Effects of Environmentally Friendly Agents on Growth Performance, Nutrient Digestibility, Nutrient Excretion and Carcass Characteristics in Growing-Finishing Pigs**

T. S. Min[2], J. D. Kim[3], Y. Hyun[4], K. S. Sohn[5] K. N. Heo* and In K. Han[1]
Department of Animal Science and Technology, College of Agriculture and Life Sciences
Seoul National University, Suweon 441-744, Korea

ABSTRACT : An experiment was conducted to investigate the effects of environmentally friendly agents (yucca extract, mineral feed additive, acidifier, nonspecific immunostimulating anionic alkali solution) on the growth performance, nutrient digestibility, nutrient excretion and carcass characteristics in growing-finishing pigs. A total of 125 pigs were allotted into 5 treatments with 5 replications, 5 pigs per pen in a completely randomized block design. Dietary treatments consisted of 1) control: basal diet, 2) YE: basal diet+120 mg/kg of yucca extract, 3) MFA: basal diet+50 mg/kg of mineral feed additive, 4) NIS: basal diet+3% of NIS (nonspecific immunostimulating anionic alkali solution), and 5) Acidifier: basal diet+0.5% of acidifier (organic acid complex). During the growing phase of the feeding trial, There were no significant differences in average daily feed intake (ADFI) and feed conversion ratio (F/G) among treatments, but the Acidifier group showed higher average daily gain (ADG) than the MFA group ($p<0.05$). During the finishing phase, there were no significant differences in growth performance among treatments, however YE supplementation increased ADG and F/G by 3.1 and 6.15%, respectively, when compared to control group. Proximate nutrients (dry matter, DM; crude protein, CP; crude ash, CA; crude fat, CF; gross energy, GE; calcium, Ca and phosphorus, P) digestibility did not show any significant differences among the treatments. And there were no significant differences in DM, N and P excretion as well. The supplementation of environmentally friendly agents tended to increase carcass weight compared to control group. Pigs fed MFA showed significantly heavier ($p<0.05$) carcass weight than those fed control or Acidifier diets. Addition of these agents except for NIS to diet for growing-finishing pigs caused a similar feed cost/kg weight gain than control group. Therefore, present study suggested that the optimum environmentally friendly agent would be yucca extracts, considering the effects on growth performance, nutrient digestibility, nutrient excretion, carcass characteristics and feed cost in growing-finishing pigs. (*Asian-Aust. J. Anim. Sci. 2001. Vol. 14, No. 4 : 540-547*)

Key Words : Pig, Yucca, Mineral Feed Additives, Acidifier, Growth Performance, Nutrient, Digestibility and Excretion, Carcass Characteristics

INTRODUCTION

A great deal of attention has been given to reduce pollutant excretion from livestock all over the world. And actually, various attempts have been conducted to reduce nutrients excretion using metabolically active substances (Kwon et al., 1995, 1997; Noh et al., 1995; Park et al., 1994; Han and Min, 1991) or synthetic amino acids (Han et al., 1978, 1995; Chae et al., 1988; Daghir, 1983; Heo et al., 1995; Jin et al., 1998).

In general, a better feed conversion ratio leads to a lower excretion of N and minerals. An improvement in feed conversion of 0.25 units would reduce nitrogen excretion by 5 to 10% (Coffey, 1996). Feed additives which promote growth may reduce the excretion of N and P as a result of better feed conversion ratio (Murphy, 1998).

There have been reported some possible ways that could reduce nutrients excretion by using yucca extracts (Gippert, 1992; Bae et al., 1999; Sutton et al., 1996; Cole et al., 1998; Morel, 1997) and zeolite (Cool and Willard, 1982; Vrzgula et al., 1982; Bartko et al., 1983; Liebscher, 1991; Castro et al., 1996). Recently, developed nonspecific immunostimulating anionic alkali solution (NIS) has been known that growth performance did not show any difference with antibiotics in growing-finishing swine. No futher information is available on the effect of NIS as an environmentally friendly agent yet.

Therefore, this study was designed to investigate effects of environmentally friendly agents (yucca extract, mineral feed additives, acidifier, NIS) on

* Corresponding Author: K. N. Heo. Department of Animal Science, North Carolina State University, Raleigh, NC 27659-7621, USA. Tel: +1-919-515-8626, Fax: +1-919-515-4050, E-mail: kheo@unity.ncsu.edu.
[1] Address reprint requests to In K. Han. Tel: +82-2-502-0757, Fax: +82-2-502-0758, E-mail: inkhan@kornet.net.
[2] Korea Science and Engineering Foundation, Korea.
[3] Institute of Animal Science & Technology, Seoul National University, Korea.
[4] Department of Animal Sciences, University of Illinois, Urbana 61801, USA.
[5] Agribrands Purina Korea Inc., Korea.
** This study was partially funded by KOSEF and Agribrands Purina Korea Inc. in Korea.
Received August 23, 2000; Accepted Novemer 25, 2000

growth performance, nutrient digestibility, nutrient excretion and carcass characteristics in growing-finishing pigs.

