# Effects of Yucca Extracts and Protein Levels on Growth Performance and Nutrient Utilization in Growing Pigs**

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**ABSTRACT :** A total of 120 pigs were used to investigate the effects of yucca extracts on the growth performance, nutrient digestibility and excretion of growing pigs fed different levels of dietary protein. Pigs were allotted into 2×3 factorial design by the supplementation with yucca extract (YE, 0 and 120 mg/kg) and 3 levels of dietary protein (16, 18, 20%). During the whole experimental period (18 to 52 kg body weight), there were no significant differences in ADG, ADFI or F/G by YE addition or different protein levels among treatments ($p>0.05$). Overall, although addition of YE to the diet and elevation of protein level showed better ADG, there were no significant differences in growth performance among treatments. Pigs fed diets with YE showed significantly ($p<0.05$) higher dry matter (DM), crude ash (CA) and crude protein (CP) digestibility than did the others during the growing period. Concerning the levels of dietary protein, only the CP digestibility was significantly higher in pigs fed high protein diet. Pig fed the low protein diet without YE showed a significantly low CP digestibility ($p<0.05$). No significant differences were found in crude fat (CF), calcium (Ca) and phosphorus (P) digestibilities regardless of YE supplementation or dietary protein levels. Pigs fed YE supplemented diets showed significantly ($p<0.05$) higher amino acid digestibility. Also, high CP level diets showed a higher amino acid digestibility than low CP diets ($p<0.05$). DM and N excretion did not show any significant differences among treatments, there was a slightly lower excretion with increase in dietary protein level. Supplementation with YE significantly decreased the DM and N excretion. Interaction (YE×protein) was found in P excretion. Pigs fed a medium protein diet without YE showed the lowest P excretion during the growing period. The $NH_3$-N content in the feces tended to be increased by the increased dietary protein levels and with YE supplementation. During the whole experimental period, the cost for YE supplementation was similar to value of the improvements of performance obtained. The cost of feeding high level protein was significantly higher than that of medium level protein by 10% and low level protein by 9% ($p<0.05$). It could be concluded that the effects of dietary protein level and yucca extract on growth performance, nutrient digestibility and excretion might play a role to some extent in growing pigs from the aspect of pollution control. *(Asian-Aust. J. Anim. Sci. 2001. Vol. 14, No. 1 : 61-69)*

**Key Words :** Pig, Growth Performance, Yucca Extracts, Protein Level, Nutrient Digestibility, Nutrient Excretion

## INTRODUCTION

Through the years, researchers and producers have focused on nutritional strategies to reduce pollutants from animal manure. Supplementation with metabolically active substances like enzymes, probiotics or yeast and synthetic amino acids have been known to be a feasible way to reduce animal excreta by the improvement of nutrient digestibilities (Kwon et al., 1995; Noh et al., 1995; Park et al., 1994; Han and Min, 1991; Han et al., 1978, 1995; Chae et al., 1988; Daghir, 1983; Heo et al., 1995; Jin et al., 1998). Researchers suggested phase feeding as an alternative feeding regimen to reduce the amount of animal excreta (Jongbloed and Lenis, 1992; Lenis, 1989; Honeyman, 1993; Paik et al., 1996; Honeyman, 1996).

Yucca has been known to be an effective agent that reduces pollutant without impairing the growth of pigs. Gippert (1992) reported that the addition of YE in growing-finishing pigs diet improved growth rate by 11%, which is similar to our previous study (Bae et al., 1999). Cromwell et al. (1985), Moser et al. (1988) and Jin et al. (1999a, b) did not observe improvements in growth performance of pigs fed yucca extract. Though the effects of yucca on the growth of pigs were inconsistent, Sutton et al. (1990, 1992, 1996), Cole et al. (1998) and Morel et al. (1997) reported a significant suppression of ammonia emission by the use of yucca. Furthermore, our previous study (Min et al., 2000) suggested that yucca extracts showed the best growth performance and a positive effect on N reduction in feces and ammonia emission in growing-finishing pigs.

