Effects of Yucca Extracts and Protein Levels on Growth Performance, Nutrient Utilization and Carcass Characteristics in Finishing 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, nutrient excretion and carcass characteristics of finishing pigs fed different levels of dietary protein. Pigs were allotted into 2×3 factorial design by the supplementation of yucca extracts (YE, 0 and 120 mg/kg) and 3 levels of dietary protein (14, 16, 18% for early finisher and 12, 14, 16% for late finisher for low, medium and high protein diet, respectively). During the early finishing period (51~76 kg BW), no significant difference was found in growth performance regardless of the YE supplementation or dietary protein levels. Growth performance of late finishing pigs (76~101 kg BW) was also not significantly different among treatments. However, ADG of pigs fed YE diet was significantly improved ($p<0.05$) regardless of the dietary protein levels. For the overall period (51~101 kg BW), although adding YE to the diet and elevating the protein level showed better ADG, there were no significant differences on growth performance among treatments. Early finishers showed significantly higher crude protein, crude ash and crude fat digestibilities when they were fed diets supplemented with YE. Digestibilities of amino acids were not affected by YE. Late finishers did not show any significant differences in proximate nutrient digestibilities regardless of YE supplementation or dietary protein levels. YE tended to slightly improve the CP digestibility, however no significant difference was found with increased dietary protein levels. There was no significant difference in amino acid digestibilities with YE supplementation or dietary CP levels during the late finishing period. Dry matter (DM) and nitrogen (N) excretion in feces did not show any significant difference among treatments. Early finishing pigs also did not respond to the inclusion of YE or dietary protein levels ($p<0.05$). Fecal N excretion of early finishing pigs seemed to be lowered in pigs fed YE. Pigs fed medium dietary protein diet tended to excrete a higher amount of N during the early finishing period, but not statistically different. A slight increase in fecal N excretion was found with the increased level of dietary protein during the late finishing period. For ammonia nitrogen excretion, although there was no significance, the NH_3-N content tended to be increased by the increased dietary protein levels and with YE supplementation. The NH_3-N content in manure increased by 24.5% with YE supplementation. There were no significant differences in carcass weight, backfat thickness, carcass grade and loin eye area among treatments. However, pigs fed non-YE with low protein diet showed a significantly ($p<0.05$) low carcass ratio among treatments and there was significant ($p<0.05$) difference between the YE-added treatment and non YE treatment in carcass ratio. As for the feed cost, the cost of feeding high level protein was higher than that of medium level protein by 5% and low level protein by 9% ($p<0.05$). Therefore, based on this study, it could be concluded that environmentally friendly agents might play a role to some extent in finishing pigs from the aspect of pollution control, and that more than 14 and 12% of dietary protein for early finishing and late finishing pigs respectively do not necessarily guarantee high growth performance. *(Asian-Aust. J. Anim. Sci. 2001. Vol. 14, No. 4 : 525-534)*

Key Words : Pig, Growth Performance, Yucca Extracts, Protein Level, Nutrient Digestibility and Excretion, Carcass Characteristics

INTRODUCTION

Nitrogen and phosphorus excretion and ammonia emissions from intensive pig production systems contribute appreciably to environmental pollution. Therefore, researchers and producers have focused on nutritional strategies to reduce pollutants from animal manure. Supplementation with metabolic active substances like enzymes, probiotics or yeast and synthetic amino acids have been known to be a feasible way to reduce animal excreta through an improvement in 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). Recently, feeding manipulations, like phase feeding, have been considered as an alternative way 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 to

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reduce pollutants without deterioration in the growth of pigs. Gippert (1992) reported that the addition of YE to a growing-finishing pig diet improved growth rate by 11%, which is similar to the result from, previous a 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. Although, the effects of yucca on the growth of pigs were inconsistent, Sutton et al. (1990, 1992, 1996), Cole et al. (1998) and Morel (1997) reported a significant suppression of ammonia emission. Our preliminary study suggested that yucca extract showed the best growth performance and positive effect on reducing fecal N 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, resulting in lower ammonia concentration in the slurry. Dourmad et al. (1996) investigated the effect of low protein diets on growth performance and carcass characteristics of pigs fed diets differing in crude protein content (17.8, 15.5 and 13.6%, re-equilibrated with industrial amino acids) and found decreased dietary protein was associated with a reduction in N output by 18-33%.

