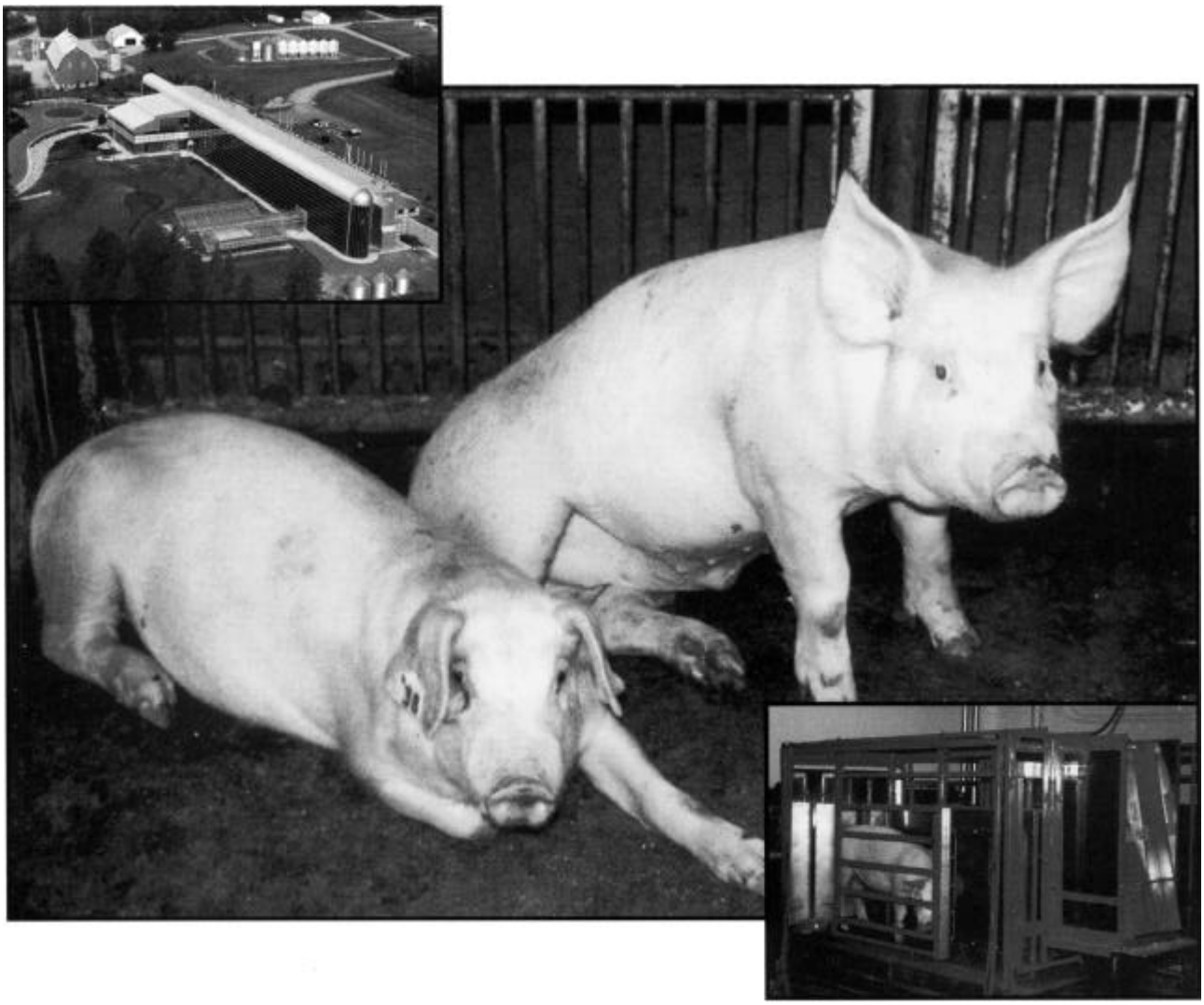
Agriculture and Agri Food Canada
Agriculture et Agroalimentaire Canada

Feeding Strategies for Minimizing Nutrient Excretion and Odours in Swine Manure



Canada

Feeding strategies for minimizing nutrient excretion and odours in swine manure

Raja R. Grandhi
Research Scientist
Manure Management

Agriculture and Agri-Food Canada
Brandon Research Centre
P.O. Box 1000A
Brandon, MB. R7A 5Y3

December 2000

Supporting Agencies:

Agriculture and Agri-Food Canada (Matching Investment Initiative)
Enquce Biochemicals Inc.
Hoffmann-La Roche Ltd.
Manitoba Pork Council
Natural Resources Canada
Saskatchewan Agriculture Development Fund
Western Grains Research Foundation
W.L.T. Distributors Inc.

