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The Impact of Individual Daily Feeding on Animal Performance and Excretion of Nitrogen and Phosphorous in Growing Pigs

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Abstract: The effect of feeding growing pigs with a traditional three-phase or with an individual daily feeding system on growth performance, the excretion of nitrogen and phosphorus was studied in two pens of twenty pigs each. There is no significant difference in average daily feed intake between these two groups ($p = 0.11$) but the average daily lysine intake is lower significantly (-21.9%) in individual daily feeding group ($p<0.001$). Compare to the three-phase groups, the protein intake during the experiment period was 13.4% less in the pigs fed with individual daily diet ($p = 0.01$), however with a greater ADG (+5.3%, $p = 0.29$). Individual daily feeding pigs reduced nitrogen and phosphorus intake, respectively by 17.0 and 9.7% and the corresponding excretions were reduced, respectively by 40.5 and 31.2%. In conclusion, the individual daily feeding method is an effective method that can reduce the intake of nitrogen and phosphorus and then reduce the nitrogen and phosphorus excretion and the feed cost.

Key words: Individual daily feeding, traditional three-phase feeding, growing pigs, nitrogen, phosphorus intake, feed cost

INTRODUCTION

Environmental pollution is an increasing concern in the pig production, mainly due to nitrogen and phosphorus in the slurry. Nitrogen excretion can be reduced by matching the protein/amino acids content of the diet as close as possible to the pigs requirement (Jongbloed and Lenis, 1992; Han, 1998; O'Connell *et al.*, 2005). Growing-finishing pigs are usually penned in groups and fed *ad libitum* with the diet that meet the daily amino acid requirement of the average pigs within the group.

However, due to the nutrient requirements show large variation between pigs of a given population (Brossard *et al.*, 2007; Pomar, 2007). This feeding system results in underfeeding of amino acids to some pigs which decrease performance and overfeeding of amino acids to other pigs which increase the nutrient excretion. Moreover, in the current nutritional programs most of the pig producers tend to feed pigs by two or three diets throughout all the growing-finishing period (Lenis, 1989; Latimier and Chatelier, 1992) which have an oversupply problem due to the nutrient requirements change over time following the individual patterns (Campbella *et al.*, 1988). Increasing the number of diets in phase feeding programs can reduce overall daily lysine intake and improved lysine conversion ratio and no effect on carcass characteristics or carcass lysine conversion ratio, comparing with a single diet (Montminy *et al.*, 2005; O'Connell *et al.*, 2005; Pomar, 2007). However, increasing the number of feeding phases will increase the cost of feed storage and management.

Precision feeding is proposed as an essential approach to improve the utilization of dietary nutrients and thus reduce feeding costs and nutrient excretion. Precision feeding involves the use of feeding techniques that allow the right amount of feed with the right composition to be provided at the right time to each pig in the herd. In the represent study, the growing pigs were fed precisely by using the new Automatic and Intelligent Precision Feeder (AIPF) which developed, especially for this project (Pomar *et al.*, 2009). The purpose of this study is assessing the pigs growth performance and the excretion of nitrogen and phosphorous in animal experimental conditions fed with individual daily diets compared to the traditional three phase system.

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MATERIALS AND METHODS

Animals: Twenty barrow piglets weighing an average of 18.7±2.5 kg were transported to the research center for experiment. The animals were healthy and they were kept in groups on arrival and fed a commercial feed meet the early maintenance and growth requirement of animals with high growth potential.

About 1 week after their arrival, the piglets were assigned to two groups of ten pigs each. Pigs were fed for 28 consecutive days starting at 28 kg BW. During experimental period, water and feed were available *ad libitum* continuously.

