Pig performance increases with the addition of DL-methionine and L-lysine to ensiled cassava leaf protein diets

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Abstract Two studies were conducted to determine the impact of supplementation of diets containing ensiled cassava leaves as the main protein source with synthetic amino acids, DL-methionine alone or with L-lysine. In study 1, a total of 40 pigs in five units, all cross-breds between Large White and Mong Cai, with an average initial body weight of 20.5 kg were randomly assigned to four treatments consisting of a basal diet containing 45% of dry matter (DM) from ensiled cassava leaves (ECL) and ensiled cassava root supplemented with 0%, 0.05%, 0.1% and 0.15% DL-methionine (as DM). Results showed a significantly improved performance and protein gain by extra methionine. This reduced the feed cost by 2.6%, 7.2% and 7.5%, respectively. In study 2, there were three units and in each unit eight cross-bred (Large White×Mong Cai) pigs with an initial body weight of 20.1 kg were randomly assigned to the four treatments. The four diets were as follows: a basal diet containing 15% ECL (as DM) supplemented with different amounts of amino acids L-lysine and DL-methionine to the control diet. The results showed that diets with 15% of DM as ECL with supplementation of 0.2% lysine +0.1% DL-methionine and 0.1% lysine +0.05% DL-methionine at the 20–50 kg and above 50 kg, respectively, resulted in the best performance, protein gain and lowest costs for cross-bred (Large White×Mong Cai) pigs. Ensiled cassava leaves can be used as a protein supplement for feeding pigs provided the diets contain additional amounts of synthetic lysine and methionine.

Keywords Amino acids · Ensiled cassava leaves · L-lysine · DL-methionine · Growing pigs · Protein deposition

Introduction

Cassava (Manihot esculenta Crantz) is an annually root crop grown widely in tropical and subtropical areas with the roots being a good source of energy while the leaves contain protein, vitamins and minerals. Cassava leaves have a high crude protein (CP) content of which almost 0.85 is true protein (Ravindran 1993). Furthermore, cassava leaf protein has an essential amino acid (EAA) content which is higher than soybean protein (Eggum 1970; Phuc 2000; Montagnac et al. 2009). The high protein content and the relatively good EAA profile are reasons for the inclusion of cassava leaves as a protein source in diets for pigs in many countries. Cassava roots and leaves, however, contain large amounts of cyanogenic glucosides that give rise to toxic hydrocyanic acid (HCN) which limits the use of these products as an animal feed ingredient (Oke 1978; Ngudi et al. 2003; Cardoso et al. 2005). Ensiling cassava roots and leaves reduce the HCN content (Gomez et al. 1985; Phuc 2000; Loc 2004) and allow increased incorporation in animal feeds.
Several studies have determined the ileal apparent digestibility of a number of protein-rich foliages (cassava leaves, leacaena leaves, groundnut foliage, sweet potato leaves) available in tropical countries (Phuc and Lindberg 2001; An et al. 2004; Nguyen et al. 2010a). In the case of cassava leaves, the first limiting amino acid for growing pigs is methionine closely followed by lysine (Chauny narong et al. 2009; Montagnac et al. 2009; Nguyen et al. 2010a). Methionine is not only required for growth and maintenance of body protein but also for in vivo detoxification of hydrogen cyanide (Job 1975; Tewe 1992) to non-toxic thiocyanate (Oke 1978) when pigs are fed cassava leaf or root ingredients. Although it is well-known that methionine is the first limiting amino acids in cassava protein for rats (Eggum 1970), little research has focused on the supplementation of diets containing ensiled cassava proteins with methionine or lysine on the performance of monogastric production animals. Loc (2004) reported studies in cross-bred pigs (Large White×Mong Cai) fed ensiled cassava root-based diets supplemented with methionine. Performance as measured by growth rate and feed conversion ratio were based diets supplemented with methionine. Performance as measured by growth rate and feed conversion ratio were based on dietary treatments with different levels of D,L-methionine supplementation (0%, 0.05%, 0.10% and 0.15%) during two growing phases. Two control diets were formulated for the two growing periods, period 1 from 20 to 50 kg and period 2 above 50 kg. The control diet (Table 1) consisted of rice bran, maize, ECR, ECL and fish meal (FM). Diets for each period included 15% and 30% of ECL and ECR, respectively on a DM basis. The control diet was formulated to contain 12.6 MJ ME, 14.1% CP, 0.66% lysine and 0.28% methionine+cysteine in period 1 and 12.6 MJ ME, 12.2% CP, 0.55% lysine and 0.25% methionine+cysteine in period 2. The chemical composition of the feed ingredients used to formulate the diets in study 1 is shown in Table 2.