MATERIALS AND METHODS

One-hundred twenty-five crossbred pigs (Yorkshire × Landrace × Duroc) initially averaging 22.28±0.37 kg body weight were used. Pigs were grouped on the basis of body weight and sex, and randomly assigned to five treatments.

The treatments included 1) control: without supplementation, 2) YE: basal diet+120 mg/kg of yucca extract, 3) MFA: basal diet+50 m/kg of mineral feed additive, 4) NIS: basal diet+3% of NIS (nonspecific immunostimulating anionic alkali solution), and 5) Acidifier: basal diet+0.5% of acidifier (organic acid complex). Each treatment had five replicates with five pigs per replicate. The basal corn-soybean meal-wheat bran based diets were formulated to contain 3,395 ME kcal/kg and 1.0% lysine for the growing phase, 3,328 ME kcal/kg and 0.98% lysine for the early finishing phase and 3,329 ME kcal/kg and 0.86% lysine for the late finishing phase, respectively (table 1).

Adequate amounts of vitamins and minerals were supplied as suggested by NRC (1998) requirements for the whole period. All pigs were removed at the average weight of 115.4±0.82 kg and slaughtered to investigate carcass characteristics. Pigs were housed in concrete floored pen, with a feeder and a nipple waterer, and allowed *ad libitum* access to feed and water throughout the fifteen weeks of experimental period. The temperature within house was maintained at 18−22℃ through the whole experimental period. Body weight and feed intake were recorded every 3 weeks during the experiment.

For the determination of nutrient digestibility, 20 pigs were allotted to metabolic crates by completely random design. A total fecal collection method was used. After 10 days of adaptation, total excreta were collected over 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 1 mm Wiley mill for chemical analyses. The analyses of proximate nutrients of the experimental diets and excreta were analyzed according to the method of AOAC (1990), and gross energy content was measured using an adiabatic bomb calorimeter (Model 1241, Parr Instrument Co., USA).

At the termination of the experiment, all pigs were slaughtered and hot carcass weights were obtained for carcass percentage calculation. Backfat thickness was measured between the 10th and 11th ribs. Carcass was graded from A to D according to appearance and quality. The pigs under 100 kg or over 120 kg were removed from the data set to reduce deviation by body weight.

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

RESULTS AND DISCUSSION

Growth performance

Growing phase: The growth performance of growing pigs is summarized in table 2. There were no significant differences in average daily feed intake (ADFI) and feed conversion ratio (F/G) among treatments, but the Acidifier group showed higher average daily gain (ADG) than the MFA group ($p<0.05$).

Table 1. Formula and chemical composition of experimental diets

	Growing	Early finishing	Late finishing
Ingredients (%):			
Corn	62.00	47.71	67.49
Soybean meal	29.00	21.12	16.98
Wheat	-	18.49	2.63
Rice bran	3.00	5.00	5.00
Animal fat	3.00	4.17	4.33
Dicalciumphosphate	1.00	1.41	1.52
Limestone	1.19	1.22	1.21
Vitamin mixture[1]	0.25	0.25	0.25
Mineral mixture[2]	0.15	0.15	0.15
Salt	0.20	0.20	0.20
L-Lysine · HCl	-	0.25	0.24
Methionine	-	0.02	-
Antibiotics	0.01	0.01	0.01
Chemical composition[3]:			
ME (Mcal/kg)	3,395	3,328	3,329
Crude protein (%)	18.43	16.01	14.00
Lysine (%)	1.00	0.98	0.86
Met+cys (%)	0.59	0.59	0.52
Threonine (%)	0.69	0.61	0.56
Calcium (%)	0.80	0.80	0.80
Phosphorus (%)	0.68	0.70	0.70

[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 and 0.5 mg folic acid.

[2] Supplied per kg diet: 200 mg Cu, 100 mg Fe, 150 mg Zn, 60 mg Mn, 1 mg I, 0.5 mg Co and 0.3 mg Se.

[3] Calculated value.

