Precision feeding can significantly reduce lysine intake and nitrogen excretion without compromising the performance of growing pigs

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Abstract. *The impact of using a mathematical model estimating real-time daily lysine requirements in a sustainable precision feeding program for growing pigs was investigated in two performance trials. Three treatments were tested in the first trial (60 pigs of 41.2±0.5 kg): a three-phase feeding program (3P) obtained by blending fixed proportions of feeds A (high nutrient concentration) and B (low nutrient concentration); and two daily-phase feeding programs in which the blended proportions of feeds A and B were adjusted daily to meet the estimated nutritional requirements of the group (MPG) or of each pig individually (MPI). The five treatments tested during second trial (70 pigs of 30.4±2.2) were a three-phase group-feeding program; against four individual daily-phase feeding programs in which the blending proportions of feeds A and B were updated daily to meet 110%, 100%, 90%, or 80% of the lysine requirements estimated using a mathematical model. Feeders identified each pig and delivered, in response to each animal request, a blend of feeds A and B containing the estimated concentration of lysine required by this pig this day according to the assigned trialal treatment. Feed intake was recorded automatically by the feeders, and the pigs were weighed weekly. These individual data was used to estimate the required concentration of lysine for each pig. Nitrogen excretion was calculated by the difference between intake and retention. In the first project, the MPG and MPI programs showed similar performance results than 3P feeding program. However, compared with the 3P, the MPI feeding program reduced (P<0.05) the standardized ileal digestible lysine intake by 27% and the estimated nitrogen excretion by 22%. In the second project, feeding pigs in a daily-basis program providing 110%, 100%, or 90% of the estimated individual lysine requirements also did not influence performance results in comparison with the 3P. However, feeding pigs individually with diets tailored to match 100% of nutrient requirements made it possible to reduce (P<0.05)*

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digestible lysine intake by 26% and estimated nitrogen excretion by 30% relative to 3P. Precision feeding is an effective approach to make pig production more sustainable without compromising growth performance.

Keywords. *nutrition, nutrient requirements, precision farming, protein, swine.*

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Introduction

Feeding programs are usually designed to maximize animal performance by providing successive diets (phases) to groups of pigs. However, the nutritional requirements vary among animals in a population and also change dynamically in the same pig through time (Brossard et al., 2009; Pomar et al., 2009). By disregarding these variability issues, the conventional phase-feeding programs leads to inaccurate nutrient supply, usually with over-formulation of the diets.

Many studies indicate that nutrient efficiency could be improved by better adjusting nutrient supply to individual animal demand (Ferket et al., 2002). Precision feeding arises in this context as a concept that aims to consider the variability aspects, allowing the exact nutrient amount to be supplied at the right time to each pig of the herd (Pomar et al., 2009).

Through simulation, precision feeding allowed reducing nitrogen excretion by up to 38% and feeding costs by up to 10% compared to a conventional system (Pomar et al., 2010). Despite the possible benefits, precision feeding is a new concept and few essays were conducted to assess its real implications. The current studies were developed, therefore, to evaluate the impact of moving from conventional to precision feeding programs on performance, nutrient balance and feeding cost in growing-finishing pigs.

Material and methods

Animals, housing and management

Two trials were conducted using 130 pigs (trial 1: 60 barrows, 41.2 ± 3.9 kg; trial 2: 35 females and 35 barrows, 30.4 ± 2.2 kg) of the same high performance genotype (Fertilis 25 X G-Performer 8.0, Génétiporc inc., Canada). Each performance trial consisted of 3 feeding phases of 28 days each, for a total trialal length of 84 days.

Water was freely available from low pressure nipple drinkers and feed was provided *ad libitum* during the entire project. Five automatic feeders interfaced with computer software were especially designed for the projects. These single space feeders were able to identify the pig through an electronic ear-tag transponder, providing feed with the right composition, by blending the premixes that were individually stored in 4 containers located in the upper part of the feeder. All the feeders were able to provide diets to any animal, regardless of treatment. This feature allowed all animals of each trial to be housed in the same pen in a single group.