"Innovating for a sustainable future by working with industry to develop and produce competitive products and processes in an environmentally sustainable manner"

Agriculture and Agri-Food Canada
Research Branch

Agriculture and Agri-Food Canada
Brandon Research Centre publication

Copies available from:
Brandon Research Centre
P.O. Box 1000A
Brandon, MB.
R7A 5Y3

Index

		Page
Introduction		4
Objectives		4
Research Findings		4
1.	Replacing soybean meal with amino acids, and supplemental Carbohydrase in Hulless-barley diets	4
2.	Hulless-barley varieties and swine manure characteristics	6
3.	Supplemental phytase and dietary ideal amino acid ratios for reduction of phosphorus and nitrogen excretion	6
4.	Feed and manure additives for reduction of odours in swine manure	8
	A. Yucca plant extracts	8
	B. Qzyme extract	9
5.	Effect of omitting some supplemental amino acids for replacing protein supplements to reduce nitrogen excretion	9
	A. Hulless-barley diets	9
	B. Covered-barley diets	10
Summary		11
Acknowledgments		11
Selected References		12

Introduction

Swine production is a significant part of animal agriculture in Canada, Abolition of grain transportation subsidies and a desire to develop more value-added economies have rapidly increased swine production in western Canada. Large swine production units close to the rural and urban population centres have raised serious environmental concerns about the potential for water and air pollution from excess nitrogen (N), phosphorus (P), and odours associated with swine manure. Movement of excess ammonia N, nitrates and P into waterways from manure storage or heavily fertilized soils is harmful to human health, and also to fish and aquatic ecosystems. Swine manure can be a good fertilizer for crop production because of its nutrient content of nitrogen, phosphorus, potassium and other minerals. However, large swine production units with a limited land base have a serious problem in effective utilization and/or disposal of manure. The distribution of liquid manure to other areas is not economical because of high transportation costs. The new environmental regulations require nutrient management plans for swine farms when the production exceeds set limits. These concerns may restrict future growth of the swine industry.

Agriculture and Agri-Food Canada, Brandon Research Centre initiated research in 1997 to develop an effective and economical means of utilizing swine manure with minimum adverse impact on the environment, Feeding strategies were developed using covered-barley (CB) or hulless-barley (HB) based swine diets, commonly used in western Canada, with supplemental amino acids, enzymes, and feed additives for minimizing nutrient excretion and odours in manure. Pigs used in these studies were housed and managed according to the Canadian Council on Animal Care guidelines (1993).

Objectives

This research was mainly focussed to develop comprehensive feeding strategies to minimize nutrient excretion and odours in swine manure. The specific areas of research were: 1) to determine the effect of replacing soybean meal with amino acids in HB diets on the excretion of N and dry matter in manure while maintaining the optimal performance of lean genotype pigs; 2) to determine the effect of feeding different varieties of HB on swine manure characteristics and on digestible energy; 3) to determine the effects of supplemental phytase and dietary ideal amino acid ratios in CB and HB diets on excretion of P and N in manure, 4) to determine the efficacy of feed and manure additives (Yucca plant extracts and Qzyme) for reduction of odours in swine manure; and 5) to determine the feasibility of omitting some expensive supplemental amino acids for replacing soybean meal in HB or CB diets to optimize the reduction of N excretion in manure without compromising the performance of lean genotype pigs.

Research Findings

1. Replacing soybean meal with amino acids, and supplemental carbohydrase in HB diets for reduction of manure dry matter and nitrogen

In western Canada, HB is commonly used in swine diets because of its relatively high energy, protein and amino acid content which can reduce the cost of protein supplements in diets. A low proportion of hulls in HB compared to CB results in less manure dry matter output, which is an important environmental benefit. Increased N excretion is a result of excess dietary protein or an imbalance of amino acids. Nutritional strategies to minimize N and dry matter excretion in swine manure include accurate dietary supplementation of amino acids to replace dietary protein supplements, and improvement of nutrient digestibility with enzymes.