Such approaches for reducing N output will be more effective in finishing pigs than growing pigs, because finishing pigs are more responsible for the bulk of nutrient excretion in manure than weaned and growing pigs. Besides, Dourmad et al. (1996) reported that average daily gain (ADG) by finishing pigs appeared much less sensitive than in growing pigs to digestible lysine supply below the requirement.

This experiment was carried out to investigate the effects of yucca extracts and protein levels on growth performance, nutrient digestibility, nutrient excretion and carcass characteristics in finishing pigs.

MATERIALS AND METHODS

One-hundred twenty crossbred pigs (Yorkshire × Landrace × Duroc) initially averaging 51±0.51 kg body weight were used. Pigs were grouped on the basis of body weight and sex, and randomly assigned into six treatments. Pigs were allotted into 2×3 factorial design by supplementation with yucca extract (0 and 120 mg/kg) and 3 levels of dietary protein (14, 16, 18% for early finisher and 12, 14, 16% for late finisher). Each treatment had five replicates with four pigs per replicate.

The experimental diets contained 3,354, 3,356 and 3,355 ME kcal/kg and 0.70, 0.85 and 1.00% lysine for the early finishers, and 3,357, 3,354 and 3,356 ME kcal/kg and 0.56, 0.70, 0.85% lysine for the late finishers (table 1). Adequate amounts of vitamins and minerals were fed, 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 the whole experimental period. Body weight and feed intake were recorded every 2 weeks during the experimental period.

For the determination of nutrient digestibility, a total feces collection method was used and feces were collected every day from 12 early finishrrs, averaging 62 kg, and 12 late finishers, averaging 85 kg, housed in individual metabolic cages. Diets corresponding to each of the treatment were offered to the pigs. After ten days adaptation, 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

Table 1. Formula and chemical composition of experimental diets in finishing phase

	Protein levels (%)			
	12	14	16	18
Ingredients (%):				
Corn	74.10	69.30	67.65	68.07
Soybean meal	11.15	16.26	21.74	27.40
Wheat	10.00	9.78	6.10	-
Animal fat	2.00	2.00	2.00	2.00
Monocalcium phosphate	0.40	0.30	-	-
Tricalcium phosphate	1.35	1.35	1.50	1.50
Limestone	0.08	0.08	0.05	-
Vit.-Min. mix.[1]	0.45	0.45	0.45	0.45
Salt	0.20	0.20	0.20	0.20
Antibiotics	0.25	0.25	0.25	0.25
Lysine-HCL	0.02	0.03	0.03	0.03
Chemical composition[2]:				
ME (Mcal/kg)	3.36	3.35	3.36	3.35
Crude protein (%)	12.00	14.00	16.01	18.01
Lysine (%)	0.56	0.70	0.85	1.00
Methionine (%)	0.22	0.24	0.28	0.33
Threonine (%)	0.43	0.51	0.60	0.71
Tryptophan (%)	0.13	0.16	0.18	0.21
Calcium (%)	0.62	0.62	0.62	0.62
Total phosphorus (%)	0.61	0.61	0.60	0.61

[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 μg 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 value.

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 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 from the caged subjects. The feces were weighed and diluted about 1:4.5 (w/w) with distilled water. 0.134 ml of 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 stored at -20℃ was determined by using a calorimetric method (Cheny and Marbach, 1962). The ammonia nitrogen concentration (mg/100 ml) was corrected for each fecal sample weight.

Statistical analysis was carried out to compare means according to Duncan's multiple range test (Duncan, 1955), using the General Linear Model (GLM) of SAS (1985) procedure package program with yucca extract and protein levels as main effects.

RESULTS AND DISCUSSION

Growth performance

The growth performances of finishing pigs fed experimental diets are presented in table 2. During early finishing period (51~76 kg BW), there were no significant differences in average daily gain (ADG), average daily feed intake (ADFI) or feed conversion ratio (F/G) with the addition of YE or different protein levels (p>0.05). During late finishing period (76~101 kg BW), there was no significance among treatments in ADG and F/G. For finishing pigs, some researchers reported that YE supplementation improved growth performance (Duffy and Brooks, 1998; Gippert, 1992; Mader and Brumn, 1987; Ma et al., 1993; Bae et al., 1999), while others did not find any improvement (Cromwell et al., 1985; Jin et al., 1999b).