Diets and feeding

For the trial 1, two premixes (named A and B) and 3 commercial complete diets were independently formulated on net energy and standardized ileal digestible (SID) amino acids basis considering the same database of ingredient composition (Table 1). The premixes differed from each other by the concentration of nutrients, being premix A formulated to contain high nutrient concentration (to satisfy the estimated requirements of the most demanding pig at the beginning of growing period), and premix B formulated to contain low nutrient concentration (to closely meet the estimated requirements of the least demanding pig at the end of finishing period). The required daily concentration of lysine was estimated in both projects according to individual information of body weight, expected feed intake and weight gain (Hauschild et al., 2012).

The 4 following feeding programs (treatments) were tested in the trial 1:

- tailored 3-phase feeding program (3P) providing within each phase a fixed blend of premixes A and B calculated during the first 3 days of each phase to satisfy the lysine requirement of the 80th percentile pig of this group, which was described in previous study as the level that maximize the

population response in terms of weight gain (Hauschild et al., 2010);

- commercial 3-phase feeding program (COM) in which pigs were fed complete diets formulated according to local industry standards, used in this project in order to validate the results of 3P group as representatives for industrial conditions;

- multi-phase group feeding (MPG) in which all pigs received the same blend of premixes A and B calculated at the beginning of each day to satisfy the lysine requirement of the 80th percentile pig of this group;

- individually tailored multi-phase feeding (MPI) in which pigs were fed with a blend of premixes A and B calculated at the beginning of each day to satisfy the lysine requirement of each pig individually.

Table 1. Composition of the premixes (A and B) and commercial diets (C1, C2, C3) used in the trial 1.

Premixes/Diets	A	B	C1	C2	C3
Ingredients, %					
Wheat	18.2	51.0	0.50	10.0	15.0
Corn	40.1	30.1	66.6	68.0	68.3
Barley	8.85	16.2	-	-	-
Wheat middlings	5.50	-	-	-	-
Soybean meal	17.2	-	24.8	18.9	14.1
Gluten meal	4.50	-	-	-	-
Soybean oil	1.50	-	-	-	-
Limestone	1.72	1.34	1.69	1.43	1.26
Di-calcium phosphate 21%	0.34	-	0.42	0.17	-
Salt	0.60	0.57	0.38	0.38	0.39
DL-methionine	0.16	-	0.10	0.09	0.03
L-lysine HCL	0.52	0.20	0.33	0.34	0.28
L-threonine	0.19	-	0.10	0.11	0.07
L-tryptophan	0.05	-	-	-	-
Phytase	0.01	0.01	0.01	0.01	0.01
Choline	0.10	0.10	0.10	0.10	0.10
Vitamin-mineral premix	0.50	0.50	0.50	0.50	0.50
Nutritional composition (calculated)					
Dry matter, %	87.7	87.3	87.1	87.1	87.0
Crude protein, %	19.0	11.2	17.8	15.9	14.2
SID lysine, %	1.06	0.40	1.02	0.89	0.74
NE, Mcal/kg	2.33	2.49	2.45	2.50	2.53
Ca, %	0.81	0.56	0.82	0.67	0.56
Total P, %	0.46	0.31	0.43	0.37	0.32
Available P, %	0.19	0.08	0.19	0.13	0.09
Ash, %	5.36	3.57	4.88	3.68	3.31

Table 2. Composition of the premixes (A and B) used in the trial 2.

Premixes/Diets	A	B
Ingredients, %		
Wheat	15.0	15.0
Corn	54.8	83.2
Soybean meal	25.4	0.17
Limestone	1.61	0.42
Di-calcium phosphate 21%	1.22	-
Salt	0.63	0.50
DL-methionine	0.09	-
L-lysine HCL	0.44	0.09
L-threonine	0.13	-
Choline	0.10	0.10
Premix[1]	0.50	0.50
Nutritional composition (calculated)		
Dry matter, %	87.7	87.0
Crude protein, %	18.1	8.15
SID lysine, %	1.15	0.26
NE, Mcal/kg	2.31	2.53
Ca, %	0.92	0.21
Total P, %	0.60	0.25
Available P, %	0.32	0.07
Ash, %	7.86	4.07

For the trial 2, premixes A and B (Table 2) were formulated independently considering the same criteria adopted in the first project. In this trial, the 5 following feeding programs were tested:

- tailored 3-phase feeding program (3P) calculated to satisfy the lysine requirement of the 80th percentile pig of this group, being similar to the equivalent treatment of trial 1;

- individually tailored multi-phase feeding programs in which pigs were fed with blends of A and B premixes calculated at the beginning of each day to provide 110% (MPI110), 100% (MPI100, equivalent to the MPI treatment of the previous trial), 90% (MPI90) or 80% (MPI80) of the estimated SID lysine requirements.