Diets: Four premixes were used in this experiment (Table 1). Premix A_1 and A_2 as well as premix B_1 and B_2 were only different in the level of added lysine. Premixes were formulated to have 10.05 MJ of net energy per kg of feed. Feed was formulated using the tabular Apparent Ileal Digestible (AID) amino acids values and the amino acid contents were based on the tabular amino acid content of the ingredients from INRA (Sauvant *et al*., 2004). The Crude Protein (CP) contents of these premixes were analyzed and the amino acid contents were adapted proportionally to the analyzed CP contents of the premixes. Premix A_1 was formulated for satisfying the most demanding pigs at the beginning of the growing period and the B_1 for low demanding pigs at the end of the growing period. Dietary Phosphorous (P) and Calcium (Ca) requirements were estimated according to (Jondreville and Dourmad, 2005). The Ca:P ratio was maintained constant in all diets. Premixes were steam-pelleted at 4 mm. The four premixes were blended to constitute the experimental diets using the new Automatic and Intelligent Precision Feeder (AIPF), especially developed for this project (Pomar *et al*., 2009). In the traditional three-phase feeding system, the dietary was mixed by 90% A_1 and 10% B_1.

Table 1: The composition and nutrient levels of four experimental diets (as fed basis)

	Experimental diets			
Ingredients (g kg^{-1})	A_1	A_2	B_1	B_2
Wheat	182.000	181.18	509.87	509.870
Corn	391.800	398.35	271.45	273.800
Barley	100.000	100.00	150.00	150.000
Wheat middlings	100.000	100.00	45.00	44.730
Dehulled soybean meal (48%)	182.120	182.12	-	-
Limestone	12.510	12.52	10.34	10.350
$CaHPO_4$	7.550	7.54	2.03	2.020
NaCl	5.980	5.98	5.73	5.720
DL-methionine	1.610	1.60	-	-
L-lysine HCl	5.680	-	2.27	0.200
L-threonine	1.930	1.92	-	-
L-tryptophane	0.370	0.36	-	-
Phyzyme (U.P.)	750.000	750.00	750.00	750.000
Premix[1]	5.000	5.00	5.00	5.000
Nutrient levels (%)[2]				
Crude protein	16.990	16.500	9.780	9.600
Lysine	1.238	0.797	0.485	0.324
Methionine	0.429	0.429	0.166	0.166
Tryptophane	0.244	0.245	0.110	0.110
Threonine	0.798	0.799	0.324	0.324
Digestible lysine	1.105	0.663	0.402	0.241
Digestible methionine	0.388	0.389	0.142	0.142
Digestible tryptophane	0.199	0.199	0.079	0.079
Digestible threonine	0.685	0.685	0.259	0.260
NE (MJ kg^{-1})	10.050	10.050	10.050	10.050
Calcium	0.730	0.730	0.500	0.500
Total phosphorous	0.560	0.560	0.360	0.360

[1]A_1 and A_2 should provide per kg of premix A_1 and A_2 at least the following nutrients: VA 9900 IU; VD 990 IU; VE 30 IU; VK (menadione) 0.78 mg; VB_{12} 0.02 mg; niacin 14 mg; pantothenic acid 11.57 mg; VB_6 0.83 mg; riboflavin 3.17 mg; thiamine 1.26 mg; choline 480 mg; Cu 121 mg; I 0.29 mg; Fe 361 mg; Mn 85 mg; Se 0.3 mg; Zn 164 mg; B_1 and B_2 should provide per kg of premix B_1 and B_2 at least the following nutrients: VA 7500 IU; VD 750 IU; VE 22 IU; VK (menadione) 0.68 mg; VB_{12} 0.02 mg; niacin 11 mg; pantothenic acid 10.5 mg; VB_6 0.4 mg; riboflavin 2.68 mg; thiamine 0.99 mg; choline 400 mg; Cu 107 mg; I 0.24 mg; Fe 247 mg; Mn 65.5 mg; Se 0.3 mg; Zn 133 mg; [2]The total values and the apparent ileal digestible values of amino acids were calculated according to the tabular amino acid contents of the ingredients and the apparent ileal digestible AA coefficient of INRA

Experimental treatment: Ten pigs had free access to one AIPF which were able to provide the right feed to each pig. The other ten pigs were fed traditionally with the same dietary lysine level of 1.03% lysine concentration according to the results of Hauschild *et al*. (2010) by using one automated feeder (IVOG-station, Insentec, Marknesse, Netherlands).