For the overall period, although addtion YE to the diet and elevating the protein level showed some im provement in ADG, there were no significant differences in overall growth performance among treatments (p>0.05).

Chae et al. (1988) reported that finishing pigs fed

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

Yucca Addition	Protein levels	Early finishing phase (51 to 76 kg BW)			Late finishing phase (76 to 101 kg BW)			Overall phase (51 to 101 kg BW)		
		ADG (g)	ADFI (g)	F/G	ADG (g)	ADFI (g)	F/G	ADG (g)	ADFI (g)	F/G
Addition	Low	861	2,476	2.89	654	2,384[ab]	3.72	753	2,430	3.23
	Medium	853	2,458	2.90	686	2,567[a]	3.85	769	2,512	3.27
	High	856	2,532	2.97	690	2,549[a]	3.75	773	2,540	3.28
No addition	Low	870	2,530	2.92	623	2,452[ab]	4.01	746	2,490	3.33
	Midium	870	2,628	3.02	624	2,313[b]	3.84	747	2,470	3.31
	High	877	2,553	2.92	664	2,537[a]	3.92	770	2,505	3.31
SE[1]		9.34	44.90	0.04	8.72	31.23	0.06	7.30	33.61	0.04
Yucca treatment										
Addition		857	2,488	2.92	674[a]	2,500	3.77	765	2,494	3.26
No additon		872	2,570	2.95	637[b]	2,433	3.92	755	2,488	3.32
Protein levels										
Low		865	2,502	2.91	634[b]	2,418	3.86	749	2,460	3.28
Medium		862	2,543	2.96	654[ab]	2,439	3.84	758	2,491	3.29
High		866	2,542	2.95	677[a]	2,542	3.84	772	2,522	3.29
Probability (P)										
Yucca		0.318	0.104	0.643	0.035	0.205	0.271	0.443	0.898	0.426
Protein levels		0.965	0.737	0.780	0.121	0.124	0.986	0.431	0.508	0.987
Yucca×Protein		0.950	0.431	0.552	0.556	0.044	0.656	0.834	0.559	0.876

[1] Pooled standard error.

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

a diet with 2% lower CP levels were not restricted in growth when the lysine level was adjusted adequately. Cromwell et al. (1993) suggested that barrows and gilts weighing 47 to 103 kg required 0.60% lysine and more than 0.90% lysine in corn-soybean meal diets for maximum performance and carcass leanness, respectively. More recently, Friesen et al. (1994) studied the dietary lysine requirement for high-lean gilts from 72 to 136 kg. In their study, growth performance was not influenced by different lysine levels in the diets (0.62 to 1.13% total lysine). Dourmad et al. (1996) reported that ADG appeared much less sensitive to the digestible lysine supply in finishing pigs than in growing pigs. Therefore, it can be suggested that over 14% of crude protein for the early finishing pigs, and over 12% of crude protein for the late finishing pigs do not necessarily guarantee high growth performance. Han et al. (1998) indicated that pigs fed over 14% crude protein diets for late finishing did not always show a high growth rate.

Nutrient digestibility and nutrient excretion

The effects of YE with different protein levels on nutrient digestibility and nutrient excretion in early finishing phase and late finishing phase are shown in tables 3 and 4, respectively.

In the early finishing phase, supplementation with YE increased the digestibility of CA, CP and CF as compared to non-supplemented feeds ($p<0.05$), but there was no significance in nutrient digestibility among CP levels and between YE treatments. Table 4 shows the effect of YE addition to diets with different CP levels on amino acid digestibility in early finishing pigs. There were no significant differences in essential amino acids and total amino acids digestibilities from supplementation of YE or between dietary CP levels. However, among the dietary CP levels, digestibility of total NEAA in high CP diet group was higher than in the medium CP diet group ($p<0.05$). As for the amount of nutrient excretion, there was no significant effect of YE addition or among CP levels ($p>0.05$).

