



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 fattening pigs fed *ad libitum* under normal climate conditions in Central Vietnam. One hundred and ninety two gilts of Mong Cai local breed (MC), F₁ Large White×Mong Cai and F₂ 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, F₁ pigs 12.1 kg at 8 weeks of age and F₂ 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 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 m² each and had *ad libitum* access to feed in a trough as well as water in bowls. The final weights after a growing period of 150 days were 66, 86 and 96 kg for MC, F₁ and F₂, respectively. Feed intake of MC pigs was highest at 13.1% CP while F₁ and F₂ 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 F₁ the maximum gain was at dietary protein levels of 16-17%. For F₂ the max gain was obtained at CP levels of 16 to 18%. Feed conversion was highest in MC pigs (~4.0) followed by F₁ (~3.3) and F₂ (~3.1), and within genotypes was lowest at the optimum CP level (p<0.05). Back fat thickness in MC (33.1 mm), F₁ (23.0 mm) and F₂ (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 production on small holder farms. Optimal performance for MC, F₁ and F₂ pigs is achieved at different dietary crude protein contents. (**Key Words :** Mong Cai, F₁, F₂, Fattening Pig, Dietary Protein)

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., 2010). 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 crossbreds between lean type of pigs and local breeds are often used e.g. an F₁ with

(Large White or Landrace×MC) and an F₂, 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.e. 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 et al., 2001). The term “operational Pdmax” has

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been introduced and represents the P_{dmax} 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 to 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; F₁, a crossbred between Large White and MC and F₂, a crossbred between F₁×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 F₁ was 12.1 kg at 8 weeks of age. The initial weight of the F₂ 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 m² 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). 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 fresh water from bowls. Animals were weighed each month and at slaughter. Average daily feed intake (ADFI) was determined by reweighing 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

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 | 31.95 | 29.45 | 30.45 | 29.45 |
| Cassava meal | 20.0 | 20.0 | 20.0 | 10.0 |
| Fish meal (44% P) | 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 | 0.05 | 0.05 | 0.05 | 0.05 |
| GE (MJ/ kg DM) | 17.3 | 17.2 | 17.1 | 16.9 |
| Crude protein (g/kg DM) | 101 | 131 | 161 | 189 |
| DE (MJ/ kg DM) ⁴ | 13.8 | 13.7 | 13.6 | 13.5 |

¹ Supplied per kg diet: 0.24 mg folic acid, 840 IU Vitamin A, 80 IU Vitamin D₃, 0.2 IU vitamin E.

² Supplied per kg diet: 108 mg Zn (as ZnO), 108 mg Fe (as Fe₂SO₄), 60 mg Mn (as MnO), 65 mg Cu (as CuSO₄·7H₂O), 0.96 mg I (as Ca(IO₃)₂), 0.11 mg Co (as CoSO₄·7H₂O), 0.07 mg Se (as Na₂SeO₃), 2 g calcium phosphate (as CaHPO₄·2H₂O).

³ HCL Lysine, manufactured by CJ CHEILJEDANG Cooperation, Seoul, Korea.

⁴ Calculated using digestibility values of individual ingredients from the NIAH (2001).

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 \times 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. The carcasses of four 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 back fat measurement was made at the first rib, last rib and at the last lumbar vertebrae. Carcass measurements collected in the cooler included: dressing percent, average back fat 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 cm²) was measured at a point 3/4 the length of the muscle from the medial side at the 10th 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, intramuscular fat, muscle (including blood vessels, ligaments, tendons and connective tissue) and bone. Carcass lean and fat ratio (%) was calculated from total weight half carcass 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 \times 0.96 (NRC, 1998). The following two equations were used:

$$\text{ME intake} = \text{ME}_m + \text{ME}_p = \text{ME}_m + cP + dF \quad (1)$$

$$0.9\text{ADG} = F + P/0.21 \quad (2)$$

in which ME_m is the energy required for maintenance (460 kJ of ME per kg of metabolic body weight, W^{0.75}), ME_p is the energy required for production, c represents the amount of ME needed for the deposition of 1 g of protein (= 53 kJ), P is the amount of protein deposited (g/d), d represent the amount of ME needed for the deposition of 1 g 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 \rightarrow 3, P_j is the effect of dietary protein level j = 1 \rightarrow 4, 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 \rightarrow 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 was the worst performing genotype after the F₁ and then the F₂. In the case of carcass length and dressing percentage across crude protein levels, there was no significant difference between the F₁ and F₂ 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