A lower dietary protein has proven to be an effective way to decrease urea excretion by the pigs,

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** This study was partially funded by KOSEF and Agribrands Purina Korea Inc. in Korea.
Received January 19, 2000; Accepted April 6, 2000

resulting in lower ammonia concentration in the slurry. Dourmad et al. (1996) investigated the low protein effect on growth performance and carcass characteristics with pigs fed diets differing in crude protein content (17.8, 15.5 and 13.6%, re-equilibrated with in synthetic amino acids) and found decreased dietary protein was associated with an important reduction in N output by 18-33%.

However, such approaches for reducing N output are effective only when growth performance is not reduced. With low or very low protein diets, feed efficiency was reduced in some studies and N output did not decrease (Latimier and Chatelier, 1992).

These experiments were done, therefore, to investigate the effects of yucca extracts and protein levels on growing performance, nutrient digestibility and excretion in growing pigs.

## MATERIALS AND METHODS

One-hundred twenty crossbred pigs (Yorkshire × Landrace × Duroc) initially averaging 18 ± 0.51 kg body weight were used as an experimental unit. Pigs were grouped on the basis of body weight and sex, and randomly assigned into six treatments. Pigs were allotted into a 2×3 factorial design by the supplementation with yucca extract (0 and 120 mg/kg) and 3 levels of dietary protein (16, 18, 20%). Each treatment had five replicates with four pigs per replicate.

The basal diets were iso-caloric (3.36 ME kcal/kg) and contained 0.85, 1.00 and 1.15% lysine at each protein levels (table 1). Adequate amounts of vitamins and minerals were contained, as recommended by the NRC (1998).

Pigs were housed in a concrete floored pen, with a feeder and a nipple waterer, and allowed *ad libitum* access to feed and water throughout a 6 weeks experimental period. Body weight and feed intake were recorded every 2 weeks.

For the determination of nutrient digestibility, a total feces collection method was used. A total of 6 pigs (3 barrows and 3 gilts) averaging 40 kg body weight were housed in individual metabolic crates. Three different diets were offered to the pigs on a weekly rotation basis. After a ten day adaptation period, the total excreta were collected through seven consecutive days. The amount of feed consumed and total excreta were recorded daily. The collected excreta were pooled and dried in an air-forced drying oven at 60℃ for 72 hours and ground with a 1 mm Wiley mill for chemical analyses. Proximate nutrients of the experimental diets and excreta were analyzed according to the methods of AOAC (1990), and the gross energy content was measured using an adiabatic bomb calorimeter (Model 1241, Parr Instrument Co., USA).

Amino acid contents of diet and feces were determined, following acid hydrolysis with 6 N HCl at 110℃ for 16 hours (Mason, 1984), using an amino acid analyzer (Biochrom 20, Pharmacia Biotech. England).

Every two weeks, fresh feces were collected in 50 ml centrifuge tubes for ammonia nitrogen analysis. The feces were weighed and diluted about 1:4.5 (w/w) with distilled water. An aliquot of 0.134 ml 6 N $H_2SO_4$ was added for inactivation of urease in feces. The samples were centrifuged at 3,000 rpm for 15 min and the supernatants were collected into plastic vials and immediately stored at -20℃ for further analysis. The ammonia nitrogen concentration in supernatants was determined by using a colorimetric method (Cheny and Marbach, 1962).

Statistical analysis was carried out to compare means according to Duncan's multiple range test (Duncan, 1955), using General Linear Model (GLM) of SAS (1985) procedure package program with yucca