Performance study and economical evaluation

In both trials, feed intake was recorded in real time for each pig through a computerized registering system. Pigs were weighed weekly during the project with no previous restriction of feed and water. At the beginning of each feeding phase (on days 0, 28 and 56) and at the end of the performance trial (on day 84), the backfat thickness and the loin muscle depth were measured between the 3rd and the 4th last ribs at 5 cm of the midline with a real-time ultrasound equipment (Ultrascan 900, Alliance Medical Inc., Canada). The body contents of fat and lean were measured on the same days with a dual-energy X-ray absorptiometry densitometry device (GE Lunar Prodigy Advance, Madison, USA).

The body amounts of protein and lipid were obtained by transforming the lean and fat values from the densitometer measurements to their chemical equivalents (Pomar and Rivest, 1996). Nitrogen retention was estimated based on protein gain. Finally, nitrogen excretion was calculated as the ratio between retention and intake.

Statistical analysis

Each pig was considered an experimental unit in both trials. Normality was checked for all variables through Shapiro-Wilks test. The variables that were not normally distributed were logarithmically transformed to approximate a normal distribution. Performance data were submitted to variance analysis aiming to evaluate the treatment effect over time (MIXED procedure). All analyses were performed using SAS software (ver. 9.3; SAS Inst. Inc., Cary, NC).

Results and discussion

Variability on individual lysine requirements

Knowing the variability in terms of amino acids requirements in a given population is a very valuable tool to define the optimum feeding strategy under different scenarios (Brossard et al., 2012; Pomar et al., 2003). The intra-day range between the requirements of the most and the least demanding pigs of the population (Figure 1) was in average 16.7 g of SID lysine during the trial 1, being a maximum range of 24.1 g observed in the 69th day of the project. In trial 2, the intra-day range was in average 15.2 g of SID lysine and the maximum range was 27 g observed in the 13rd day. The intra-day coefficient of variation tended to increase with animal age in both projects. On average, an intra-day coefficient of variation of 22% was observed in trial 1 and 20% was observed in the trial 2.

The daily variation on estimated lysine requirements could be associated to environmental or sanitary aspects, but it may be also related to the methodology used in the projects. By considering these variability aspects, the use of precision feeding (MPI and MPI100 treatments) allowed reducing the content of dietary SID lysine by 27% in the trial 1 and by 26% in the trial 2 in relation to 3P diets (Figure 2).

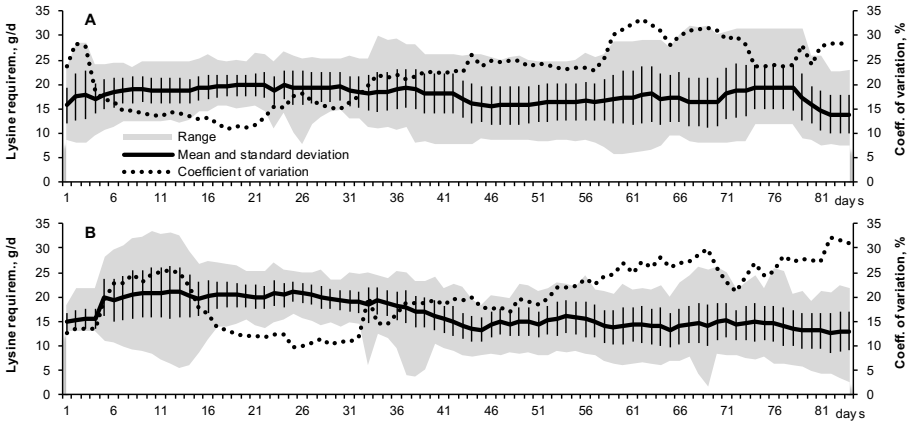

Fig 1. Mean, range and coefficient of variation on standardized ileal digestible lysine requirements estimated for each pig of the project 1 (A) and trial 2 (B).