Two experiments were conducted, using a total of 224 crossbred pigs. In Experiment 1, Duroc x Yorkshire pigs were used whereas, in Experiment 2, crossbred pigs from a commercial source were used. The experimental diets were 1) CB control diet, 2) HB *(Ch Condor)* diet, 3) same as diet 2 except the soybean meal was replaced by supplemental amino acids (lysine, threonine,

methionine and tryptophan to provide ideal amino acid ratios, and 4) same as diet 3 with supplemental carbohydrase (Ronozyme ™ W), with a combination of xylanase and B-glucanase activities. All diets were fed as pellets ad libitum with free access to drinking water. Nutrient balance studies were conducted, using gilts during the finisher period. A total collection of faeces and urine (through Foley catheters) for four 24-h periods was analysed to determine the digestibility, retention and excretion of dry matter, energy and N in manure.

The results (Table 1) indicated that the growth rate was similar between CB and HB diets. Supplemental amino acids or carbohydrase did not improve the growth rate for HB diets, Pigs fed HB diets had superior feed conversion efficiency compared to CB diet. Supplemented amino acids and carbohydrase improved ($P < 0,05$) feed conversion efficiency. Carcass index values were not different among the diets, The digestibility of dry matter and energy was higher for HB than CB diet. Feeding HB diets decreased the faecal dry matter excretion by 31.6%, and this allows manure from more pigs to be spread on same land base. Replacing soybean meal with amino acids decreased N excretion in manure by 22.5%, ammonia production by 30% and hydrogen sulfide by 60%.

Conclusions: Feeding HB decreases fecal dry matter excretion compared to CB diets. Replacing soybean meal with amino acids in HB diets decreases N excretion in manure. This allows large swine production units to utilize more manure on a limited land base with minimum impact on environment. The reduction of N,

Table 1. Growth performance, carcass index, and nutrient excretion in pigs fed HB diets with supplemental amino acids and carbohydrase (20 to 105 kg)

Diet[z]	1	2	3	4	Significance
Average daily gain (kg/d):					
Grower	0.78	0.78	0.82	0.82	NS
Finisher	0.91	0.88	0.88	0.90	NS
Combined	0.84	0.83	0.85	0.86	NS
Gain to Feed ratio:					
Grower	0.431 ab	0.421 a	0.447bc	0.454c	
Finisher	0.295a	0.303a	0.302a	0.323b	
Combined	0.348a	0.352a	0.359a	0.374b	
Carcass Index	108.4	106.5	108.0	108.7	NS
Plasma urea nitrogen (mg/dL)	13.5	12.6	12.2	11.9	NS
Dry matter:					
Digestibility (%)	83.7a	88.9b	89.2b	89.4b	
Faecal excretion (g/d)	383.7a	262.3b	256.9b	247.8b	
Energy digestibility (%)	84.1 a	87.8b	89.2b	89.5b	
Nitrogen excretion (g/d):					
In feces	10.2	10.5	7.7	6.3	NS
In urine	12.9	17.2	13.9	14.6	NS
Total	23.2	27.7	21.6	20.9	NS

z Diet: 1 = CB control diet; 2 = HB diet; 3 = Same as diet 2 except the soybean meal was replaced by supplemental amino acids (lysine, threonine, methionine and tryptophan), 4 = Same as diet 3 plus carbohydrase.
NS = not significant; * = significant ($P < 0.05$)
Means followed by different letters are significantly different ($P < 0.05$).

ammonia, and hydrogen sulfide in manure also help to reduce the odour intensity in swine buildings, and during the storage and spreading of manure.

2. Hulless-barley varieties and swine manure characteristics

Energy utilization from different HB varieties currently grown in western Canada may vary because of the differences in their nutrient composition. Increase in digestibility of dry matter and energy would be very beneficial from both feed utilization efficiency and environmental stand point, Feeding *Falcon* variety of HB was reported to cause "sticky faeces" in pigs which may result in sanitation problems in swine buildings, It is not known whether feeding any other HB varieties cause similar manure handling problems.