Table 2. Effects of environmentally friendly agents on growth performance in growing pigs

Item	Control	YE	MFA	NIS	Acidifier	SE[1]
Initial BW (kg)	22.27	22.27	22.26	22.28	22.29	0.37
Final BW (kg)	64.63^{ab}	64.76^{ab}	63.19^{b}	64.39^{ab}	66.02^{a}	0.53
ADG (g)	883^{ab}	885^{ab}	853^{b}	878^{ab}	911^{a}	6.99
ADFI (g)	2,253	2,167	2,215	2,265	2,323	25.92
F/G	2.55	2.45	2.60	2.58	2.55	0.02

[1] Pooled standard error.

Abbreviations: YE, yucca extracts; MFA, mineral feed additive; NIS, Non-specific immunostimulating anionic alkali solution; Acidfier, Acidifier.

Until now, inconsistent results have been reported on the effects of acidifiers in pigs. Burnell et al. (1988) reported that 1% citric acid in diets containing 15% dried whey showed no improvement in weight gain in weaned pigs. While, Falkowski and Aherne (1984) reported that 2% citric acid in diets showed improvement by 7.5% in weight gain and Krause et al. (1994) also showed improved weight gain in pigs more than 5% using 2.5% citric acid in the diets. Similarly, the present study showed an increased weight gain of 3.2% by the supplementation of acidifier when compared to the control. This disagreement appears to be related to variations in the experimental methods and materials. These variables include differences in dietary ingredients, age of animals, types and dosages of acidifiers, and husbandry conditions (Ravindran and Kornegay, 1993).

Although, a lot of experiments have been conducted to evaluate the efficacy of organic acids on piglets, there has been little information on pig. But the result of this study implies the possibility to use an organic acid on growing-finishing pig as well as piglets.

High feed intake in acidifier treatment of this experiment is consistent with the report that acidifier increased feed intake (Kirchgessner and Roth, 1982). Interestingly, in the study of Henry et al. (1985), when free access was allowed to both acidified and nonacidified diets, the pigs consumed significantly more of nonacidified diet.

Meanwhile, there are some reports about the low ADG with mineral feed additives. Milne and Froseth (1982) and Thielemans and Bodart (1982) found that zeolite consumption has negative effect on the growth performance of livestocks. It is reported that zeolite had no influence on growth performance (Ballard and Edwards, 1988; Daly et al., 1990).

The reason for the poor ADG of MFA group could not be explained, but this is related to the report by Easter et al. (1993) that the effect of inclusion of clinoptilolite and clay minerals on animal performance seem quite variable. Mumpton and Fishman (1977) also indicated that the growth rate of livestock varies with different types of zeolite and their characteristics, and also depends on the amount of zeolite inclusion.

Although there was no significant difference in feed efficiency, supplemented YE tended to improve feed efficiency of pigs. As for the feed efficiency of the YE group in the present study, the feeding efficacy in these situations is consistent with the report by Moser et al. (1988). They found that the inclusion of sarsaponin which is main component of YE improved the growth performance of nursery pigs, however, in growing-finishing pigs the responses to sarsaponin have been positive but smaller in magnitude in results from several universities.

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. Similarly, Jin et al. (1999a) found no significant difference in growth performance with the addition of yucca extract. By contrast, Mader and Brumn (1987) reported improved feed efficiency in pigs when *Yucca schidigera* extract is added to the diet.

Finishing phase: The growth performance of finishing pigs fed experimental diets are presented in table 3. During phase I (0-28 day), there were no significant differences in the ADG, ADFI and F/G ratio among the treatments. Pigs fed NIS showed better ADG than other treatments numerically. Kim et al. (1999) did not find any significant difference in a feeding trial with early finishing swine, however pigs fed NIS grew more efficiently than others.

During phase II (29-63 day), there were no significant differences in ADG, ADFI or F/G among treatments as well ($p>0.05$). Pigs fed YE diet showed the best feed efficiency while those fed mineral feed additives showed the lowest F/G. For the overall period, there were no significant differences in ADG, ADFI or F/G among the treatments ($p>0.05$), but YE group tended to improve ADG and F/G ratio by 3.1 and 6.15%, respectively.

Some researchers reported that yucca extracts 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 in the growth

Table 3. Effects of environmentally friendly agents on feed intake and growth performance in finishing pigs

Item	Control	YE	MFA	NIS	Acidifier	SE[1]
Initial BW (kg)	63.96	63.94	63.92	63.88	63.88	0.64
Final BW (kg)	114.67	116.32	115.83	115.70	114.68	0.82
D 0-28						
ADG (g)	894	884	862	928	846	13.64
ADFI (g)	3,244	2,989	2,975	3,168	3,014	63.26
F/G	3.64	3.38	3.46	3.41	3.57	0.06
D 29-63						
ADG (g)	734	787	795	740	775	12.08
ADFI (g)	3,392	3,385	3,473	3,325	3,496	40.83
F/G	4.62	4.33	4.83	4.53	4.52	0.07
D 0-63						
ADG (g)	805	830	825	822	806	7.13
ADFI (g)	3,326	3,209	3,252	3,326	3,282	44.69
F/G	4.13	3.88	3.95	4.05	4.07	0.05

[1] Pooled standard error.