Study 1: D,L-methionine supplementation

Forty cross-bred pigs (Large White×Mong Cai) with an average initial body weight of 20.5 kg (SD=0.7) and of similar ages were randomly allocated to five units. In each unit, eight pigs (four males and four females) were randomly allocated to one of four pens (2×1 m), with two pigs (one male and one female) per pen. Each pen was randomly allocated to one of the four dietary treatments which differed in the level of D,L-methionine supplementation (0%, 0.05%, 0.10% and 0.15%) during two growing phases. Two control diets were formulated for the two growing periods, period 1 from 20 to 50 kg and period 2 above 50 kg. The control diet (Table 1) consisted of rice bran, maize, ECR, ECL and fish meal (FM). Diets for each period included 15% and 30% of ECL and ECR, respectively on a DM basis. The control diet was formulated to contain 12.6 MJ ME, 14.1% CP, 0.66% lysine and 0.28% methionine+cysteine in period 1 and 12.6 MJ ME, 12.2% CP, 0.55% lysine and 0.25% methionine+cysteine in period 2. The chemical composition of the feed ingredients used to formulate the diets in study 1 is shown in Table 2.

Study 2: D,L-methionine and L-lysine supplementation

Twenty four cross-bred pigs (12 males and 12 females) (Large White×Mong Cai) with an average initial weight of 20.1 kg (SD=0.2) and of similar ages were randomly allocated according to gender to three units. The eight pigs (four males and four females) per unit were randomly allocated to four pens (2×1 m), with two pigs (one male and one female) per pen. Each pen was randomly allocated to one of the four dietary treatments with different levels of supplemented L-lysine and D,L-methionine. Throughout the growing period, pigs were fed the basal diets depending on body weight (20 to 50 kg and above 50 kg). The control diet consisted of rice bran, maize, ECR, ECL and FM and included on a dry matter basis 15% of ECL and ECR 17% of DM for period 1 and 25% in period 2 (see Table 3). During period 1, the control diet contained 12.6 MJ ME, 14.9% CP, 0.70% lysine and 0.28% methionine while during period 2 the diet contained 12.6 MJ ME, 12.8% CP, 0.58% lysine and 0.23% methionine (Table 3). The control diet was supplemented with no, low, medium or high levels of L-lysine and D,L-methionine. The low amino acid diet was supplemented with 0.10% and 0.05% L-lysine and D,L-methionine, respectively during period 1 and during

Materials and methods

The experiments reported here were carried out in eight units in the Huong Van commune, which is one of the main pig production areas of Thua Thien Hue province in Vietnam. The protocol of the study was approved by the ethical committee of Hue University, Hue, Vietnam.

Preparation and preservation of ensiled cassava leaves

Fresh leaves of cassava were collected at the time of root harvest and spread out for 5 h on the floor for wilting during which time the dry matter (DM) content increased from 24% to 28–29%. After wilting, the leaves were separated from the stems and petioles, chopped into small pieces (2–3 cm), mixed with 0.5% NaCl and rice bran at 5% of the wilted weight of the cassava leaves. The mixture was kept in air tight nylon bags with a capacity of 30 kg and stored during 2 months before use. This ensiling procedure resulted in a stable silage pH and a low cyanide content.

Animals, experimental design and feeding

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period 2 with 0.05% L-lysine and 0.03% DL-methionine. In the medium supplemented diet in periods 1 and 2, 0.20% and 0.10% L-lysine and 0.10% and 0.05% DL-methionine, respectively were added to the basal diet. The high supplemented diet was obtained by adding 0.30% L-lysine and 0.15% DL-methionine during period 1 and with 0.15% L-lysine and 0.08% DL-methionine during period 2. The dietary composition of the eight diets is given in Table 3.