In the individual feeding group, the individual daily Apparent Ileal Digestible Lysine (AIDLys) requirements (g day^{-1}) were calculated assuming that maintenance requirements were of $0.036{*}BW^{0.75}$ (Fuller *et al*., 1989), that 16% of the Body Weight (BW) gain was protein (De Lange *et al*., 2003) that 7% of the body protein was lysine (Mahan and Shields Jr., 1998) and that the efficiency for lysine retention from dietary AIDLys was of 72% (Mohn *et al*., 2000).

Other amino acid requirements were calculated based on the ideal protein concept (NRC, 1998). Vitamins, trace minerals and all other nutrients met or exceeded the NRC recommended levels. Every day, the required concentrations of AIDLys and other nutrients of individual pigs were obtained by mixing the four experimental premixes.

Dietary AIDLys concentration was estimated daily dividing the estimated requirement (g day^{-1}) by the expected feed intake (FI, kg day^{-1}). Thus, the AIPF analyzed at the end of each day historical FI and growth data and then estimated the expected daily FI, BW and ADG of the coming day. These next day expected FI, BW and ADG was obtained by extrapolating from a polynomial quadratic relationship updated daily from up-to-date observed values and time. FI was collected daily while pigs were weighted every week. Daily AIDLys requirement was estimated for each pig and the pigs were then fed according to these requirements. All these calculations were made using the REG procedure and the programming capabilities of SAS (SAS Inst. Inc., Cary, NC).

Measurements: Individual daily FI was measured throughout this experiment using the AIPF. The FI of traditional three-phase feeding method was measured throughout the experiment using the automated feeder recording system. The animals were weighted individually every week.

Backfat thickness and muscle depth were measured at the beginning and at the end of the experiment with a B-mode ultrasound device (Ultrascan 50, Alliance Medicale inc., Canada; 120 mm, 3.5 MHz) at the 3rd and 4th last ribs, 7 cm off the mid-line. Total body fat and body lean tissues were estimated by Dual-energy X-ray Absorptiometry (DXA) using a densitometer (DPX-L, Lunar corp., Madison, WI). Total body protein and body lipids masses were obtained by converting the muscle and fat values obtained with DXA into their chemical equivalents (Pomar and Rivest, 1996).

Calculations: Daily lysine intake was calculated for each pig by adding the amount of lysine provided by each premix which was obtained by the product between each premix intake and the corresponding AIDLys content. Total period weight gain was obtained by difference between weights measured at the beginning and end of the experiment.

Total period Protein Deposition (PD, kg) and total Lipid Deposition (LD, kg) were obtained by difference between body protein and lipid masses estimated at the beginning and end of the experiment. ADFI (kg day^{-1}), average daily lysine intake (ADLysI, g day^{-1}), ADG (kg day^{-1}) were individually calculated by dividing the corresponding variables by the 28 days experimental period while Feed Conversion Ratio (FCR) is the ratio between ADFI and ADG.

Statistical analysis: The experiment treatment was the unit. The animal performance data was analyzed with the Mixed procedure of SAS (SAS Inst. Inc., Cary, NC). Two means are considered different when $p<0.05$.

RESULTS AND DISCUSSION

Growth performance: There is no significant difference on the animal initial conditions between the two feeding system groups ($p>0.05$). The significant difference was not observed in the final BW ($p = 0.30$), backfat ($p = 0.24$) and muscle depth ($p = 0.80$).

However, the body protein mass was 7% higher in individual daily feeding pigs than in the pigs of traditional feeding method ($p = 0.04$).

There is no significant difference in ADFI between these two feeding methods ($p = 0.11$). But the average daily lysine intake is lower significantly (-21.9%) in the pigs of individual daily system ($p<0.001$) than traditional feeding system. The protein intake during the experiment period was 13.4% less in the pigs fed with individual daily system ($p = 0.01$). The pigs fed with individual daily feeding program have a greater ADG (+5.3%, $p = 0.29$) than the pig fed with traditional feeding program, additional gain seems to do more as protein than fat. The feed conversion was not affected by the feeding method ($p = 0.88$).