**Table 1.** Formula and chemical composition of experimental diet in growing phase

| | Protein level (%) | | |
|---|---|---|---|
| | 16 | 18 | 20 |
| Ingredients (%): | | | |
| Corn | 67.67 | 68.00 | 62.90 |
| Soybean meal | 21.75 | 27.58 | 32.52 |
| Wheat | 6.10 | - | - |
| Animal fat | 2.00 | 2.00 | 2.10 |
| Tricalcium phosphate | 1.50 | 1.50 | 1.45 |
| Limestone | 0.05 | - | - |
| Vit.-min. mix.[1] | 0.45 | 0.45 | 0.45 |
| Salt | 0.20 | 0.20 | 0.20 |
| Antibiotics | 0.25 | 0.25 | 0.25 |
| Lysine-HCL | 0.03 | 0.02 | 0.05 |
| DL-methionine | - | - | 0.05 |
| Threonine | - | - | 0.03 |
| Chemical composition[2]: | | | |
| ME (Mcal/kg) | 3.36 | 3.36 | 3.35 |
| Crude protein (%) | 16.00 | 18.01 | 20.00 |
| Lysine (%) | 0.85 | 1.00 | 1.15 |
| Methionine (%) | 0.27 | 0.30 | 0.35 |
| Threonine (%) | 0.59 | 0.67 | 0.77 |
| Tryptophan (%) | 0.18 | 0.21 | 0.24 |
| Calcium (%) | 0.62 | 0.62 | 0.62 |
| Total phosphorus (%) | 0.60 | 0.61 | 0.62 |

[1] Supplied per kg diet: 8,000 IU vitamin A, 2,500 IU vitamin $D_3$, 30 IU vitamin E, 3 mg vitamin K, 1.5 mg thiamin, 10 mg riboflavin, 2 mg vitamin $B_6$, 40 $\mu$g vitamin $B_{12}$, 30 mg pantothenic acid, 60 mg niacin, 0.1 mg biotin, 0.5 mg folic acid, 200 mg Cu, 100 mg Fe, 150 mg Zn, 60 mg Mn, 1 mg I, 0.5 mg Co, 0.3 mg Se.

[2] Calculated values.

extract and protein levels as main effects.

## RESULTS AND DISCUSSION

### Growth performance

The growth performances of the growing pigs fed experimental diets are presented in table 2. Although addition of YE to the diet and elevation of protein level showed better ADG and F/G, there were no significant differences in average daily gain (ADG), average daily feed intake (ADFI) or feed conversion ratio (F/G) by the addition of YE or different protein levels ($p>0.05$).

This is consistent with the results from Cromwell et al. (1985) and Jin et al. (1999a). Cromwell et al. (1985) reported that there was no effect on growth performance in growing swine when sarsaponin (62 mg/kg) was added to the diet. Jin et al. (1999a) also found that there was no significant difference in growth performance with the addition of YE. On the other hand, Mader and Brumn (1987) reported that when *Yucca schidigera* extract was added to the diet, feed efficiency was improved. Gippert (1992) reported that the addition of *Yucca schidigera* (60-120 mg/kg) in growing-finishing pigs resulted in an 11% improvement in ADG and a 15.6% reduction in mortality. Foster (1983) found 5% faster weight gain ($p<0.05$) and 4% greater feed consumption ($p<0.01$) in growing-finishing pigs. Also Mader and Brumn (1987) observed an increased daily gain and feed intake in growing swine.

In the present study, it is interesting to note that there were no significant differences in growth performance with different levels of protein in the diet although higher protein treatment tended to show a better record than the other protein treatments. Dourmad et al. (1996) suggested that ADG seemed more sensitive to a reduction in digestible lysine supply below the requirement in growing animals or in post-weaning piglets than finishing pigs. The levels of lysine per each protein level in this experiment, however, were 0.85, 1.00, 1.15% respectively, so they were not so low even in the low protein treatment compared with the NRC (1998) requirement. These levels of lysine were 89, 105 and 121% of the NRC (1998) requirement. The result of this experiment is consistent with what was indicated by Goodband et al. (1989). They observed no additional improvements in performance when pigs were offered a dietary lysine content exceeding 0.60%.