In both studies, the pigs had been vaccinated against hog cholera and Pasteurellosis, and had been dewormed 2 weeks before starting the experiment. The composition of the control diets for the two growing periods in both studies is given in Table 2. The diets were fed at a level of 4% of body weight (BW) as recommended by the National Institute of Animal Husbandry (NIAH 2001). Both experiments lasted 90 days and were conducted during the cool season in Vietnam with average daily temperatures between 22°C and 26°C. The diets were distributed equally into three meals per day (7, 11 and 17 h) with refusals collected the following morning before the first meal. Drinking water was provided ad libitum.

Chemical analyses

The feedstuffs in the experimental diets were analysed for DM, crude protein (CP), crude fibre and HCN (AOAC 1990) and amino acids. DM was measured by drying fresh

| Table 1 | Ingredient content (percent), chemical composition (% DM), calculated metabolisable energy content (megajoules per kilogramme DM) and hydrogen cyanide content (milligrams per kilogramme DM) of the experimental diets for the pigs in study 1 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Ingredient/component | Diet | 20 to <50 kg | | | | | | | | | |
| | | | Basal | + DL-methionine | 0.05 | 0.10 | 0.15 | Basal | + DL-methionine | 0.05 | 0.10 | 0.15 |
| Rice bran | 29 | 29 | 29 | 29 | 30 | 30 | 30 | 30 |
| Yellow maize | 18 | 18 | 18 | 18 | 21 | 21 | 21 | 21 |
| Ensiled cassava roots | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| Ensiled cassava leaves | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Fish meal | 8 | 8 | 8 | 8 | 4 | 4 | 4 | 4 |
| DL-methionine<sup>a</sup> | – | 0.05 | 0.10 | 0.15 | – | 0.05 | 0.10 | 0.15 |

Chemical composition

| Metabolisable energy | 12.6 | 12.6 | 12.6 | 12.6 | 12.6 | 12.6 | 12.6 | 12.6 |
| Crude protein | 14.1 | 14.1 | 14.1 | 14.1 | 12.2 | 12.2 | 12.2 | 12.2 |
| Crude fibre | 6.8 | 6.8 | 6.8 | 6.8 | 6.9 | 6.9 | 6.9 | 6.9 |
| Lysine | 0.66 | 0.66 | 0.66 | 0.66 | 0.55 | 0.55 | 0.55 | 0.55 |
| Methionine+cysteine | 0.28 | 0.33 | 0.38 | 0.43 | 0.25 | 0.30 | 0.35 | 0.40 |
| Ileal digestible<sup>b</sup> | Lysine | 0.51 | 0.51 | 0.51 | 0.51 | 0.44 | 0.44 | 0.44 | 0.44 |
| Methionine+cysteine | 0.21 | 0.26 | 0.31 | 0.36 | 0.19 | 0.24 | 0.29 | 0.34 |
| Hydrogen cyanide | 43.5 | 43.5 | 43.5 | 43.5 | 43.5 | 43.5 | 43.5 | 43.5 |

<sup>a</sup>Ninety-eight percent DL-methionine (Sumitomo Chemical Co., Ltd./Ajinomoto Co., Inc, Japan)

<sup>b</sup>Calculated values based on analysed crude protein and amino acid composition and apparent ileal digestibility data from Nguyen et al. (2010a) and Ngoan and Lindberg (2001)

| Table 2 | Dry matter and chemical composition of the dietary ingredient used to formulate the experimental diets |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Component | Rice bran | Yellow corn | ECR | ECL | Fish meal |
| | Exp 1 | Exp 2 | Exp 1 | Exp 2 | Exp 1 | Exp 2 | Exp 1 | Exp 2 | Exp 1 | Exp 2 |
| Dry matter (%) | 88.0 | 86.3 | 85.5 | 84.4 | 40.6 | 41.0 | 28.0 | 32.8 | 90.0 | 90.0 |
| Crude protein (% DM) | 11.3 | 11.4 | 9.8 | 9.9 | 3.0 | 3.1 | 23.0 | 20.8 | 58.5 | 58.5 |
| Crude fibre (% DM) | 9.7 | 9.8 | 2.8 | 2.8 | 4.0 | 3.9 | 15.0 | 12.8 | ND | ND |
| Lysine (g/kg DM) | 4.8 | 4.9 | 3.2 | 3.3 | 1.2 | 1.1 | 11.5 | 10.8 | 31.6 | 31.6 |
| Methionine+cysteine (g/kg DM) | 2.3 | 2.3 | 2.0 | 2.0 | 0.11 | 0.1 | 4.6 | 3.8 | 10.5 | 10.5 |
| Metabolisable energy (MJ/kg DM) | 12.1 | 12.1 | 15.4 | 15.4 | 12.4 | 12.4 | 9.7 | 9.6 | 14.3 | 14.3 |
| Hydrogen cyanide (mg/kg DM) | ND | ND | ND | ND | 29 | 29 | 232 | 162 | ND | ND |