Bone mineral density estimated by X-ray absorbance was not affected by the feeding systems ($p = 0.46$). Bone mineral content and total body P, however are higher ($p = 0.08$) in pigs fed according to individual daily feeding group compared to traditional three-phase feeding group. Despite the large variation between animals, pigs fed according to individual daily feeding accumulated on average 9.7% less minerals and the same proportion of P than pigs in traditional feeding group. There is no difference in the nitrogen and phosphorous retained per kg body weight gain between both feeding systems ($p>0.05$) (Table 2).

Excretion of nitrogen and phosphorus: The amount of nitrogen and phosphorus deposition was similar between these two feeding systems ($p>0.05$), although the pigs fed with individual daily feeding method deposited a higher 7.2% nitrogen and 6.9% phosphorous than the pigs fed with traditional method. Compare to the traditional feeding system, feeding pigs with individual daily diets reduced N and P intake, respectively both by 17 and 9.7% ($p<0.01$) and the corresponding excretions were reduced both >30% ($p<0.01$). The feed cost per kg of gain reduced 5.9% in individual daily feeding pigs (Table 3).

Swine production systems have dramatically changed in the last decades. Since, the seventies swine production became more intensive leading to a reduction in the number of farms raising pigs but at the same time having many more animals per farm. The concentration of much of the feeder hog industry in small geographical areas produced a dramatic increase in environmental load. Land application of manure attained excessive levels are no longer accepted. Reducing feed costs, the excretion of excess nutrients such as nitrogen and phosphorus and

Table 2: Initial and final animal body conditions and composition, animal performance of pigs fed according to a three-phase feeding or individually daily feeding system

Condition and performances	Feeding method: Three-phase feeding	Individual feeding	SEM	p-value
Initial conditions				
Body weight (kg)	28.40	28.90	2.1700	0.620
Backfat (mm)	5.10	5.05	0.4250	0.810
Muscle depth (mm)	30.73	32.49	2.1830	0.090
Body protein mass (kg)	4.14	4.46	0.4600	0.130
Body lipid mass (kg)	4.08	4.15	0.2100	0.450
Bone mineral content[a] (g)	455.00	483.00	57.6000	0.300
Bone mineral density[a] ($g\ cm^{-2}$)	0.66	0.68	0.0700	0.390
Phosphorous content[b] (g)	114.00	121.00	14.4100	0.300
Final condition and animal performance				
Body weight (kg)	55.10	57.00	4.0000	0.300
Backfat (mm)	7.82	8.33	0.9560	0.240
Muscle depth (mm)	46.00	45.64	3.1170	0.800
Body protein mass (kg)	8.67	9.32	0.6800	0.040
Body lipid mass (kg)	8.68	9.07	1.1700	0.470
Bone mineral content (g)	1112.00	1185.00	86.8000	0.080
Bone mineral density ($g\ cm^{-2}$)	0.92	0.93	0.0510	0.460
Phosphorous content (g)	278.00	296.00	21.7100	0.080
Feed intake ($kg\ day^{-1}$)	1.93	2.05	0.0660	0.110
Lysine intake ($g\ day^{-1}$)	19.89	14.32	2.3660	<0.001
Protein consumed (kg)	8.80	7.60	0.9000	0.010
Total P consumed (g)	291.90	263.50	28.7000	0.040
Average daily gain ($kg\ day^{-1}$)	0.95	1.00	0.1030	0.290
Feed converstion (FCR)	2.04	2.06	0.2120	0.880
Protein retained (kg)	4.50	4.90	0.4900	0.150
Lipid retained (kg)	4.60	4.90	1.1100	0.540
N retained (g kg) gain	27.46	27.72	2.9200	0.840
Phosphorous retained ($g\ kg^{-1}$) gain	6.21	6.30	0.7660	0.780