Canh et al. (1998) compared three diets with different crude protein levels (16.5, 14.5 and 12.5%), with similar net energy contents and ileal digestible lysine, methionine+cystine, threonine and tryptophan in growing-finishing pigs, and found no improvements in daily gain, feed intake, feed conversion ratio, and carcass yield. Jongbloed and Lenis (1992) reported that growing pigs use only about 30 to 35% of ingested N

**Table 2.** Effects of addition of yucca extract with different protein levels on growth performances in growing pigs

| Yucca addition | Protein levels | Ini. Wt. (kg) | Fin. Wt. (kg) | ADG (g/day) | ADFI (g/day) | F/G |
|---|---|---|---|---|---|---|
| Addition | Low | 18.40 | 51.40 | 786 | 1,963 | 2.37 |
| | Medium | 18.41 | 52.02 | 800 | 1,819 | 2.27 |
| | High | 18.51 | 52.96 | 820 | 1,833 | 2.24 |
| No addition | Low | 18.41 | 50.74 | 770 | 1,824 | 2.37 |
| | Medium | 18.46 | 52.03 | 800 | 1,807 | 2.25 |
| | High | 18.50 | 52.00 | 798 | 1,779 | 2.24 |
| SE[1] | | 0.51 | 0.84 | 10.3 | 17.9 | 0.02 |
| Between yucca addition | | | | | | |
| Addition | | 18.46 | 52.13 | 802 | 1,838 | 2.30 |
| No addition | | 18.44 | 51.59 | 789 | 1,804 | 2.28 |
| Among protein levels | | | | | | |
| Low | | 18.40 | 51.07 | 778 | 1,843 | 2.37 |
| Medium | | 18.43 | 52.03 | 780 | 1,813 | 2.26 |
| High | | 18.50 | 52.49 | 809 | 1,807 | 2.24 |
| Probability (P); | | | | | | |
| Yucca addition | | 0.987 | 0.771 | 0.550 | 0.375 | 0.847 |
| Protein levels | | 0.997 | 0.813 | 0.490 | 0.700 | 0.050 |
| Yucca × Protein | | 1.000 | 0.976 | 0.913 | 0.899 | 0.970 |

[1] Pooled standard error.

and P. Thus, it is very important to supply dietary N and P in close accordance with the animals' requirements. This increases the possibility of reducing the crude protein content in pig diet.

**Nutrient digestibility and nutrient excretion**

The effects of YE with different protein levels on nutrient digestibility and nutrient excretion in growing pigs are shown in table 3.

Pigs fed the YE supplemented diets showed significantly ($p<0.05$) higher digestibility of dry matter (DM), crude ash (CA) and crude protein (CP) than the others. The increased DM digestibility was in consistent with the report by Sadil et al. (1992) who showed the beneficial effects on ruminal ammonia levels, DM digestibility and rumen pH in lactating cows fed 1% urea supplements to which the YE had been added.

Pigs fed high protein diets showed significant difference from pigs fed low protein diets, and pigs fed low protein without YE showed significantly low CP digestibility ($p<0.05$). Supplementation with YE or CP levels had no significant effect on crude fat (CF), calcium (Ca) and phosphorus (P) digestibilities.

The effects of YE on essential amino acids and non essential amino acids digestibilities are shown in tables 4 and 5. Pigs fed YE supplemented diets show significantly ($p<0.05$) higher amino acid digestibility. Also, high CP level diets showed a higher amino acid digestibility than the low CP diet ($p<0.05$).

The supplementation with YE tended to reduce the excretion of DM and N as a result of better DM and CP digestibility as compared to non-supplemented feeds.

In this experiment, N excretion was not significantly different among CP levels, although lowering the protein level decreased N excretion numerically in the growing phase. This is not similar to many reports about N excretion reduction by decreasing protein level. Schutte et al. (1990) reported that lowering dietary crude protein level for growing-finishing pigs by 2 percentage units reduced N excretion by approximately 20%. Lenis (1989) also reported that lowering the protein level in the diets of growing pigs by 2% units resulted in about a 25% reduction of N excretion. Jongbloed and Lenis (1992) suggested that lowering the dietary crude protein level for growing-finishing pigs by 2% would reduce N excretion by approximately 20%.