In the late finishing phase, there were no significant differences in nutrient digestibility, amino acids digestibilities and nutrient excretion with the YE supplementation or dietary CP levels (tables 5 and 6). The results from present study concurred with findings from Bae et al. (1999) and Jin et al. (1999b). Bae et al. (1999) reported that when YE (125 mg/kg) was added to diets for finishing pigs, there was no significant difference in nutrient digestibility. Similarly, Jin et al. (1999b) investigated the effects of YE supplementation on the growth performance and nutrient digestibility in growing-finishing pigs, but did not find any improvement by the YE addition.

In the present study, there was no significant effect on fecal N excretion among CP levels, although

Table 3. Effects of addition of yucca extract with different protein levels on nutrient digestibility and fecal nutrient excretion in early finishing pigs

Yucca addition	Protein levels	Nutrient digestibility (%)						Nutrient excretion (g/day)		
		DM	CA	CP	CF	Ca	P	DM	N	P
Addition	Low	89.4	66.7	88.0	91.8	83.7	63.3	244.97	6.53	2.99
	Medium	89.3	62.9	86.5	86.0	82.1	61.8	246.67	8.38	3.00
	High	89.0	73.7	89.2	93.1	84.7	64.0	258.30	7.16	3.07
No addition	Low	90.0	62.0	85.7	80.5	84.4	60.4	219.52	7.09	3.10
	Medium	89.4	61.2	84.1	86.8	81.3	62.6	249.24	9.96	3.05
	High	89.0	61.0	85.7	87.3	83.2	62.9	253.39	8.70	3.07
SE[1]		0.19	1.66	0.60	1.39	0.73	1.84	8.91	0.44	0.12
Yucca treatment										
Addition		89.2	67.8[a]	87.9[a]	90.3[a]	83.5	63.0	249.98	7.35	3.02
No addition		89.5	61.1[b]	85.1[b]	84.9[b]	83.0	62.0	240.72	8.58	3.07
Protein levels										
Low		89.7	64.4	86.8	86.2	84.0	61.8	232.25	6.81	3.05
Medium		89.4	62.0	85.3	86.4	81.7	62.2	247.96	9.16	3.03
High		89.0	66.9	87.4	90.2	83.9	63.4	255.84	7.94	3.07
Probability (P);										
Yucca		0.569	0.043	0.027	0.042	0.765	0.797	0.637	0.157	0.855
Protein levels		0.402	0.450	0.317	0.361	0.410	0.946	0.605	0.096	0.991
Yucca × protein		0.901	0.279	0.893	0.173	0.845	0.938	0.830	0.850	0.989

[1] Pooled standard error.

[a,b] 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 nutrient digestibility and fecal nutrient excretion in late finishing pigs

Yucca addition	Protein levels	Nutrient digestibility (%)						Nutrient excretion (g/day)		
		DM	CA	CP	CF	Ca	P	DM	N	P
Addition	Low	91.5	70.9	89.7	79.8	83.6	62.6	207.90	5.21	7.35
	Medium	91.0	71.7	88.1	79.5	80.1	62.0	253.73	6.68	8.21
	High	91.2	68.7	86.9	78.8	82.9	61.0	208.53	6.66	7.59
No addition	Low	91.5	69.6	87.7	79.1	54.6	61.0	220.10	7.03	8.57
	Medium	91.7	68.9	87.4	79.6	82.5	61.4	207.81	6.74	7.85
	High	90.3	68.4	87.5	79.5	79.1	64.6	254.24	7.07	7.67
SE[1]		0.38	1.69	0.58	1.41	1.56	2.24	11.65	0.34	0.50
Yucca treatment										
Addition		91.2	70.4	88.2	79.3	82.2	61.9	217.39	6.18	7.72
No addition		91.1	68.9	87.5	79.4	82.1	82.3	227.38	6.95	8.03
Protein levels										
Low		91.5	70.2	88.7	79.4	84.1	61.8	214.00	6.12	7.95
Medium		92.3	70.3	87.7	79.5	81.2	61.7	221.77	6.71	8.03
High		90.7	68.5	87.2	79.1	81.0	62.8	231.39	6.87	7.63
Probability (P);										
Yucca		0.915	0.700	0.569	0.989	0.976	0.926	0.695	0.301	0.785
Protein levels		0.715	0.912	0.624	0.995	0.721	0.982	0.852	0.676	0.953
Yucca × protein		0.855	0.965	0.721	0.982	0.745	0.908	0.499	0.583	0.844