Commonly grown HB varieties - Condor; *CDC-Buck, Falcon, CDC-Gainer,* and *AC-Bacon* were compared to the CB control diet to determine digestible energy, faecal excretion of dry matter and manure characteristics in a nutrient balance study. The viscosity of faecal sample extracts was measured, using a Brookfield LVDVII+ cone/plate viscometer with a CP40 spindle. The results (Table 2) indicated that all HB diets had higher digestible energy and reduced faecal dry matter excretion than the CB control diet. The physical characteristics - appearance, consistency, texture etc. of faecal samples were not different among HB diets. The stickiness score was relatively higher for all HB varieties than CB diet. The viscosity measurements of faecal samples from the diets of *Condor; CDC-Buck,* and *Falcon* were higher than the CB diet.

Conclusions: The digestibility of dry matter and energy was higher in all the five HB varieties than CB evaluated in this study. The physical characteristics of swine manure for all HB diets were similar except the viscosity was higher for *Condor, CDC-Buck* and *Falcon* varieties.

3. Supplemental Phytase and dietary ideal amino acid ratios for reduction of phosphorus and nitrogen excretion in swine manure

The second major nutrient in swine manure is P, and movement of excess P into waterways from manure storage or heavily fertilized soils causes eutrophication. Approximately 60 to 75% of P in cereal grains and protein supplements is organically bound in the form of phytate which is poorly digested by pigs. Phytate also combines with protein to form phytate-protein complex thus making the protein less available. Pig diets are usually supplemented with inorganic P for normal growth performance. Phytase enzyme was shown to improve phytate P utilization in corn-soybean meal diets thus reducing the need for inorganic P supplementation in diets resulting in less P excretion in manure. The effect of phytase on phytate P utilization in HB or CB swine diets is not known.

Table 2. Nutrient digestibility and swine manure characteristics in gilts fed different varieties of hulless-barley diets during the finisher period

	Energy digestibility (%)	Dry matter excretion (%)	Stickiness Score	Viscosity (cP)
Covered barley	83.9a	16.3a	4.9	13.3
Hulless-barley varieties:				
Condor	87.2b	12.2b	5.5	23.2
CDC-Buck	88.0b	11.7b	5.3	24.4
Falcon	88.7b	10.6b	5.9	18.1
CDC-Gainer	86.9b	12.9b	6.5	9.6
AC-Bacon	87.0b	13.1 b	6.7	11.1

Means followed by different letters are significantly different ($P < 0.05$)

A total of 144 crossbred pigs were used to determine the effects of supplemental Ronozyme-phytase (Hoffmann-La Roche Ltd.) at 500 units per kg and reducing dietary protein with amino acids to provide ideal amino acid ratios in CB and HB diets on excretion of P and N in swine manure. All diets were fed as pellets ad libitum with free access to drinking water. Nutrient balance studies were conducted during both grower and finisher periods to determine the digestibility and retention of P and N, and the quantity of their excretion in manure. The results (Table 3) indicated that replacing inorganic P in diets with phytase did not adversely affect growth rate or feed conversion efficiency. Supplemental phytase and amino acids improved feed conversion efficiency. Carcass index was not different among the diets. The plasma P levels were relatively higher in pigs fed supplemental phytase indicating that phytase enzyme increased the dietary phytate P availability, and no P deficiency symptoms were observed. Supplemental amino acids decreased plasma urea nitrogen indicating an improvement in N utilization.

The results of nutrient balance studies (Table 4) indicated that during the grower period, phytase supplementation reduced the excretion of P by 26.8% in manure. There was no further reduction of P excretion by amino acid supplementation. Phytase supplementation also reduced the excretion of N in manure by 8.0%, and it was further reduced by 23.2% with amino acid supplementation. During the finisher period, phytase supplementation reduced the excretion of P by 25.9%, and amino acid supplementation further reduced it by 44.2%. Phytase supplementation reduced the excretion of N by 11.3%, and amino acid supplementation further reduced it by 28.6% in manure. A positive response in N retention with supplemental phytase indicated that the phytate-protein complexes are being acted upon by the phytase enzyme releasing the protein for digestion. Omitting the inorganic P in diets reduced daily P intake by about 1,0 and 1.5 g/kg diet during the grower and finisher periods, respectively. The extra cost of supplemental phytase and amino acids can be partially recovered by the savings in omitting inorganic P and protein supplements in diets and improved feed conversion efficiency.