In the review by Kerr (1995), the impact of amino acid supplementation with low-CP diets in reducing N excretion ranged from 3.2 to 62%, depending on the

**Table 3.** Effects of addition of yucca extract with different protein levels on nutrient digestibility and nutrient excretion in growing pigs

| Yucca Addition | Protein levels | Nutrient digestibility | | | | | | Nutrient excretion | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | DM (%) | CA (%) | CP (%) | CF (%) | Ca (%) | P (%) | DM (g/day) | N (g/day) | P (g/day) |
| Addition | Low | 82.7 | 49.0$^{a}$ | 77.4$^{ab}$ | 53.4 | 85.1 | 73.5 | 247.61 | 8.13 | 3.37$^{ab}$ |
| | Medium | 81.6 | 50.3$^{a}$ | 78.9$^{a}$ | 52.1 | 83.3 | 70.1 | 268.82 | 9.43 | 3.68$^{a}$ |
| | High | 81.3 | 44.3$^{ab}$ | 77.6$^{ab}$ | 54.2 | 80.1 | 71.8 | 288.93 | 9.88 | 3.86$^{a}$ |
| No addition | Low | 80.5 | 40.5$^{b}$ | 73.5$^{c}$ | 51.0 | 81.6 | 71.9 | 297.75 | 10.25 | 3.79$^{a}$ |
| | Medium | 78.3 | 33.1$^{c}$ | 75.4$^{bc}$ | 51.4 | 80.4 | 70.5 | 310.35 | 10.43 | 2.81$^{b}$ |
| | High | 81.4 | 48.0$^{ab}$ | 78.4$^{a}$ | 52.3 | 82.4 | 73.3 | 296.55 | 10.15 | 3.32$^{ab}$ |
| SE[1] | | 0.39 | 1.52 | 0.56 | 0.92 | 0.55 | 0.73 | 5.57 | 0.20 | 0.11 |
| Between yucca addition | | | | | | | | | | |
| Addition | | 81.9$^{a}$ | 57.9$^{a}$ | 78.0$^{a}$ | 53.2 | 82.8 | 71.8 | 268.45$^{a}$ | 9.15$^{a}$ | 3.63 |
| No addition | | 80.1$^{b}$ | 40.5$^{b}$ | 75.8$^{b}$ | 51.6 | 81.5 | 71.9 | 301.55$^{b}$ | 10.28$^{b}$ | 3.30 |
| Among protein levels | | | | | | | | | | |
| Low | | 81.6 | 44.8 | 75.4$^{b}$ | 52.2 | 83.3 | 72.7 | 272.68 | 9.19 | 3.58 |
| Medium | | 80.0 | 41.7 | 77.1$^{ab}$ | 51.8 | 81.8 | 72.5 | 289.58 | 9.93 | 3.24 |
| High | | 81.4 | 46.1 | 78.0$^{a}$ | 53.3 | 81.2 | 70.3 | 292.74 | 10.01 | 3.59 |
| Probability (P); | | | | | | | | | | |
| Yucca addition | | 0.012 | 0.002 | 0.007 | 0.429 | 0.170 | 0.963 | 0.001 | 0.002 | 0.104 |
| Protein levels | | 0.095 | 0.204 | 0.031 | 0.823 | 0.214 | 0.384 | 0.111 | 0.077 | 0.274 |
| Yucca × Protein | | 0.088 | 0.002 | 0.032 | 0.937 | 0.052 | 0.707 | 0.094 | 0.067 | 0.036 |

[1] Pooled standard error.

[a,b,c] Values with different superscript in the same column differ ($p<0.05$).

**Table 4.** Effects of addition of yucca extract with different protein levels on essential amino acids digestibility in growing pigs (%)