[1] Pooled standard error.

lowering the protein level decreased fecal N excretion numerically in the early and late finishing phase. This is not similar to the results from studies on fecal 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 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%. Han et al. (1998) also found that although fecal nutrient excretion was not significantly influenced by dietary treatment, except for phosphorus, pigs fed low nutrient content diets tended to excrete a smaller amount of nitrogen and phosphorus than did pigs fed a high nutrient content diet. In their study, reducing crude protein by about 2% units resulted in an 18% reduction in fecal N excretion in 85 kg pigs.

Ammonia nitrogen excretion

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

Although, not statistically different, the NH_3-N content in manure increased 24.5% with YE supplementation. Presumably the efficacy of feeding YE in these situations relates to the reduction in

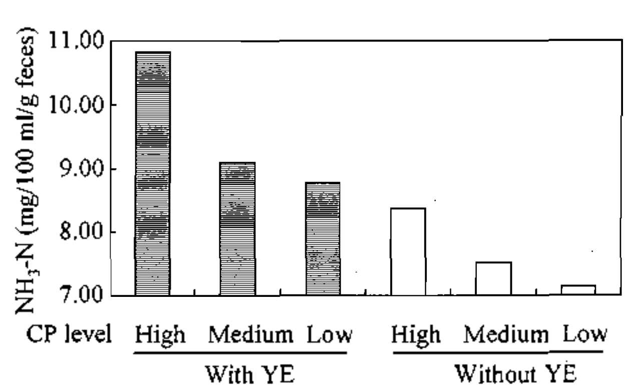

Figure 1. Effects of yucca extract on ammonia nitrogen contents in feces of finishing pigs fed different levels of dietary protein (N=24)

Table 5. Effects of addition of yucca extract with different protein levels on amino acid digestibility in early finishing pigs (%)

Yucca addition	Protein levels	THR	LYS	MET	ARG	HIS	ILE	LEU	PHE	VAL	EAA	ASP	SER	GLU	PRO	GLY	ALA	CYS	NEAA	TOTAL
Additon	Low	90.4	91.0	87.5	85.7	88.3	85.8	85.2	81.9	87.0	89.8	84.2	89.9	88.9^{ab}	90.0	86.3^{a}	84.45	89.9	87.6	87.2
	Medium	87.2	90.3	84.6	85.0	87.5	89.3	88.2	83.9	81.6	86.4	88.1	90.1	87.2^{b}	92.2	77.6^{b}	81.7	88.8	86.3	86.4
	High	91.9	90.1	85.8	86.3	86.3	87.3	86.8	84.7	83.8	87.0	87.0	89.2	89.7^{a}	91.3	86.7^{a}	85.5	89.2	87.6	87.6
No addition	Low	91.4	90.0	84.5	85.2	85.2	86.2	87.5	83.4	80.7	86.0	85.9	88.3	88.9^{ab}	90.6	85.6^{a}	85.9	89.6	87.7	86.8
	Medium	91.4	88.3	83.9	85.6	84.6	85.7	87.1	82.	79.3	85.4	85.4	88.1	88.6^{ab}	90.6	85.1^{a}	83.6	88.5	87.0	86.2
	High	91.4	85.7	84.7	87.9	85.3	86.3	89.5	86.6	83.3	86.7	86.0	88.4	88.9^{ab}	90.7	87.5^{a}	87.7	88.8	88.1	87.4
SE[1]		0.73	1.01	0.89	0.58	0.86	0.60	0.64	1.04	1.67	0.60	0.67	0.29	0.28	0.44	1.00	0.91	0.55	0.30	0.43
Yucca treatment																				
Addition		89.8^{b}	90.4	86.0	85.7	87.4^{a}	87.4^{a}	86.7	83.5	84.1	86.7	86.4	89.7^{a}	88.6	91.2	83.5	83.8	89.3	87.4	87.1
No addition		91.4^{a}	88.0	84.4	86.2	85.0^{b}	86.1^{b}	88.1	84.2	81.1	86.1	85.8	88.3^{b}	88.8	90.6	86.0	85.7	89.0	87.6	86.8
Protein levels																				
Low		90.9^{a}	90.4	86.0	85.4	86.7	86.0^{b}	86.3	82.6^{b}	83.9	86.4	85.0^{b}	89.1	88.9	90.3^{b}	85.9^{a}	85.1^{ab}	89.7	87.6^{ab}	87.0
Medium		89.3^{b}	89.3	84.3	85.3	86.2	87.5^{a}	87.7	83.3^{ab}	80.4	85.9	86.7^{a}	89.1	87.9	91.4^{a}	81.3^{b}	82.6^{b}	88.7	86.7^{b}	86.3
High		91.7^{a}	87.9	85.2	87.1	85.8	86.8^{a}	88.2	85.6^{a}	83.5	86.9	86.5^{a}	88.8	89.3	91.0^{b}	87.1^{a}	86.6^{a}	89.0	88.2^{a}	87.5
Probability																				
Yucca		0.001	0.061	0.062	0.484	0.018	0.018	0.343	0.499	0.232	0.292	0.216	0.020	0.678	0.117	0.091	0.155	0.796	0.687	0.629
Protein levels		0.001	0.238	0.228	0.124	0.677	0.078	0.547	0.069	0.463	0.461	0.027	0.877	0.143	0.052	0.009	0.064	0.792	0.052	0.154
Yucca×protein		0.001	0.524	0.463	0.511	0.580	0.019	0.468	0.436	0.627	0.885	0.009	0.680	0.275	0.044	0.065	0.976	0.997	0.740	0.987