Exp experiment, ECR ensiled cassava root, ECL ensiled cassava leaves analysed at 60 days after ensiling, ND not determined
samples at 105°C for 24 h. Total nitrogen (N) was
determined on fresh samples by the macro Kjeldahl method
and CP was calculated from total nitrogen (N*6.25). Amino
acids were analysed according to Spackman et al. (1958) o
an ion-exchange column using an HPLC. Samples were
hydrolysed for 24 h at 110°C with 6 M HCL containing
2 g/L reagent grade phenol and 5 μmol norleucine
(internal standard) in evacuated and sealed ignition tubes.
Methionine+cysteine were determined as methionine
sulphone and cysteic acid with separate samples hydro-
ysed for 24 h as described above following oxidation
with performic acid overnight at 0°C (Moore 1963). The
HCN content was determined in the fresh ensiled samples
by titration with AgNO3 after boiling the samples and
concentrating the HCN in KOH (AOAC 1990). All
samples were analysed in triplicate except amino acids
which were analysed in duplicate. Most analyses were
done in the Hue University laboratories except the amino
acids (AAs) which were analysed at the National Institute
of Animal Husbandry laboratories (Ha Noi).

Measurements

Feed consumption was determined by weighing the
amounts given and subtracting any feed remaining the
following morning. The pigs were individually weighed at
the start of the study, monthly and at slaughter, and the
average daily gain (ADG), dry matter intake and feed
conversion ratio (FCR) were calculated for each treatment.
Feed costs were calculated for the quantity of feed
consumed by each pig, the individual feed ingredient prices
and the composition of the feed.

Protein and fat deposition was calculated using the
following assumptions: one gramme of protein and fat
contains 23.4 and 39.7 kJ of energy per gramme,
respectively (NRC 1998) and ME intake
\[\text{ME intake} = \text{MEM} + c \times \text{protein deposition} + d \times \text{fat deposition} \]
where MEM is the amount of ME required for maintenance (460 kJ of ME per
kg of metabolic BW (BW^{0.75})); c and d represent the
amount of ME needed for the deposition of 1 g of protein
and fat, respectively. The required amounts of ME needed
to deposit protein and fat deposition (MEp) was assumed to
be 53 kJ ME per g protein and 53 kJ per gramme of fat
(NRC 1998).

On the basis of the literature review of Kotarbinska and
Kielanowski (1969), it can be assumed that about 10% of
weight gain is gut fill and ash, thus:
\[0.9 \times \text{ADG} = \text{water} + \text{protein} + \text{fat}.\]

The deposition rate of protein and fat in the empty body of
the pig was calculated based on the following two equations:
\[0.9 \times \text{ADG} = F + P/0.21 \quad (1)\]
MEp = F × 53 + P × 53

where ADG is the average rate of gain (grammes/day), 0.21 is the ratio of protein to protein+water, F is the amount of fat deposited (grammes/day), P is the amount of protein deposited (grammes/day) and MEp the metabolizable energy used for fat and protein deposition.

Statistical analysis

The experimental unit was a pen (two pigs). An analysis of variance was done according to the following model:

\[ Y_{ij} = \mu + T_i + e_{ij} \]

where \( Y \) is a dependent variable, \( \mu \) is the overall mean, \( T_i \) is the treatment effect (i=1, 2, 3 …4) and \( e_{ij} \) is the random error.