Conclusions: Supplemental phytase replaces the need for inorganic P in diets, and it decreases the P

Table 3. Growth performance, carcass index, and blood serum levels of P and urea nitrogen in pigs fed supplemental phytase and amino acids (20 to 105 kg)

	Barley		Diet [z]			Significance	
	CB	HB	1	2	3	Barley	Diet
Average daily gain (kg/d):							
Grower	0.68	0.71	0.69	0.69	0.70	NS	NS
Finisher	0.89	0.97	0.92	0.95	0.93	NS	NS
Combined	0.78	0.83	0.79	0.80	0.81	NS	NS
Gain/feed:							
Grower	0.437	0.461	0.447	0.445	0.457	*	NS
Finisher	0.340	0.371	0.341 a	0.357ab	0.368b	*	*
Combined	0.380	0.408	0.383a	0.394ab	0.405b	*	*
Carcass Index	109.3	107.6	108.2	108.1	108.9	NS	NS
Serum levels (mg/dL):							
Phosphorus	7.3	8.9	7.9	8.4	7.9	*	NS
Urea nitrogen	14.5	15.0	15.6a	15.9a	12.7b	NS	*

[z] Diet: 1 = Control; 2 = Same as diet 1 except the inorganic P was replaced with supplemental phytase; 3 = Same as diet 2 with reduced soybean meal, and supplemental amino acids.
NS = not significant; * = significant at $P < 0.05$.
Means followed by different letters are significantly different ($P < 0.05$)

Table 4. Phosphorus and nitrogen excretion in gilts fed supplemental phytase and amino acids

	Grower period			Finisher period		
Diets [z]:	1	2	3	1	2	3
Phosphorus:						
Intake (g/d)	7.1 a	5.5b	5.4b	11.2a	8.8b	8.3b
Retention (%)	41.1	44.4	47.1	31.3a	36.7a	49.0b
Excretion (g/d)						
In feces	4.11 a	3.01 b	2.86b	7.18a	5.22b	4.25b
In urine	0.02	0.02	0.02	0.50a	0.44a	0.02b
Total	4.14a	3.03b	2.88b	7.68a	5.66b	4.27b
Nitrogen:						
Intake (g/d)	43.5	39.4	37.2	49.3	44.2	45.4
Retention (%)	48.4a	47.8a	53.9b	46.1 a	47.5a	57.8b
Excretion (g/d)						
In feces	7.4	5.9	6.3	8.9	7.3	6.5
In urine	15.0a	14.7a	10.9b	17.8	16.3	12.5
Total	22.4a	20.6a	17.2b	26.7	236	19.0

z Diet: 1 = Control; 2 = Same as diet 1 except the inorganic P was replaced with supplemental phytase at 500 FTU/kg diet; 3 = Same as diet 2 with reduced soybean meal, and supplemental amino acids.
Means in grower and finisher periods followed by different letters are significantly different ($P < 0.05$).

excretion in manure. A combination of phytase and ideal dietary amino acid ratios decreases both P and N excretion. If the environmental benefits caused by the reduction of P and N excretion are taken into consideration, then supplementation of phytase and amino acids to CB or HB diets will be economically sound and environmentally advantageous for effective swine manure management and sustainable swine production.

4. Feed and manure additives for reduction of odours in swine manure

The major objection for the swine production units near urban or rural population centres focus on the odours associated with swine manure. Certain management practices, such as proper ventilation, dust control, and sanitation in swine buildings, covering of manure storage tanks and lagoons with straw and other materials, and injection of manure into the soil on less windy days etc. have decreased the odour problems to a varying degree. However, the root cause of odour in swine manure needs to be addressed for an effective solution. The odour causing agents are of very complex in nature, and there is a lack of appropriate evaluation techniques for measurement and standardization of odours. Although ammonia and hydrogen sulfide are considered as part of swine manure odour, they are poorly related to odour intensity in swine buildings. Certain feed additives like Jerusalem artichoke, zeolite, and yucca plant extracts in corn-soybean meal swine diets appeared to control odours in swine manure but their efficacy in barley based diets was not reported.