Abbreviations: YE, yucca extracts; MFA, mineral feed additive; NIS, non-specific immunostimulating anionic alkali solution; Acidfier, acidifier.

performance of finishing pigs (Cromwell et al., 1985; Jin et al., 1999b).

Gippert (1992) reported that the addition of *Yucca schidigera* (60-120 mg/kg) in growing-finishing pigs resulted in an 11% improvement in daily gain and 15.6% reduction in mortality when compared to control. Bae et al. (1999) also showed 11% improvement in daily gain with the inclusion of *Yucca schidigera* (125 mg/kg) was for finishing swine. But Cromwell et al. (1985) reported that there was no effect on growth performance in growing-finishing swine when sarsaponin (62 mg/kg) added to the diet. Jin et al. (1999a, b) also found no significant difference in the growth performance and carcass characteristics, when supplemented yucca extracts in pig diet.

Nutrient digestibility

The effects of various feed additives on nutrient digestibility and nutrient excretion during the late finishing phase was given in table 4. Proximate nutrients (dry matter: DM, crude protein: CP, crude ash: CA, crude fat: CF, gross energy: GE, calcium: Ca and phosphorus: P) digestibilities did not show any significant differences among the treatments ($p>0.05$). Also, there was no significance in the amount of DM, N and P in feces as well ($p>0.05$). The results of this report contradicted those that showed improved feed efficiency due to the addition of environmentally friendly agents (Sadil et al., 1992; Eckel et al., 1992; Kirchgessner et al., 1992; Kondo and Wangai, 1968) but concurred with reports that showed their consumption did not influence the nutrient utilization ratio (Bae et al., 1999; Jin et al., 1999a, b; Ly et al., 1996; Kim et al., 1999; Falkowski and Aherne, 1984; Radecki et al., 1988; Mosenthin et al., 1992; Ballard and Edwards, 1988).

Much research reported that the supplementation of feed additives reduces excretion of N and P as a result of a better feed conversion ratio as compared to non-supplemented feeds. Sadil et al. (1992) have shown the beneficial effects on ruminal ammonia levels, dry matter digestibility and rumen pH in lactating cows fed 1% urea supplements to which yucca extract had been added. In the study of Eckel et al. (1992), formic acid supplementation improved digestibility during feeding period. In a follow-up study, Kirchgessner et al. (1992) reported improved nitrogen retention with formic acid supplementation.

In contrast, however, Bae et al. (1999) reported that when yucca extract (125 mg/kg) was added for finishing swine diets, there was no significant difference in nutrient digestibility. Similarly, Jin et al. (1999a, b) did not find any improvements by the addition of yucca extract. Ly et al. (1996) found no treatment effect on N digestibility, but N retention was higher ($p<0.10$) when 6% zeolite was added to fattening pig diets. Kim et al. (1999) conducted experiments to compare the effects of an antibiotic (0.05% Chlortetracycline) with that of NIS (3%, rice bran was used as carrier) on nutrient digestibility in fattening pigs. In all digestibility parameters, the record of the NIS group was not superior to the others. Similar trends were observed by Falkowski and Aherne (1984). They demonstrated that fumaric or citric acid showed no improvement in the digestibility of DM and CP for pigs weaned at 4 weeks of age. Radecki et al. (1988) and Mosenthin et al. (1992) failed to observe any improvements in energy digestibility with diet acidification.

Table 4. Effects of environmentally friendly agents on nutrient digestibility and nutrient excretion during late finishing phase

Item	Control	YE	MFA	NIS	Acidifier	SE[1]
Nutrient digestibilites (%)						
Dry matter	95.04	96.02	95.68	95.36	95.95	0.159
Crude protein	83.41	85.14	83.41	82.71	84.59	0.614
Crude ash	63.72	60.73	60.49	61.44	60.47	1.183
Crude fat	60.05	65.06	62.34	60.56	60.66	2.427
Gross energy	87.20	87.29	86.79	88.19	85.28	0.413
Calcium	60.22	61.55	61.94	62.88	60.35	1.168
Phosphorus	60.61	64.21	63.45	62.54	62.74	1.165
Fecal nutrient excretions (g/day)						
Dry matter	172.47	160.55	167.02	164.32	167.36	4.319
Nitrogen	5.93	5.48	6.25	5.66	5.87	0.207
Phosphorus	4.34	3.28	3.90	3.57	3.69	0.186

[1] Pooled standard error.