Data were analysed by ANOVA using the general linear model of the Minitab Statistical Software version 14 (2004). A Tukey pairwise comparison was used to determine the differences between the treatment means at \( P<0.05 \).

Results

Study 1

The data in Table 4 indicate that supplementing diets containing 45% (in DM) of ensiled cassava (30% ECR+15% ECL) with 0.05%, 0.1% and 0.15% DL-methionine significantly increased the final BW, ADG, and decreased the FCR in the pigs. The ADG differed between treatments \( (P<0.001) \) and were 534, 560, 596 and 608 g/day for the control, +0.05% met, +0.10% met and +0.15% met, respectively. The FCR for these groups were 2.97, 2.86, 2.69 and 2.65 kg DM per kilogramme gain, respectively \( (P<0.001) \). The data in Table 4 show that protein deposition of the F1 pigs used increased significantly while the fat deposition was decreased as levels of supplementary DL-methionine increased in the diet. The protein deposition of the pigs fed the control, control+0.05% met, +0.10% met and +0.15% met diet were 60.2, 66.3, 75.1 and 77.5 g/day, respectively \( (P<0.001) \).

Supplementing diets containing 45% (in DM) ensiled cassava (30% ECR+15% ECL) with DL-methionine at levels of 0.05%, 0.10% and 0.15% gave lower feed costs by 2.6%, 7.2% and 7.5%, respectively. Differences in feed cost per kilogramme weight gain were significant among the treatments \( (P<0.005) \). The feed cost per kilogramme gain for the control+0.15% met diet was lowest although this was not significantly different from the control+0.10% met diet.

Study 2

The effects of the supplementation of the diets containing 15% ECL in the DM with L-lysine and DL-methionine on the performance of pigs are shown in Table 5.

The final BW and ADG were highest for pigs fed with the two highest levels of supplementary L-lysine plus DL-methionine. The FCR was higher in the control diet than in

Table 4 Performance and feed costs of growing (20–80 kg) Large White×Mong Cai pigs fed diets containing ensiled cassava leaves and supplemented with different levels of DL-methionine in study 1

| Parameter                              | Diet* |        |        |        |        | SEM  | \( P \) |
|----------------------------------------|-------|--------|--------|--------|--------|------|--------|
|                                        | Basal | + DL-methionine |        |        |        |      |        |
|                                        |       | 0.05   | 0.10   | 0.15   |        |      |        |
| Initial body weight (kg)               | 20.1  | 20.8   | 20.6   | 20.2   | 0.3    | 0.213|        |
| Final body weight (kg)                 | 68.2a | 71.2ac | 74.2bc | 74.9b  | 1.0    | 0.001|        |
| Average daily gain (g/day)             | 534a  | 560ac  | 596bc  | 608b   | 12     | 0.001|        |
| Dry matter intake (kg/day)             | 1.59  | 1.60   | 1.61   | 1.62   | 0.02   | 0.475|        |
| Feed conversion ratio (kg DM/kg gain)  | 2.97a | 2.86a  | 2.69b  | 2.65b  | 0.05   | 0.001|        |
| Calculated deposition (g/day)          |       |        |        |        |        |      |        |
| Protein                               | 60.2a | 66.3a  | 75.1b  | 77.5b  | 2.5    | 0.001|        |
| Fat                                   | 194.3a | 188.1ab | 179.1b | 178.4b | 3.6    | 0.009|        |
| Feed cost* (VND/kg gain)               | 6,289a | 6,126a | 5,837b | 5,816b | 102    | 0.005|        |
| Costs compared to control (%)          | 100   | 97.4   | 92.8   | 92.5   | –      | –    |        |

Means with different letters within rows differ \( (P<0.05) \)

*Price of feed ingredients at Hue during the time of the study in Viet Nam Dong (VND per kilogramme): ensiled cassava roots, 400; ensiled cassava leaves, 500; rice bran, 2,000; maize, 2,000; fish meal, 6,000; DL-methionine, 52,000. At the time of this study: US $1=15,000 VND
the other three diets supplemented with L-lysine and DL-methionine. The final BW and ADG of the pigs were highest, and the FCR was lowest at the medium level of L-lysine and DL-methionine supplementation in the diet. Similarly, the estimated protein depositions of F1 pigs was increased significantly ($P<0.001$) when both L-lysine and DL-methionine were added to the diets. Protein deposition of the pigs fed the control diet+supplementary L-lysine and DL-methionine at the medium level was higher than for the other three treatments. The protein deposition of the pigs fed the control diet+supplementary L-lysine and DL-methionine at the medium level was lower than that of pigs fed the control diet+supplementary L-lysine and DL-methionine at the high level. A trend ($P<0.099$) was observed in the feed costs per kilogramme gain with the medium supplementary L-lysine and DL-methionine diets having the lowest value.