| Yucca addition | Protein levels | THR | LYS | MET | ARG | HIS | ILE | LEU | PHE | EAA |
|---|---|---|---|---|---|---|---|---|---|---|
| Addition | Low | 79.7 | 82.8 | 60.8 | 72.2 | 89.0 | 74.6 | 66.6[b] | 73.8 | 74.9 |
| | Medium | 84.5 | 87.6 | 60.8 | 75.7 | 91.5 | 76.1 | 76.0[a] | 75.1 | 78.5 |
| | High | 85.4 | 86.8 | 58.3 | 76.9 | 91.9 | 73.7 | 74.4[a] | 73.3 | 77.5 |
| No addition | Low | 79.3 | 82.3 | 60.1 | 69.2 | 89.2 | 68.2 | 67.8[b] | 70.6 | 73.3 |
| | Medium | 80.8 | 83.7 | 59.0 | 71.5 | 90.0 | 72.5 | 68.4[b] | 72.1 | 74.8 |
| | High | 83.6 | 86.0 | 58.6 | 78.3 | 92.4 | 75.2 | 75.9[a] | 74.9 | 78.1 |
| SE[1] | | 0.77 | 0.53 | 0.96 | 0.78 | 0.38 | 1.09 | 0.93 | 1.14 | 0.50 |
| Between yucca addition | | | | | | | | | | |
| Addition | | 83.2 | 85.7[a] | 60.0 | 74.9 | 90.8 | 74.8 | 72.3 | 74.1 | 77.0[a] |
| No addition | | 81.2 | 84.0[b] | 59.2 | 73.0 | 90.6 | 72.0 | 70.7 | 72.5 | 75.4[b] |
| Protein levels | | | | | | | | | | |
| Low | | 79.5[b] | 82.5[b] | 60.5 | 70.7[c] | 89.1[b] | 71.4 | 67.2[c] | 72.2 | 74.1[b] |
| Medium | | 83.1[a] | 85.6[a] | 59.9 | 73.6[b] | 90.8[a] | 74.3 | 72.2[b] | 73.6 | 76.6[a] |
| High | | 84.0[a] | 86.4[a] | 58.4 | 77.6[a] | 92.2[a] | 74.5 | 75.1[a] | 74.1 | 77.8[a] |
| Probability | | | | | | | | | | |
| Yucca addition | | 0.169 | 0.023 | 0.708 | 0.065 | 0.679 | 0.247 | 0.117 | 0.561 | 0.041 |
| Protein levels | | 0.038 | 0.001 | 0.681 | 0.000 | 0.002 | 0.490 | 0.000 | 0.826 | 0.002 |
| Yucca × Protein | | 0.426 | 0.102 | 0.907 | 0.077 | 0.334 | 0.387 | 0.002 | 0.697 | 0.064 |

[1] Pooled standard error.

[a,b] Values with different superscript in the same column differ ($p<0.05$).

**Table 5.** Effects of addition of yucca extract with different protein levels on non essential amino acids digestibility in growing pigs (%)

| Yucca addition | Protein levels | ASP | SER | GLU | PRO | GLY | ALA | CYS | NEAA | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Addition | Low | 76.6[c] | 78.8[b] | 77.7 | 74.8 | 59.4 | 68.7[a] | 60.3[b] | 70.9 | 72.9 |
| | Medium | 86.3[a] | 84.0[a] | 84.2 | 78.1 | 43.5 | 63.2[a] | 70.2[a] | 72.8 | 75.7 |
| | High | 87.0[a] | 82.5[a] | 85.1 | 77.1 | 41.3 | 62.4[a] | 68.3[a] | 71.9 | 74.7 |
| No addition | Low | 82.6[b] | 76.6[b] | 80.0 | 75.0 | 43.1 | 52.3[b] | 57.7[b] | 66.8 | 70.1 |
| | Medium | 83.9[b] | 78.4[b] | 81.6 | 75.7 | 40.6 | 53.6[b] | 60.9[b] | 67.8 | 71.3 |
| | High | 87.8[a] | 83.6[a] | 86.0 | 78.5 | 42.6 | 64.6[a] | 66.6[a] | 72.8 | 75.5 |
| SE[1] | | 0.81 | 0.71 | 0.95 | 0.91 | 2.85 | 1.61 | 1.08 | 0.74 | 0.58 |
| Between yucca addition | | | | | | | | | | |
| Addition | | 83.3[b] | 81.7[a] | 82.3 | 76.7 | 48.1 | 64.8[a] | 66.3[a] | 71.9 | 74.4[a] |
| No addition | | 84.8[a] | 79.5[b] | 82.5 | 76.4 | 42.1 | 56.8[b] | 61.7[b] | 69.1 | 72.3[b] |
| Protein levels | | | | | | | | | | |
| Low | | 79.6[c] | 77.7[b] | 78.9[b] | 74.9 | 51.2 | 60.5 | 59.0[b] | 68.8[b] | 71.5[b] |
| Medium | | 85.1[b] | 81.2[a] | 82.9[ab] | 76.9 | 42.1 | 58.4 | 65.6[a] | 70.3[ab] | 73.5[ab] |
| High | | 87.4[a] | 83.0[a] | 85.5[a] | 77.8 | 42.0 | 63.5 | 67.4[a] | 72.4[a] | 75.1[a] |
| Probability | | | | | | | | | | |
| Yucca addition | | 0.007 | 0.034 | 0.914 | 0.879 | 0.350 | 0.006 | 0.001 | 0.054 | 0.036 |
| Protein levels | | 0.000 | 0.001 | 0.017 | 0.483 | 0.398 | 0.275 | 0.000 | 0.124 | 0.023 |
| Yucca × Protein | | 0.000 | 0.040 | 0.465 | 0.711 | 0.498 | 0.024 | 0.030 | 0.184 | 0.105 |