[a]Body protein mass and fat mass were calculated according to Pomar and Rivest (1996) from the corresponding DXA values; [b]Body phosphorus calculated from the DXA total bone mineral content

Table 3: Feeding cost and Nitrogen (N) and Phosphorus (P) balance in pigs fed according to a commercial three-phase feeding or individual daily feeding system

Food balance	Feeding method: Three-phase feeding	Individual feeding	SEM	p-value	Δ (%)
Nitrogen intake (kg)	1.47	1.221	0.15	0.013	-17.0
Nitrogen retention (kg)	0.73	0.778	0.08	0.150	7.2
Nitrogen excretion (kg)	0.75	0.444	0.11	<0.001	-40.5
Total phosphorous intake (g)	291.90	263.500	28.70	0.037	-9.7
Phosphorous retained (g)	164.30	175.700	17.60	0.160	6.9
Phosphorous excreted (g)	127.70	87.800	28.60	0.006	-31.2
Feed cost/ADG ($\$\ kg^{-1}$*)	0.83	0.780	0.08	0.184	-5.9

*Feed cost/ADG, $\$\ kg^{-1}$ were calculated according to Hauschild *et al.* (2010) described as Feed cost/ADG, $\$\ kg^{-1} = FCR_{Lys}$: NE×Feed cost, Feed cost ($\$\ kg^{-1}$) = 0.3272+0.0791×Lys: NE

the use of non-renewable resources is essential to the development of sustainable pig production systems (Honeyman, 1996; Jondreville and Dourmad, 2005; Rotz, 2004). Nitrogen and phosphoro us excretion are affected by the amount of these nutrients intake, their metabolic availability and the balance between the available nutrients' intake and the animal requirements (Jongbloed and Lenis, 1992). Providing the pigs with precise nutrient can decrease the excretion of nitrogen and phosphorous (Han, 1998; Jongbloed and Lenis, 1992; O'Connell *et al.*, 2005).

For growing-finishing pigs, the precision feeding may be an essential approach by improving the utilization of dietary nutrients and thus, reduce feeding costs and nutrient excretion. The development of feeding systems that allow blend feeding and the automatic distribution of two premixes that combined in variable ratios could meet the requirement of pigs throughout their growth period (Feddes *et al.*, 2000).

This technique reduces the nutrients excretion without increasing feeding costs (Montminy *et al.*, 2005). These premixes can be complete diets formulated to satisfy the requirements of pigs at the beginning and at the end of their growing period (Bourdon *et al.*, 2005). This technique laid the foundation for the development of precision individual daily feeding system. Precision feeding involves the use of feeding techniques that allow the right amount of feed with the right composition to be provided at the right time to each pig in the herd. So, it may be an essential approach to improve the utilization of dietary nutrients and thus reduce feeding costs and nutrient excretion.

For the feeding of a population, however optimal feed composition is difficult to estimate as the response of the population to rising concentrations of nutrients is affected by many factors including genetics, gender and the environment as well as the variability between the individuals of the population to be fed (Pomar *et al.*, 2003).

In the present study, the animal performance, nitrogen and phosphorous intake and excretion were compared between these two growing pig groups fed separately with individually daily precision diet and traditional three-phase method.

Most of the pigs fed with traditional three-phase feeding system and all the pigs fed with individual daily feeding system can consume enough or more nutrient to meet their maintenance and growth requirement. For most of the nutrient such as protein and phosphorous, the pigs can obtain the maximum growth performance by providing excess nutrients (Table 2). Therefore, there is no difference on the animal growth performances between these two feeding methods. However, nitrogen and phosphorous intake and excretion decreased significantly in the pigs fed with individual precision feeding system. The result of Pomar (2007) showed the nitrogen excretion decreased 12% in the pigs fed with daily feeding program.

However, the difference caused by heterogeneity of group is bigger than that of growth period, the depressed nitrogen and phosphorous was lower than the values of present study.

CONCLUSION

The results improved the individual daily precision feeding is an effective approach to improve the utilization of dietary nutrients and thus reduce feeding costs and nutrient excretion without counteract the animal growth performance.

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