**Discussion**

Cassava is a major staple root crop in many tropical and subtropical, developing countries. It is well-known that cassava roots are high in starch but low in crude protein, while cassava leaves are rich in crude protein. The protein quality of a food is the product of its AA content and the nutritional availability of these AAs. Eggum (1970) and Phuc (2000) reported that the concentration of the sulphur-containing amino acids is low in cassava leaves and roots which cause a relatively low biological value of this protein ranging from 44 to 57. Recently, several researchers have reported that methionine is the most limiting AA both in cassava leaves and roots for growing pigs and poultry, followed by lysine (Loc 2004; Chauynarong et al. 2009; Montagnac et al. 2009; Nguyen et al. 2010a). In addition, the high cyanide content further limits the use of cassava leaves as a protein source in diets for pigs. Methionine not only plays a role as an EAA in protein deposition but is also important in the hydrogen cyanide detoxification process, particularly in rations with high levels of cassava roots or leaves. Therefore, pig diets with a high inclusion level of cassava root and leaves could benefit from additional supplementation with synthetic methionine and lysine. In order to determine the magnitude of the effect of supplementation, we formulated diets to contain 45% of ensiled cassava root and leaves and added increasing levels of supplementary DL-methionine (from 0% to 0.15% in DM) to diets for growing pigs. The results show that there were significant effects of the diet on the final BW, ADG, FCR and protein deposition. Increasing levels of supplementary DL-methionine from 0.05% up to 0.15% in the diets improved ADG and FCR. These results can be explained by the fact that the supplemental methionine was not used for protein deposition and provided sulfydril groups (−SH) necessary for the detoxification of cyanide as the HCN content of the

Table 5 Performance and feed costs of growing (20–80 kg) Large White x Mong Cai pigs fed diets containing ensiled cassava leaves and supplemented with different levels of L-lysine and DL-methionine in study 2

| Parameter                          | Dieta               | Basal | + L-lysine and DL-methionine | SEM | P  |
|-----------------------------------|---------------------|-------|-----------------------------|-----|----|
|                                   | Low                 | Medium| High                        |     |    |
| Initial body weight (kg)          | 20.1                | 20.0  | 20.8                        | 19.6| 0.4| 0.247|
| Final body weight (kg)            | 68.8a               | 72.6a | 80.3b                       | 74.2a| 1.5| 0.001|
| Average daily gain (g/day)        | 53.7a               | 58.4a | 66.0b                       | 60.4b| 17 | 0.001|
| Dry matter intake (kg/day)        | 1.60a               | 1.59a | 1.71b                       | 1.64ab| 0.02| 0.001|
| Feed conversion ratio (kg DM/kg gain) | 2.99a               | 2.73b | 2.59b                       | 2.72b| 0.06| 0.001|
| Calculated deposition (g/day)     |                     |       |                             |     |    |
| Protein                           | 59.6a               | 71.9ab| 84.3b                       | 73.3b| 3.5 | 0.001|
| Fat                               | 199.5               | 183.7 | 192.8                       | 192.0| 3.9 | 0.063|
| Feed costa (VND/kg gain)          | 6,482               | 6,269 | 6,193                       | 6,692| 145| 0.099|
| Costs compared to control (%)     | 100                 | 96.7  | 95.5                        | 103 | –  | –  |

Means with different letters within rows differ ($P<0.05$). Supplementation with L-lysine and DL-methionine during the growing phase (20–50 and 50–80 kg) in% DM: low level, 0.10 and 0.05 and 0.05 and 0.03; medium level, 0.20 and 0.10 and 0.10 and 0.05; and high level, 0.3 and 0.15 and 0.15 and 0.08

*a Price of feed ingredients in Hue at the time of the study in Viet Nam Dong (VND per kilogramme): ensiled cassava root, 400; ensiled cassava leaves, 500; rice bran, 2,200; maize, 2,200; fish meal, 6,000; DL-methionine, 65,000; L-lysine, 75,000. US $1=15,500 VND
diets ranged from 29.3–43.5 mg/kg DM. In the body, cyanide is detoxified by the enzyme rhodanese, forming thiocyanate, which is excreted in the urine (Oke 1978; Tewe et al. 1977).