[1] Pooled standard error.

[a,b] Values with different superscript in the same column differ ($p<0.05$).

size of the pig, level of dietary CP reduction, and initial CP level in the control diet. The average reduction in N excretion per unit of dietary CP reduction was 8.4%.

**Ammonia nitrogen excretion**

The effects of YE on the ammonia nitrogen content in the feces of growing pigs fed different levels of dietary protein are shown in figure 1. Although there was no significance, the $NH_3$-N content tended to increase with increasing protein levels and with YE supplementation in growing pigs.

The $NH_3$-N content in feces increased 36.4% with YE supplementation. Presumably the efficacy of feeding YE in these situations relates to the reduction in ammonia levels in the fermenting digesta in the large intestine together with a residual ammonia-binding capacity in the feces which is available to bind ammonia originating from urine deposited at the same sites as the faces (Leek, 1993). That is, yucca's binding ability for ammonia, suggested by Headon et al. (1991), might have played a role in the intestinal tract, thereby, blocking the liberation of the ammonia. Much excess nitrogen present in manure is in inorganic form. Some may be lost to the atmosphere as ammonia. YE in manure might have played a role in hindering the liberation of ammonia into the atmosphere. It was theorized that a reduction in intestinal free ammonia induced by YE might decrease the maintenance requirement energy and increase weight gain. Decreased gut ammonia production could be the cause of reduced small intestinal mass in pigs, because ammonia increases weight and nucleic acid synthesis in the intestinal mucosal cells in the animal (Yen and Pond, 1993). So, further studies on the relation between small intestinal mass and ammonia supplementation is necessary to discover the action mechanism of yucca.

Ammonia nitrogen excretion was reduced, but not significantly, by 9.5% for high protein vs. medium protein, 13.3% for high protein vs. low protein and 4.2% for medium protein vs. low protein. There have been many similar reports on ammonia reduction by decreasing protein level, including Sutton et al. (1996). They reported that reducing the crude protein level in the corn-soybean meal of growing-finishing diets by 3% (from 13 to 10% CP) and supplementing the diet with lysine, tryptophan, threonine and methionine reduced ammonium and total N in freshly excreted manure by 28%.

Also, there have been many reports with results similar to those of this experiment on YE supplementation. Preston et al. (1985) concluded that one effect of sarsaponin was to decrease mean ruminal $NH_3$-N levels in cattle. Sutton et al. (1990) reported that litter ammonium nitrogen content was lower