Abbreviations: YE, yucca extracts; MFA, mineral feed additive; NIS, non-specific immunostimulating anionic alkali solution; Acidfier, acidifier.

Meanwhile, the result of this experiment on nutrient excretion is inconsistent with that of Jongbloed's conclusion (1992) that the supplementation of feed additives (growth promoters) might reduce the excretion of N and P as compared to non-supplemented feeds. He estimated that the excretions of N and P per pigs was 7 and 3% on average respectively, and higher when no feed additives were used. These differences might due to the age of the experimental pigs. In this experiment older pigs was used than that experiment. Thus, the effect of feed additives on nutrient digestibility might be diluted.

Carcass characteristics

The effect of environmental agents on carcass characteristics are presented in table 5. The MFA group increased carcass weight significantly ($p<0.05$) compared to the Control and Acidifier group.

Angelova et al. (1985) reported that no effect was observed in carcass characteristics and meat chemical composition in the experiment on fattening hybrid pigs fed 4% zeolite-added feed. Also, Pearson et al. (1985) found no effect on carcass measurements with the addition of Clinoptilolite (40 to 80 g/kg live weight). Moreover, Yang (1999) reported that he could not find any efficacy in zeolite (CEC 72.0 meq/100 g) and 3% scoria (1,000 μm) in the carcass characteristics in fattening pigs. The difference between the present study and previous literatures was not clearly understood. But this may be related to the report by Sellier (1987) and that of Heinze and Mitchell (1991) that the glycogen level included in muscle fluctuates according to the genetic background of the swine and that meat quality also varies according to the response to stress before slaughter.

There was no significant differences in carcass ratio, carcass length, carcass grade, loin eye area and backfat thickness at the 10th rib among treatments. But carcass length, carcass grade, loin eye area and backfat thickness tended to be improved with the

Table 5. Effects of environmentally friendly agents on carcass characteristics[1]

Item	Control	YE	MFA	NIS	Acidifier	SE
Carcass weight (kg)	91.7^{b}	93.1^{ab}	93.4^{a}	92.6^{ab}	91.7^{b}	0.51
Carcass percentage	80.1	79.9	80.3	79.8	79.5	0.18
Carcass length (cm)	81.8	82.0	81.9	83.0	82.5	0.34
Backfat thickness (mm)	2.97	2.70	2.71	2.87	2.81	0.05
Carcass grade[2]	2.58	2.57	2.23	2.19	2.23	0.10
Loin eye area (cm^2)	26.7	26.0	27.3	28.1	28.4	0.98

[a,b] Means with different superscript in the same row differ at $p<0.05$.

[1] Means of carcass weight, carcass percentage, carcass length, backfat thickness, carcass grade and loin eye area were corrected based on average lean final slaughter weight (92.5 kg) as a covariate.

[2] Grade : A=1, B=2, C=3.

Abbreviations: YE, yucca extracts; MFA, mineral feed additive; NIS, non-specific immunostimulating anionic alkali solution; Acidfier, acidifier.

Table 6. Effects of environmentally friendly agents on total feed cost during finishing phase

Item	Control	YE	MFA	NIS	Acidifier	SE
Total weight gain (kg)	50.70	52.38	51.90	51.80	50.78	0.456
Total feed cost (₩)	53,291[b]	51,645[b]	52,487[b]	61,073[a]	55,054[b]	996.9
Feed cost/kg weight gain (₩)	1,050.5[b]	988.9[b]	1,011.6[b]	1,179.5[a]	1,083.8[b]	18.98

[a,b] Means with different superscript in the same row differ at $p<0.05$.
Abbreviations: YE, yucca extracts; MFA, mineral feed additive; NIS, non-specific immunostimulating anionic alkali solution; Acidfier, acidifier.

addition of environmentally friendly agents compared to control group. Similar trends were observed in reports by Cromwell et al. (1985) and Jin et al. (1999b) with yucca extract; Angelova et al. (1985), Pearson et al. (1985) and Yang(1999) with mineral feed additive; Kim et al. (1999b,c) with NIS.

Feed cost

Table 6 summarizes the effects of environmentally friendly agents on feed cost during finishing phase. Weight gain was not significantly different by the supplementation of environmentally friendly agents. Adding these agents to diet for growing-finishing pigs caused a similar or higher feed cost/kg weight gain than the control. The YE group showed a lower cost by 6% than the Control group. Interestingly, the feed cost/kg weight gain of the NIS group was highest among treatments (12% higher over the Control group).

