increased by supplementation of diets with lysine.

7. Wooden floors had a positive effect on sow and piglet performance under the typical, tropical Vietnamese climatic conditions.

FUTHER RESEARCH

Since amino acids are expensive dietary ingredients, it is necessary to know the crude protein (amino acid) content of feedstuffs which are used for pig in Central Vietnam. From this and the requirements, the need for pig's diet in Central Vietnam is additional CP have to be added. Knowledge of the variation in the crude protein (amino acid) content of local feed ingredients during season and between regions is important to provide pigs with sufficient protein (amino acids). Besides supplying lysine in the sow diets, the addition of DL–methionine, L–treonine and L–tryptophan and potentially other limiting amino acids, such as valine and isoleucine in the diets for pig may need to be evaluated for MC sows. From this thesis, the optimum protein/lysine level for fattening pigs and sows commonly used in Vietnam can be derived under the hot humid climatic condition in Central Vietnam. However it is necessary to study the relationship between dietary protein/lysine level and energy intake especially with different locally available feed ingredients being used in diets for pigs in Vietnam. For lean pigs, the current study shows that at 16 % CP it is difficult to have the highest performance and carcass quality with the ingredients used.

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