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) | G×CP |
|---------------------------------------|-------------------|-------------------|-------------------|------------|-----------------|--------------------|-----------------|
| | 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 |
| Carcass length (cm) | 66.4 ^a | 78.4 ^b | 80.0 ^b | 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 ^b | 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 |

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

NS = Not significant (p>0.05); ADG = Average daily gain, ADFI = Average daily feed intake, FCR = Feed conversion ratio.

crude protein level for back fat, longissimus 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. The F₂ was the best performing genotype with the highest ADG, lowest FCR and lowest back fat thickness followed by the F₁ and MC. ADFI (Figure 2) increased for the F₂ and F₁ from 10.1-16.1% 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 (10.1% CP) and 30.1% (16.1% CP) while the F₁ was relatively constant ranging from 22.5 to 23.1%. The back

fat of the F₂ increased from 18.7 when the diet contained 13.1% crude protein to 22.9% 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 F₁ 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 F₁ (15.9%) and highest for the F₂ (16.4%). The optimal dietary crude protein content to minimize FCR was 15.7 for the F₂, 16.9 for the F₁ and 16.3 for MC. The maximum lean percentage for the F₂, F₁ and MC are obtained with a dietary crude protein content of 16.4, 15.5 and 13.8%.

DISCUSSION

This study was conducted to determine the optimum

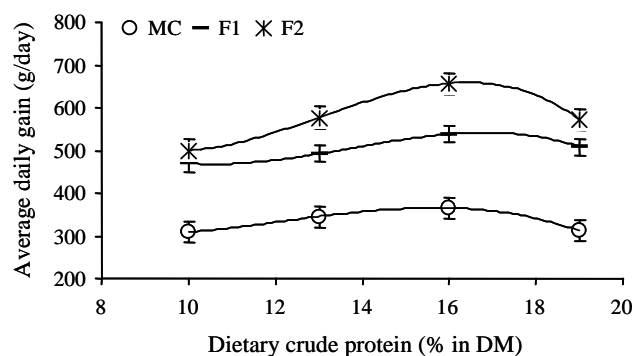


Figure 1. Effect of dietary crude protein content on average daily gain of the difference genotypes. Pig genotypes: MC as: Mong Cai, F₁ as: (LW×MC); F₂ as: (LD×MC)×LW.

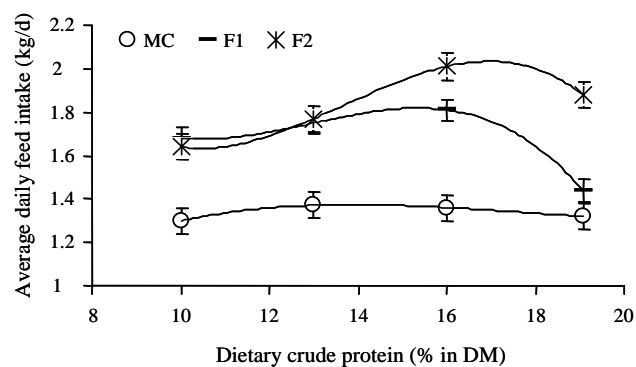


Figure 2. Effects of dietary crude protein content on feed intake of the different genotypes. Pig genotypes: MC as: Mong Cai, F₁ as: (LW×MC); F₂ as: (LD×MC)×LW.

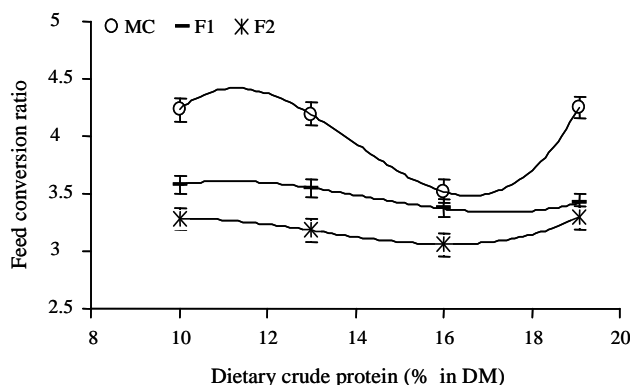


Figure 3. Effect of dietary crude protein content on FCR of the difference genotypes. Pig genotypes: MC as: Mong Cai, F₁ as: (LW×MC); F₂ as: (LD×MC)×LW.