REFERENCES

Angelova, L., G. Valchev, D. Nesev and H. Stanchev. 1985. A study of the effect of zeolite containing compound feeds for fattening hybrid pigs raised under industrial conditions. Zhivotnovadni Nauki. 22(10):43.

AOAC. 1990. Official Methods of Analysis (15th Ed.). Association of Official Analytical Chemist. Washington, DC., USA.

Bae, K. H., T. G. Ko, J. H. Kim, W. T. Cho, Y. K. Han and In K. Han. 1999. Use of metabolically active substances to substitute for antibiotics in finishing pigs. Korean J. Anim. Sci. 41(1):23.

Ballard, R. and H. M. Edwards, Jr. 1988. Effects of dietary zeolite and vitamin A on tibial dyschondroplasia in chickens. Poultry Sci. 67:113.

Bartko, P., J. Chabada, L. Vrzgula and J. Blazovky. 1983. Supplementation with zeolites of diets for pigs kept in cages. Vet. Med. 28(7):429.

Burnell, T. W., G. L. Cromwell and T. S. Stahly. 1988. Effects of dried whey and copper sulfate on the growth responses to organic acid in diets for weaning pigs. J. Anim. Sci. 66:1100.

Castro, M. M. A. Guerra and Y. Rodriguez. 1996. Efect of zeolite on swine diets and concentrate feed with Saccharina for fattenings pig. Cuban J. of Agri. Sci. 30(2):177.

Chae, B. J., In K. Han and M. K. Kim. 1988. Protein sparing effects of supplemental L-lysine in growing swine diet. Kor. J. Anim. Nutr. Feed. 12: 76.

Coffey, M. T. 1996. Environmental Challenges as a related to animal agriculture-swine. In: Nutrient management of food animals to enhance and protect the environment (Ed. E. T. Kornegay). Lewis Publishers.

Cole, D. J. A. H. G. Schuerink and A. Morel. 1998. The French and Dutch experiences in controlling odour on farms. In: Biotechnology in the Feed Industry (Ed. T. P. Lyons and K. A. Jacqued). Nottingham Univ. Press, Nottingham, UK. p. 73.

Cool, W. M. and J. Willard. 1982. Effect of clinoptilotile on swine nutrition. Nutr. Rep. Int. 26:759.

Cromwell, G. L., T. S. Stahly, H. J. Monegue. 1985. Efficacy of sarsaponin for weanling and growing-finishing swine housed at two animal densities. J. Anim. Sci. 61(Suppl. 1).

Daghir, N. J. 1983. Effect of lysine and methionine supplementation of low protein rooster diets fed after six weeks of age. Poultry Sci. 62:1572.

Daly, K. R., R. A. Peterson, G. Carpenter, and W. T. Jones, 1990. Effect of feeding Ethacal™ feed component on growth performance of broilers. Poultry Sci. 69(Suppl. 1):40(Abstr.).

Duffy C. and P. Brooks. 1998. Using *Yucca schidigera* in pig diets: effects on nitrogen metabolism. In: Biotechnology in the Feed Industry (Ed. T. P. Lyons and K. A. Jacqued). Nottingham Univ. Press, Nottingham, UK. p. 61.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometric. 11:1.

Easter, R. A., H. Stein and N. L. Trottier. 1993. Use of biotechnology and feed additives. In: Proceedings of the First International Symposium on Nitrogen Flow in Pig Production and Environmental Consequences. (Ed. M. W. A. Verstegen, L. A. den Hartog, G. J. M. van Kempen and J. H. M. Metz). EAAP Publication, Pudoc, Wageningen, The Netherlands. 69. p. 169.

Eckel, B., M. Kirchgessner and F. X. Roth. 1992. Influence of formic acid on daily weight gain, feed intake feed conversion rate and digestibility. 1. Communication: Investigations about the nutritive efficacy of organic acids in the rearing of piglets. J. Anim. Physiol. Anim. Nutr. 67:93.

Falkowski, J. F. and F. X. Aherne. 1984. Fumaric acid and citric acid as additives in starter pig nutrition. J. Anim. Sci. 58:935.

Gardner, W. H. 1972. Acidulants in food processing. In: CRC Handbook of Food Additives (2nd Ed.). (Ed. T. E. Furia). CRC Press, Cleveland, OH, USA.