[1] Pooled standard error.

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

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 feces (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. Also, there is the possibility that YE in the feces prevented nitrification. 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 have decreased the maintenance requirement energy and increased 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 extracts.

Also, there have been many reports with results similar to those of this experiment on YE supplementation. Preston et al. (1985) concluded that supplementation with sarsaponin was effective to decrease mean ruminal NH_3-N levels in cattle. Sutton et al. (1990) reported that litter ammonium nitrogen content was lower ($p<0.05$) due to whey-sarsaponin feed additive as compared with no feed additive. Sutton et al. (1992) also found that ammonia emission was significantly suppressed by 55.5% in manure tested in an incubation trial from pigs fed a sarsaponin extract. Morever, Jin et al. (1999b) reported that the yucca treatments emitted significantly more fecal ammonia-nitrogen when compared with the control during the finishing phase ($p<0.05$).

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). In this report, 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 supression of NH_3 from urea. The form and source of extract may have had an influence on the NH_3 emission results.

Ammonia nitrogen excretion was reduced by 15.9% for high protein vs. medium protein, 18.8% for high protein vs. low protein and 3.5% for medium protein vs. low protein with a decreased protein level in the diet of this experiment. There have been many reports showing similar results to those of the present experi-

Table 6. Effects of addition of yucca extract with different protein levels on amino acid digestibility in late finishing pigs (%)