A. Yucca plant extracts (Biopowder-3000 and Bioliquid-3000)

Yucca *Schidigera* plant is grown in desert areas of Mexico and California, and the extracts of these plants are known for their effectiveness in reduction of ammonia, mainly in poultry houses. Saponins in the Yucca plant extracts were the active ingredients, and their mode of action appears to be in the binding of ammonia. The efficacy of Yucca plant extract products (Biopowder-M and Bioliquid-300) for reducing odours from swine manure was studied using a total of 64 crossbred pigs. Results indicated that feeding Biopowder-M in CB or HB diets

did not influence average daily gain or feed conversion efficiency of pigs. However, it had some beneficial effect on average daily gain (6.0%) and feed conversion efficiency (8.0)% of gilts. Feeding Biopowder-M did not influence the volatile fatty acids (butyric, propionic, acetic, and valeric) and Bifido bacterial counts in fecal samples. Treating liquid manure with Bioliquid-3000 reduced percent solids and ammonia nitrogen in stored manure. The concentrations of ammonia, hydrogen sulfide and mercaptans in stored manure were not different among diets. The odour intensity evaluation by trained panel members indicated that adding Bioliquid-3000 to manure from pigs fed Biopowder-M appeared to decrease (P = 0.06) the odour intensity of swine manure.

Conclusions: Yucca plant extract as feed additive had limited beneficial effect on growth performance of gilts, and in combination with manure additive, it tends to decrease the odour intensity of swine manure.

B. Efficacy of Qzyme for reduction of odours in swine manure

Qzyme, a plant extract product developed at the Agriculture and Agri-Food Canada's Saskatoon Research Centre in collaboration with Enquce Biochemicals, Kamsack, Saskatchewan, contains 49% saponin compared to 6% saponin in Biopowder-M. The efficacy of Qzyme as a feed additive (0, 6, 12, and 24 g per tonne of feed) in CB based diets on growth performance, carcass merit, nutrient utilization and odour control in swine manure was studied, using a total of 64 crossbred pigs. Results indicated that feeding Qzyme at increasing levels did not influence average daily gain, feed conversion efficiency or carcass quality. Average feed intake of pigs was not different among the treatment diets indicating that there were no feed refusal problems with higher dietary levels of Qzyme. The digestibility and retention of dry matter, energy and nitrogen were not different among the diets indicating that feeding Qzyme at increasing levels did not influence the nutrient metabolism. The ammonia levels and percent solids in the manure were not different among the diets. The total nitrogen, ammonium nitrogen, and organic nitrogen concentrations in manure were Qzyme levels but the odour intensity was not different among the diets.

Conclusions: Qzyme did not influence the growth performance or nutrient utilization of pigs, and had no effect on manure odour.

5. Effect of omitting some supplemental amino acids for replacing protein supplements to reduce nitrogen excretion in swine manure

Our research has shown that N excretion can be decreased by replacing soybean meal in HB diets with lysine, threonine, methionine and tryptophan according to an ideal amino acid ratios. Supplemental amino acids increase the feed cost because some of the synthetic amino acids are expensive at the present time. The feasibility of omitting some amino acids (threonine, tryptophan or methionine) for replacing protein supplement in HB and CB based grower and finisher diets on pig performance and N excretion in manure was studied in two experiments, using a total of 320 crossbred lean genotype pigs.

A. Hulless-barley diets

Results (Table 5) indicated that, during the grower period, amino acid supplementation to HB diets improved the growth rate by 11 % and feed conversion efficiency by 10% compared to HB control diet. Replacing soybean meal in HB diets with lysine, threonine, methionine and tryptophan maintained the growth rate and feed conversion efficiency to the same level as amino acid supplemented diet. Omitting threonine and tryptophan in diet 4 or omitting threonine, tryptophan and methionine in diet 5 decreased the growth rate by 16.5% than diet 3 during the grower but not finisher period indicating that all the amino acids are required to effectively replace the soybean meal protein supplement in grower diets. Omitting some of the amino acids in diets 4 and 5 decreased the feed conversion efficiency by 13.5% during the grower period and 10% during the finisher period than diet 3. Pigs fed diet 3 had higher carcass index compared to other diets indicating that higher

Table 5. Growth performance and N excretion in pigs fed HB diets with different combinations of supplemental amino acids (20 to 105 kg)