Gippert, T. 1992. Effect of de-odorase on performance and health of growing and fattening pigs. In: Biotechnology

in the Feed Industry (Ed. T. P. Lyons). Alltech Technical Publications, Nicholasville, Kentucky, USA. p. 31.

Han, In K. and T. S. Min. 1991. The effects of dietary supplementation with Kemzyme in broiler. Kor. J. Anim. Nutr. Feed. 15(1):9.

Han, In K., K. Kwon, K. H. Na and M. I. Yoo. 1978. Protein sparing effect of L-lysine in the rations of weaning pigs and growing-finishing hogs. Kor. J. Anim. Sci. 20(6):566.

Han, In K., K. N. Heo, I. S. Shin and H. Lee. 1995. Protein sparing effect and amino acid digestibilities of supplemental lysine and methionine in weanling pigs. Asian-Aus. J. Anim. Sci. 8(4):393.

Heinze, P. H, and G. Mitchell. 1991. A comparison of some muscle metabolites in stress- susceptible and resistant landrace gilts after halothane exposure or exercise stress. Meat Sci. 30:337.

Henry, R. W., D. W. Pickard, P. E. Hughes. 1985. Citric acid and fumaric acid as food additives for early-weaned piglets. Anim. Prod. 40:505.

Heo, K. N., In K. Han and H. Lee. 1995. Protein sparing effect and amino acid utilization in broilers fed two types of lysine. Asian-Aus. J. Anim. Sci. 8(4):403.

Jin, C. F., J. H. Kim, In K. Han and S. H. Bae. 1998. Effects of supplemental synthetic amino acids to the low protein diets on the performance of growing pigs. Asian-Aus. J. Anim. Sci. 11:1.

Jin, J., W. D. Chung, W. T. Cho and In K. Han. 1999a. Effects of fructo-oligosaccharide and *Yucca schidigera* extract supplementation on the growth performance and nutrient digestibility in growing pigs. Biennial Reporter on Research and Education, Seoul National University. Suweon, Korea. p. 137.

Jin, J., W. D. Chung, W. T. Cho and In K. Han. 1999b. Effects of fructo-oligosaccharide and *Yucca schidigera* extract supplementation on the growth performance and nutrient digestibility in finishing pigs. Biennial Reporter on Research and Education, Seoul National University. Suweon, Korea. p. 140.

Jongbloed, A. W. 1992. Quantification of the efficacy of feed additives on the excretion of nitrogen and phosphorus, amount of manure and feed consumption of pigs (In Dutch), Mededelingen IVVO-DLO No. 17, Lelystad, The Netherlands.

Kim, J. D., T. G. Ko, Y. K. Han and In K. Han. 1999. Study on the development of antibiotic-free diet for growing-finishing pigs. Kor. J. Anim. Nutr. Feed. 23(4):283.

Kirchgessner, M. and F. X. Roth. 1982. Fumaric acid as a feed additive in pig nutrition. Pig News Inf. 3:259.

Kirchgessner, M., B. Eckel, F. X. Roth and U. Eidelsburger. 1992. Influence of formic acid on carcass composition and retention of nutrients. 2. communication: Investigations about the nutritive efficacy of organic acids in the rearing of piglets. J. Anim. Physiol. a Anim. Nutr. 67:93.

Kondo, N. and B. Wangai. 1968. Experimental use of clinoptilolite as dietary supplements for pigs. Yonokai, May 1-4.

Krause, D. O., P. C. Harrison and R. A. Easter. 1994. Characterization of the nutritional interactions between organic acids and inorganic bases in the pig and chick. J. Anim. Sci. 72:1257.

Kwon, K., C. H. Kwon, M. I. Yoo, K. S. Sohn, J. H. Kim and In K. Han. 1997. The effect of phosphorus sources and phytase supplementation on growth performance and nutrient digestibility in weaning-growing pigs. Kor. J. Anim. Nutr. Feed. 21:363.

Kwon, K., In K. Han, K. S. Sohn, C. H. Kwon and J. H. Kwack. 1995. Effects of microbial phytase on performance, nutrient digestibility and phosphorus excretion in weaning-growing pigs fed corn-wheat-soy diets. Kor. J. Anim. Sci. 37(4):353.

Liebscher, A. 1991. Einflu ß der Futterkomponente Heulandit (Zeolith) auf Mast-und Schlachtleistung in der Geschwisterprufung. Die Bodenkultur. 42(4).

Ly J., W. E. Lon and M. Castro. 1996. N and energy balance in pigs fed suger cane molasses diets and natural zeolites from different deposits. Cuban J. Agri. Sci. 30(3):287.