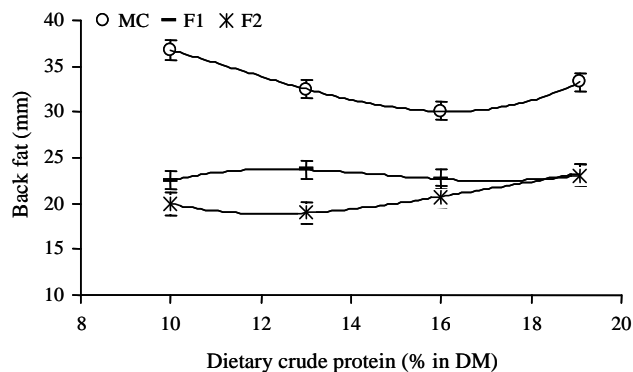


Figure 4. Effect of dietary crude protein content on back fat of the difference genotypes. Pig genotypes: MC as: Mong Cai, F₁ as: (LW×MC); F₂ as: (LD×MC)×LW.

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 (F₁ and F₂) perform much better than MC pigs. The F₂ 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 F₁ and F₂ 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 and Carr (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

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 (g/g) | 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 = Back fat, Lean = Percentage lean. All coefficients were significantly different from zero at p<0.05.

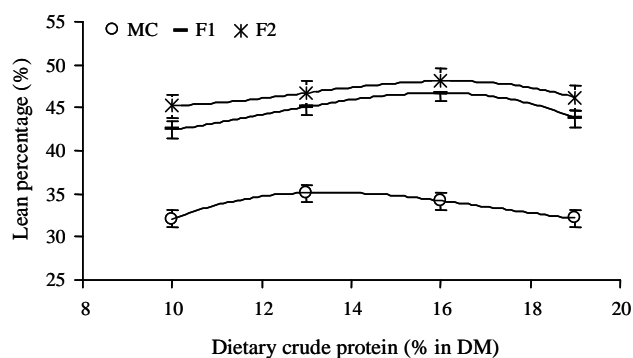


Figure 5. Effect of dietary protein content on lean percentage of the different genotypes. Pig genotypes: MC as: Mong Cai, F₁ as: (LW×MC); F₂ as: (LD×MC)×LW.

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), Reneaudeau 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. 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, 1992).

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 dry-cured products is approximately 20% of the total input of this type of pig (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 F₁ and F₂ pigs required a dietary crude protein content of 16 to 17%, which provided 160 g of protein per kilogram of diet, 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 F₁ and F₂ breeds, but in MC pigs this is likely related to a reduced voluntary feed intake compared to the F₁ and F₂ 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 F₁ and F₂ pigs. A relevant indication of this lower body protein mass is the 20 to 30% smaller muscle size found in MC pigs compared with F₁ and F₂ of similar BW and fed the same balanced dietary protein pattern to those used in the present experiment.

Our study confirmed the lower growth performance by MC compared to F₁ and F₂ pigs. ADFI and ADG in particular were much lower in MC than F₁ and F₂ 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 crossbreeds. Similar results were reported when Iberian pigs (Morales et al., 2003) were compared to lean breeds of pigs.

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 | Protein deposition (g/d) | | | | Fat deposition (g/d) | | | |
|----------------|--------------------------|-----|-----|-----|-----------------------|-----|-----|-----|
| | Dietary crude protein | | | | Dietary crude protein | | | |
| | 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 |

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 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 F₁ and F₂. 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 genotype would be approximately 16% CP but for lean %, a distinct difference is noted in 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 F₁ and F₂ 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 F₁ and F₂ 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 F₁ and F₂ pigs (Pham et al., 2010). In previous studies, Le 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 recommend from the investigations reported here that the CP content in diets for F₁ and F₂ pigs should be raised to 16 or 19% in order to increase pig production. In this respect, protein concentration should be adjusted in combination with a nutrition education intervention. 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 F₁ and F₂ 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. F₁ and F₂ 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), F₁ (Large White×Mong Cai) and F₂ 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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