Diets [z] :	1	2	3	4	5	Significance
Ave. daily gain (kg)						
Grower	0.84	0.95	0.91	0.76	0.76	NS
Finisher	0.99	1.06	1.05	1.13	1.13	NS
Combined	0.91	1.01	0.98	0.93	0.93	NS
Gain to Feed ratio						
Grower	0.462a	0.516b	0.505b	0.437c	0.432c	*
Finisher	0.341 a	0.373abd	0.379bd	0.419c	0.395cd	*
Combined	0.389ac	0.429b	0.428b	0.426b	0.412bc	*
Carcass Index	107.7a	107.8a	109.5b	106.7a	107.3a	*
Plasma						
urea nitrogen (mg/dL)	19.8a	16.6b	15.3bc	15.8bc	14.6c	*
Nitrogen excretion (g/d):						
In feces	7.6	7.1	6.9	7.1	7.2	NS
In urine	19.5a	15.4b	8.0c	8.2c	8.5c	*
Total	27.1 a	22.5b	14.9c	15.3c	15.7c	*

[z] Diet: 1 = HB control diet; 2 = Same as diet 1 with supplemental amino acids according to 1998 NAS-NRC recommended levels; 3 = Same as diet 2 except the soybean meal was replaced with supplemental amino acids (lysine, threonine, tryptophan and methionine); 4 = Same as diet 3 with threonine and tryptophan omitted; 5 = Same as diet 3 with threonine, tryptophan and methionine omitted.
NS = not significant; * = significant ($P < 0.05$)
Means followed by different letters are significantly different ($P < 0.05$)

urea nitrogen concentration for diets 3, 4 and 5 than diet 2 indicated an improved N utilization. Feeding diet 3 in which soybean meal was replaced by all four amino acids decreased N excretion by 33.8% than diet 2. Feeding diets 4 and 5 also decreased N excretion by 32.0 and 30.2% respectively compared to diet 2.

Conclusions: Threonine, tryptophan or methionine can be omitted for replacing soybean meal in HB diets to decrease feed cost and N excretion in manure with a minimal adverse effect on pig performance.

B. Covered-barley diets

Results (Table 6) indicated that amino acid supplementation to CB diets improved ($P < 0.05$) the growth rate and feed conversion efficiency than CB control diet. Replacing soybean meal in CB diets with lysine, threonine, methionine and tryptophan did not maintain the growth rate and feed conversion efficiency to the same level as diet 2 indicating that some other amino acids may be limiting. Omitting threonine and tryptophan in diet 4 or omitting threonine, tryptophan and methionine in diet 5 decreased the growth rate and feed conversion efficiency during both grower and finisher periods. The carcass index was not different among the diets. The plasma urea nitrogen was lower only in diet 3 than diet 2 indicating an improved N utilization. Feeding diet 3 in which soybean meal was replaced by all four amino acids decreased N excretion by 34.7% than diet 2. Feeding diets 4 and 5 also decreased N excretion by 10.9% and 7.5% respectively compared to diet 2.

Conclusions: Threonine, tryptophan or methionine can not be omitted to replace soybean meal in CB diets for reduction of N excretion because of severe adverse effect on pig performance.

Table 6. Growth performance and N excretion in pigs fed CB diets with different combinations of supplemental amino acids (20 to 105 kg)

Diets [z] :	1	2	3	4	5	Significance
Ave. daily gain (kg)						
Grower	0.83a	0.96b	0.75c	0.57d	0.55d	*
Finisher	1.07a	1.18b	1.03a	0.84c	0.81 c	*
Combined	0.94a	1.06b	0.87c	0.68d	0.65d	*
Gain to Feed ratio						
Grower	0.417a	0.516b	0.434a	0.286c	0.302c	*
Finisher	0.374a	0.394a	0.386a	0.320b	0.298b	*
Combined	0.393a	0.444b	0.407a	0.300b	0.298b	*
Carcass Index	106.3	107.8	105.9	106.1	105.8	NS
Plasma						
urea nitrogen (mg/dL)	14.3a	11.6b	6.5bc	9.5bd	11.2b	*
Nitrogen excretion (g/d):						
In feces	7.7	7.1	6.7	7.0	7.6	NS
In urine	10.8a	7.6b	2.9c	6.1 b	6.0b	*
Total	18.5a	14.7ab	9.6c	13.1 be	13.6bc	*