Yucca addition	Protein levels	THR	LYS	MET	ARG	HIS	ILE	LEU	PHE	EAA	ASP	SER	GLU	PRO	GLY	ALA	CYS	NEAA	TOTAL
Addition	Low	93.0	92.1	80.0	91.1	97.7^{a}	92.3^{a}	88.3	91.9	91.2	93.3	94.4	85.8	92.4	84.6^{a}	89.3	85.2	89.3	90.2
	Medium	91.5	92.8	77.2	87.4	95.6^{b}	85.6^{b}	86.0	85.4	87.7	92.9	90.5	91.8	87.5	66.7^{b}	79.5	82.7	84.5	86.1
	High	92.5	93.6	79.9	88.9	96.1^{b}	87.3^{ab}	87.7	87.1	89.1	93.7	91.6	92.8	89.0	70.6^{b}	81.9	84.7	86.3	87.7
No addition	Low	90.8	92.2	75.4	85.7	84.9^{b}	84.5^{b}	84.9	84.3	86.6	92.3	89.7	91.2	86.5	64.0^{b}	77.8	81.3	83.3	84.9
	Medium	92.3	93.5	79.4	88.6	96.0^{b}	87.0^{ab}	87.3	86.8	88.9	93.6	91.4	92.6	88.7	69.8^{b}	81.4	84.3	86.0	87.4
	High	91.8	93.0	77.9	87.8	95.7^{b}	86.1^{b}	86.4	85.9	88.1	93.1	90.7	92.1	87.9	67.6^{b}	80.1	83.2	85.0	86.5
SE[1]		0.38	0.36	0.97	0.62	0.26	0.81	0.63	0.81	0.59	0.31	0.52	0.73	0.66	2.05	1.19	0.77	0.76	0.67
Yucca treatment																			
Addition		92.4	93.8	79.0	89.1	96.5	88.4	87.3	88.1	89.3	93.3	92.1	90.1	89.6	73.9	83.6	84.2	86.7	88.0
No addition		91.6	92.9	77.6	87.4	95.6	85.8	86.2	85.6	87.8	93.0	90.6	92.0	87.7	67.2	79.8	83.0	84.7	86.3
Protein levels																			
Low		91.9	93.7	77.7	88.4	96.4	88.4	86.6	88.1	88.9	92.8	92.0	88.5^{b}	89.5	74.3	83.6	83.3	86.3	87.6
Medium		91.9	93.1	78.3	88.0	95.8	86.3	86.7	86.1	88.3	93.2	90.9	92.2^{a}	88.1	68.2	80.2	83.5	85.2	86.8
High		92.1	93.3	78.9	88.3	95.9	86.7	87.0	86.5	88.6	93.4	91.2	92.4^{a}	88.4	69.1	81.0	84.0	85.6	87.1
Probability																			
Yucca		0.407	0.208	0.504	0.169	0.072	0.116	0.427	0.126	0.234	0.653	0.144	0.124	0.155	0.86	0.108	0.471	0.226	0.229
Protein levels		0.970	0.826	0.901	0.962	0.597	0.522	0.962	0.563	0.921	0.780	0.635	0.019	0.677	0.376	0.482	0.939	0.863	0.879
Yucca×protein		0.367	0.159	0.456	0.118	0.037	0.074	0.386	0.083	0.183	0.596	0.098	0.098	0.108	0.049	0.066	0.431	0.177	0.179

[1] Pooled standard error.

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

ment 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%.

Carcass characteristics

There were no significant differences in carcass weight, backfat thickness, carcass grade and loin eye area between YE treatments and among protein levels (table 7), but the pigs fed the low protein diet without YE showed a significantly ($p<0.05$) low carcass ratio than those of high and medium protein diets. Duffy and Brooks (1998) found an 11.5% reduction in backfat thickness for growing-finishing pigs with YE supplementation. Also, they suggested that a possible increase in lean mass was in response to the extract. Vander et al. (1994) reported that serum creatine levels and serum insulin levels were significantly increased by yucca extract. Since it is known that creatine levels increase in proportion to muscle mass, those changes may indicate differences in muscle mass. Also, insulin promotes energy storage, protein synthesis and increased nitrogen balance, that is increase in muscle mass and reduction in the urea synthesis rate.

As for carcass length, the pigs fed high protein diet without YE showed the best records. Carcass grade was improved with YE supplementation, however there was no significant difference among treatments.

Jin et al. (1999a, b) and Bae et al. (1999) reported there was no significant difference in carcass characteristics with the inclusion of the *Yucca schidigera* for finishing swine.

The present study did not show any improvement in the carcass characteristics of pigs fed high protein. These results agreed with reports from Easter and Baker (1980) and Canh et al. (1998). Easter and Baker (1980) noted that synthetic lysine spared 1 to 2 percentage units of dietary protein, without improving the carcass quality. Oldenberg and Heinrichs (1996) reported that there was no negative effect on performance and carcass leanness by the reduced dietary protein levels from 17 to 13.5% between 50 and 110 kg live weight. Canh et al. (1998) compared three diets with different crude protein levels (16.5, 14.5 and 12.5%) with similar net energy and amino acid contents in growing-finishing pigs, and found no significant effects from reduced protein levels on carcass yield.