Ma, M. D., W. Y. Huang, J. F. Wu and C. M Fu. 1993. Effect of adding deodorizers to diets on the performance of pigs and deodorization of pig wastes (comparison between sarsaponin and zeolite poweder). J. Chinese Society Anim. Sci. 22:232.

Mader, T. L. and M. C. Brumm. 1987. Effect of feeding sarsaponin in cattle and swine diets. J. Anim. Sci. 65(Suppl. 1):9.

Milne, T. A. and J. A. Froseth. 1982. Zeolites reduced pig scours, but didn't improve feed:gain. Feedstuffs 54(16):13.

Morel, A. 1997. Effects de l' incorporation de Deodorase dans l' aliment porc charcutier. Ph.D. Dissertation. Ecole Nationale Veterinaire d'Alfort Paris, France.

Mosenthin, R. W. C. Sauer, F. Ahrens, C. F. M. de Lange and U. Bornholdt. 1992. Effect of dietary supplements of propionic acid, siliceous earth of a combination and amino acid digestibilities and concentrations of microbial metabolites in the digestive tract of growing pigs. Anim. Feed Sci. Technol. 37:245.

Moser, R. L., S. G. Cornelius, C. D. Hagen, S. El Kandelgy and J. E. Pettigrew. 1988. Dietary additions of copper sulfate and fed alone or in combination with antibacterials, or sarsaponin for growing pig. J. Anim. Sci. 66(Suppl. 1).

Mumpton, T. A. and P. H. Fishman. 1977. The application of natural zeolites in animal science and aquaculture. J. Anim. Sci. 45:1188.

Murphy, J. 1998. Advances in swine nutrition to address nutrient management issues. Ontario Ministry of Agriculture, Food and Rural Affairs (OMFRA).

Noh, S. H., H. K. Moon, In K. Han and I. S. Shin. 1995. Effect of dietary growth promoting substances on the growth performance in pig. Kor. J. Anim. Sci. 37(1):66.

NRC. 1998. Nutrient requirements of swine (10th Ed.). National Academy Press, Washington DC., USA.

Park, H. Y., In K. Han and K. N. Heo. 1994. Effects of supplementation of single cell protein and yeast culture on growth performance in broiler chicks. Kor. J. Anim. Nutr. Feed. 18(5):346.

Pearson, G., W. C. Smith and J. M. Fox. 1985. Influence of dietary zeolite on pig performance over the liveweight range 25-87 kg. New Zealand. J. Exp. Agric. 13(2):151.

Radecki, S. V., M. R. Juhr and E. R. Miller. 1988. Fumaric and citric acids as feed additives in starter pig diets: Effect on performance and nutrient balance. J. Anim. Sci. 66:2598.

Ravindran, V. and E. T. Kornegay. 1993. Acidification of weaner pig diets: a review. J. Sci. Food Agric. 62:313.

Sadil, M., R. Wanderly and J. T. Huber. 1992. Influence of De-Ordorase on rumen fermentation and microbial protein synthesis of lactating cows. In: Biotechnology in the Feed Industry (Ed. T. P. Lyons). Alltech Technical Publications, Nicholasville, Kentucky, USA.

SAS. 1985. SAS User's Guide; Statistics. Statistical Analysis System. Inst. Inc., Cary, NC, USA.

Scipioni, R., G. Zahgini and A. Biavati. 1978. Acidified diets in early weaning piglets. Zootechn. Nutr. Anim. 4:201.

Sellier, P. 1987. Cross-breeding and meat quality in pigs. In: Evaluation and Control of Meat Quality in Pigs, (Ed. P. V. Tarrant and G. Eikelenboom). Monin, Martinus Nijhoff Publishers, Dordecht, The Netherlands. p. 329.

Sutton, A. L., K. B. Kephart, J. A. Patterson, R. Mumma, D. T. Kelly, E. Bogus, D. D. Jones and Heber. 1996. Manipulating swine diets to reduce ammonia and odor emissions. In: Proc. 1st Conf. Air Pollution from Agric. Operations. Kansas, MO., USA. p. 445.

Theilemans, M. F. and C. Bodart. 1982. La zeolite dans l'alimentation du porc en croissance-finitrion 1. Influence sur les performances zootechniques. Rev. Agr. 35:2799.

Vrzgula, L., P. Bartko, J. Blazowsky and J. Kozac. 1982. The effect of feeding clinoptilolite on the health status, blood picture and weight gain in pig. Vet. Med. 27(5):267.

Yang, C. B. 1999. Effects of Scoria on growth performance, carcass characteristics and pollutant excretion in pigs. Ph. D. Dissertation, Seoul National University, Korea.