[z] Diet: 1 = HB control diet; 2 = Same as diet 1 with supplemental amino acids according to 1998 NAS-NRC recommended levels; 3 = Same as diet 2 except the soybean meal was replaced with supplemental amino acids lysine, threonine, tryptophan and methionine; 4 = Same as diet 3 with threonine and tryptophan omitted; 5 = Same as diet 3 with threonine, tryptophan and methionine omitted.
NS = not significant; * = significant ($P < 0.05$)
Means followed by different letters are significantly different ($P < 0.05$)

Summary

Feeding hulless-barley in swine diets decreased faecal dry matter excretion in manure resulting in less manure production for storage and disposal, and this allows manure from more pigs to be spread on same land base. Protein supplements can be completely replaced in HB diets with amino acids to decrease N excretion and ammonia production. Supplemental phytase completely eliminate the need for inorganic P in HB or CB based diets for normal pig performance with a reduction of P excretion in manure. A combination of phytase and amino acids decreased the excretion of both P and N in manure, and this allows the utilization of more manure on a limited land base. These feeding strategies can be used to minimize the adverse effects of swine manure on environment and for sustainable swine production.

Acknowledgments

Thanks to Mr. F. Willms, D. Sykes and staff for taking care of experimental animals, to Mr. R Westwood, Mrs. G.I. Turner, and Ms. N. Thiry for technical help, to Dr. M. Monreal for fecal bacterial counts, and to Mrs. S. Ramsay and Dr. R. Kucey for review of the manuscript.

Selected References

Agricultural Research Council (ARC), 1981. The Nutrient Requirements for Farm Livestock 3. Pigs. Commonwealth Agriculture Bureau, Slough, UK.

Bruchem, J.V. and Tamminga, S. 1997. Sustain ability and the future of animal production: Options for environmental tuning of the systems in The Netherlands for nitrogen, phosphorus and potassium. Pages 48-67. *in* Scott, S.L. and Zhao, X. eds. Proceedings of the Canadian Society of Animal Science meetings. Montreal, Quebec.

Canadian Council on Animal care. 1993. Guide to the care and use of experimental animals. Volume 1. 2nd edition. ed. E.D. Olfert, B.M. Cross, and A.A. McWilliam. ISBN: 0-919087-18-3.

Grandhi, R.R. 2000. Effect of dietary ideal amino acid ratios, and supplemental carbohydrase in hullessbarley based diets containing no protein supplement on pig performance and nitrogen excretion in manure, Canadian Journal of Animal Science : (In press).

Grandhi, R.R. 2000. Effect of dietary ideal amino acid ratios, and supplemental carbohydrase in hullessbarley based diets containing no protein supplement on pig performance and nitrogen excretion in manure. Canadian Journal of Animal Science : (In press).

Grandhi, R.R. 2000 Supplemental phytase and ideal dietary amino acid ratios in covered and hulless barley based diets on pig performance and excretion of phosphorus and nitrogen in manure. Canadian Journal of Animal Science : (In press).

Jongbloed, A.W. Lenis, N.P. 1997. Animal production and the environment. Pages 27-47. In Scott, S.L. and Zhao, X. eds. Proceedings of the Canadian Society of Animal Science meetings. Montreal, Quebec.

Kerr, B.J. and Easter, R.A. 1995. Effect of feeding reduced protein, amino acid supplemented diets on nitrogen and energy balance in grower pigs. Journal of Animal Science. 73: 3000-3008

Kornegay, E.T. 1996. Nutritional, environmental and economic considerations for using phytase in pig and poultry diets, Pages 277-302 *in* E.T. Kornegay, ed, NUTRIENT MANAGEMENT OF FOOD ANIMALS. Lewis Publishers, Bocaraton, FL, USA.

Leneman, H., Giesen, G.W.J. and Berentsen, P.B.M. 1993. Costs of reducing nitrogen and phosphorus emissions on pig farms in The Netherlands. Journal of Environmental Management. 39: 107-119.

National Academy of Sciences-National Research Council (NAS-NRC). 1998. Nutrient Requirements of swine. loth revised edition,. NAS-NRC, Washington, DC.