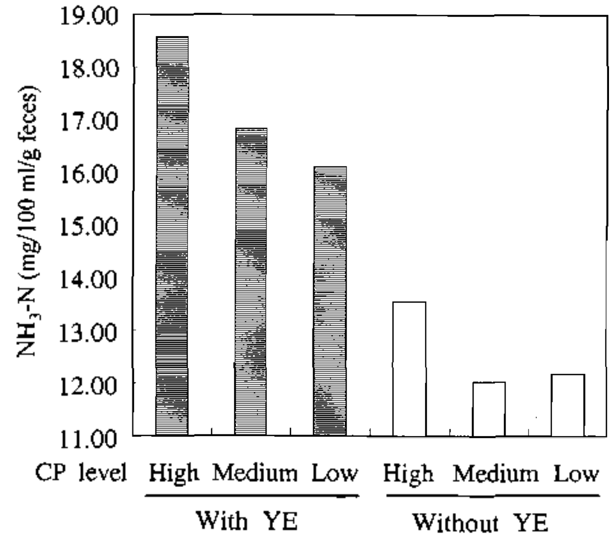


**Figure 1.** Effects of yucca extract on ammonia nitrogen contents in feces of growing pigs fed different levels of dietary protein (N=24)

($p<0.05$) due to whey-sarsaponin feed additive as compared with no feed additive. Sutton et al. (1992) also found that ammonia emission was significantly supressed by 55.5% in manure tested in an incubation trial from pigs fed a sarsaponin extract.

Cole et al. (1998) reviewed the study conducted in the Netherlands during 1994-1995 (Schuerink, 1995) and a later study in France during 1996-1997 (Morel, 1997). The use of *Yucca schidigera* in the diet (120 mg/kg) was effective in reducing ammonia under practical farm conditions in both the Netherlands and France. However, Kemme et al. (1993) conducted incubation trials with manure; they did not verify the same response to $NH_3$ inhibition, and they found that 6,000 mg/kg of the extract was necessary for maximal suppression of $NH_3$ from urea. The form and source of extract may have had an influence on the $NH_3$ emission results.

**Feed cost**

Table 6 summarizes the effects of the yucca extract with different protein levels on total feed costs during the growing period. The cost for adding YE was similar to the value of performance improvements obtained. The cost of feeding the high level protein was significantly higher than those of the medium and low levels by 10% and 9%, respectively.

This experiment shows a great deal of the production costs of animal feeds depends on the prices of the protein sources. Also, the result of this report about YE supplementation contradicts to report that feed cost per kg of weight gained was lowered by 8.1% with YE supplementation (Gippert, 1992), but

**Table 6.** Effects of addition of yucca extract with different protein levels on total feed cost during the growing phase

| Yucca addition | Protein levels | Total weight gain (kg) | Total feed cost (₩) | Feed cost /kg weight gain (₩) |
|---|---|---|---|---|
| Addition | Low | 33.01 | 19,722[bc] | 597.6 |
| | Medium | 33.61 | 19,857[cb] | 591.1 |
| | High | 34.46 | 23,290[a] | 678.2 |
| No addition | Low | 32.34 | 19,192[c] | 594.3 |
| | Midium | 33.58 | 19,667[bc] | 588.6 |
| | High | 33.51 | 20,613[b] | 616.4 |
| SE[1] | | 0.430 | 330.2 | 8.18 |
| Between yucca addition | | | | |
| Addition | | 33.69 | 20,957[a] | 622.3 |
| No addition | | 33.14 | 19,824[b] | 599.8 |
| Among protein levels | | | | |
| Low | | 32.67 | 19,457[b] | 595.9[b] |
| Medium | | 33.59 | 19,762[b] | 589.8[b] |
| High | | 33.99 | 21,952[a] | 647.3[a] |
| Probability (P) | | | | |
| Yucca addition | | 0.431 | 0.001 | 0.088 |
| Protein levels | | 0.297 | 0.000 | 0.002 |
| Yucca×Protein | | 0.857 | 0.004 | 0.112 |

[1] Pooled standard error.

[a,b,c] Means with different superscripts are different at $p<0.05$.

concurs with the report that YE supplementation does not spare feed costs in growing-finishing swine (Jin et al., 1999a, b).

In conclusion, present study suggest that the addition of yucca extract is a possibility as an environmentally friendly agent which improves growth rate and reduces nutrient excretion. But, when yucca extract is supplemented in pig diet, feed cost will be high, so optimum inclusion level will be determined by further research.

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