The estimated fat and protein deposition of F1 (Large White×Mong Cai) pigs were significantly affected by the dietary treatment. The data in Table 4 show that protein deposition in the DL-methionine supplemented diets were higher than in the control animals. Increased levels of supplementary methionine decreased fat deposition because at the same ME intake, less of the MEP is available for lipid gain. Supplementation with 0.15% methionine gave the highest protein deposition among diets although this was not significantly different from the protein deposition of the pigs fed the control+0.10% methionine diet. These results confirm the studies by Eggum (1970) who reported that addition of synthetic methionine to diets for rats increased the biological value of cassava protein. Loc (2004) studied the addition of DL-methionine (0%, 0.1%, 0.2% and 0.3%) to diets containing 20% to 40% of the DM ensiled cassava root to F1 (Large White×Mong Cai) pigs. This author showed that an increased performance, as measured by growth rate and feed conversion ratio could be achieved with DL-methionine supplementation. In the present study, supplementary DL-methionine at 0.05%, 0.10% and 0.15% in diets containing 45% (in DM) ensiled cassava (30% ECR+15% ECL) reduced the feed cost by 2.6%, 7.2% and 7.5%, respectively.

Study 2 was designed to test whether further increases in performance can be obtained by adding lysine to methionine-supplemented ensiled cassava leaves and root-containing diets. Identical methionine supplementation levels were used compared to study 1. Table 5 shows that supplementary L-lysine and DL-methionine in diets of growing pigs improved ADG, FCR and protein deposition. In this study, final BW, ADG and protein deposition were highest at the two highest levels of supplementation (medium and high). The FCR and protein deposition were lower in the control diet than in the other three diets with supplemented L-lysine and DL-methionine. The final BW, ADG and protein deposition of the pigs were highest, and the FCR was the lowest at the medium level of supplementation with lysine and methionine. It appears that those levels met the requirements for lysine and methionine+cysteine for growing F1 (Large White×Mong Cai) pigs. The content of lysine and methionine in the high supplemented diet was somewhat higher than the requirements for lysine and methionine as set by (NRC 1998). The reason for the numerical increase in FCR from the medium to the high level of supplementation is difficult to explain. Loc (2004) also found a slightly reduced daily gain of pigs fed 0.30% supplemental methionine compared to the 0.20% when fed an ensiled cassava root-based diet. In study 1, no reduction in growth rate, FCR or protein deposition was observed indicating that this effect was likely due to the lysine addition instead of the methionine.

The most common procedures for reducing the cyanide content in cassava are sun drying and ensiling (Phuc et al. 2001; Borin et al. 2005; Nguyen et al. 2010b). Considerable amounts of cassava leaves are readily available as a by-product at the time of harvesting the roots. However, in many tropical countries, the harvest season of cassava roots coincides with the rainy season making sun drying difficult or unfeasible. Ensiling is a suitable alternative way of preserving the roots and leaves (Van Man and Wiktorsson 2001, 2002) and recently Nguyen et al. (2010c) showed that ensiling cassava leaves for 90 days reduced the HCN concentration by 70–80%. Our results in study 2 show that the diet supplemented with 0.20% L-lysine and 0.10% DL-methionine, and 0.10% L-lysine and 0.05% DL-methionine in the growing and finishing periods, respectively, resulted in the highest economic returns for farmers.

The present study further develops the practical and economical feasibility of using ensiled cassava leaves in diets for pigs. By supplementing diets containing ensiled cassava leaves with methionine and lysine, the performance of Large White×Mong Cai pigs can be significantly increased as well as the economic benefits for farmers.

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