However, Cromwell et al. (1996) showed that pigs can perform optimally at 4 percentage units crude protein reduction with adequately supplemented amino acids, but carcass leanness was reduced. Tuitoek et al.

Table 7. Effects of addition of yucca extract with different protein levels on carcass characteristics in finishing pigs[1]

Yucca addition	Protein levels	Carcass weight (kg)	CR (%)	Carcass length (cm)	BF (mm)	Carcass grade[2]	LEA (cm^2)
Addition	Low	76.06	76.81[ab]	97.6	25.20	2.55	47.32
	Medium	78.03	77.65[a]	98.9	28.30	2.05	43.10
	High	75.90	76.39[ab]	99.0	26.15	2.22	41.98
No addition	Low	77.14	75.31[b]	98.3	26.95	2.45	46.08
	Medium	76.92	77.18[a]	98.3	26.95	2.40	45.70
	High	77.96	77.26[a]	100.0	26.20	2.35	49.05
SE[3]		0.93	1.09	0.32	0.62	0.09	1.45
Yucca treatment							
Addition		76.66	75.34	98.51	26.55	2.28	45.00
No addition		77.34	75.38	98.87	26.67	2.40	46.08
Protein levels							
Low		76.60	73.93[b]	97.96[b]	26.08	2.50	45.21
Medium		77.48	78.10[a]	98.59[ab]	27.58	2.23	44.03
High		76.93	75.56[ab]	99.51[a]	26.18	2.30	47.38
Probability (P)							
Yucca		0.487	0.440	0.533	0.909	0.419	0.677
Protein levels		0.755	0.035	0.110	0.411	0.283	0.561
Yucca × protein		0.699	0.003	0.466	0.443	0.443	0.357

* Pigs were slaughtered when they reached 105 kg of average body weight. ** Abbreviations - CR : Carcass ratio, BF : Backfat thickness, LEA : Loin eye area. [1] Means of CWT, CR. Length, BF. Grade and LEA were corrected based on lean final slaghter weight as a covariate. [2] Grade: A=1, B=2, C=3. [3] Pooled standard error. [a,b] Means with different superscripts are different at p<0.05.

Table 8. Effects of addition of yucca extract with different protein levels on total feed cost during the finishing phase

Yucca addition	Protein levels	Total weight gain (kg)	Total feed cost (₩)	Feed cost /kg weight gain (₩)
Addition	Low	49.48	35,874	725.4
	Medium	49.80	38,098	767.2
	High	48.60	39,539	815.3
No addition	Low	48.40	36,545	755.1
	Medium	47.97	37,001	772.3
	High	48.76	39,055	803.8
SE[1]		0.5289	537.25	11.35
Yucca treatment				
Addition		49.29	37,837	769.3
No addition		48.38	37,533	777.1
Protein levels				
Low		48.94	36,210[b]	740.3[b]
Medium		48.88	37,550[b]	769.8[ab]
High		48.68	39,296[a]	809.5[a]
Probability (P)				
Yucca		0.413	0.654	0.698
Protein levels		0.980	0.004	0.031
Yucca × protein		0.758	0.555	0.195

[1] Pooled standard error. [a,b] Means with different superscripts are different at p<0.05.

(1997) also found increased fat content in the carcass in pigs fed diets reduced by 4 percentage units of dietary protein despite the supplementation with synthetic amino acids added to meet an ideal amino acid ratio. Yu et al. (1991) observed that pigs fed diets reduced by 5 percentage units of crude protein and supplemented with amino acids showed negative performance responses and an increase in carcass fat content.

Feed cost

Table 8 summarizes the effects of the yucca extract with different protein levels on total feed costs during the finishing period. The cost of feeding high level protein was higher than that of medium level protein by 5% and low level protein by 9% (p<0.05).

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 present study about YE supplementation contradicts the report that feed cost per kg of weight gain was lowered by 8.1% with YE supplementation (Gippert, 1992), but concurs with the report that YE supplementation does not spare feed costs in growing-finishing swine (Jin et al., 1999a, b).

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