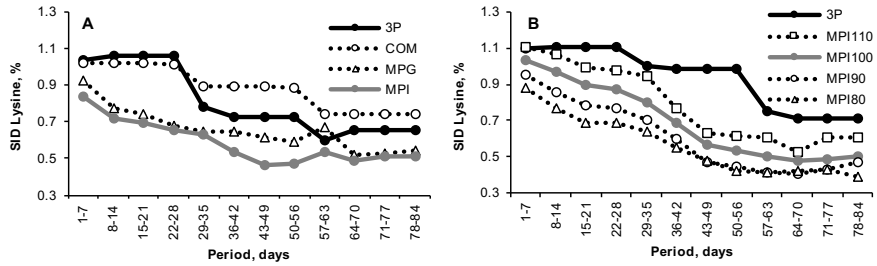

Fig 2. Dietary SID lysine level in trial 1 (A) and trial 2 (B).

Performance and body composition

Pigs consumed feed and gained weight normally throughout the projects. Pigs fed COM diets ate less feed ($P<0.05$), showed a better feed efficiency ($P<0.05$) and a lower final backfat thickness than the 3 others tailored treatment groups in trial 1 (Table 3), which may be related to the variation on nutrient and ingredient compositions of the diets. However, COM and 3P treatments showed similar results for most of the studied variables, suggesting that 3P was as a good reference for industrial scenarios.

In trial 1, feeding pigs on MPG or MPI programs did not alter any of the performance variables in relation to 3P program. The similarity among feeding programs in terms of performance response was expected in the current study because all the pigs received at least the amount of nutrients required for maintenance and growth. Previous publications also demonstrated that feeding strategies considering multi-phases programs (adjusted daily or weekly) had no effect on pig performance (Bourdon et al., 1995; Pomar et al., 2007).

The sex by treatment interaction was not significant for any of the variables studied in the second trial and therefore, only the across sex pooled values are presented in this document (Table 4). Feed intake, feed efficiency, lipid gain and final backfat thickness were similar for all treatments. Feeding pigs in a daily basis program considering 110%, 100% or 90% of the

estimated individual nutrient requirements also did not influence final body weight, weight gain and protein gain in relation to animals kept in the 3P feeding system. However, a further decrease bringing the supply level down to 80% of requirements interfered on some of the performance results. Pigs fed MPI80 showed an 11% reduction (P<0.05) on gain of weight and gain of protein, and a 9% reduction on final body weight in relation to 3P group. These results suggest that the model used to estimate individual lysine requirements is properly calibrated.

Table 3. Performance, feeding costs and nitrogen balance of pigs fed in 3-phases (3P), commercial (COM), multi-phases per group (MPG) and individual multi-phases (MPI) feeding programs (trial 1).

Response	Treatments[1]				SEM	*P* value
	3P	COM	MPG	MPI		
Daily feed intake, kg/day	3.05^{b}	2.73^{a}	3.07^{b}	3.05^{b}	0.04	<0.01
Daily weight gain, kg/day	1.11	1.07	1.11	1.10	0.01	0.58
Gain:Feed ratio, kg/kg	0.38^{b}	0.40^{a}	0.37^{b}	0.37^{b}	0.01	0.01
Daily protein gain, g/day	161	155	155	154	2.30	0.65
Daily lipid gain, g/day	343	326	366	369	9.11	0.16
Final BW, kg	134	131	135	136	1.12	0.24
Final backfat thickness, mm	19.1^{a}	16.8^{b}	19.5^{a}	19.1^{a}	0.50	0.03
Final loin muscle depth, mm	70.1	70.2	71.5	70.2	0.74	0.91
Daily crude protein intake, g/day	480^{a}	433^{b}	433^{b}	405^{b}	5.80	<0.001
Daily SID lysine intake, g/day	23.8^{a}	23.9^{a}	19.7^{b}	17.4^{c}	0.42	<0.001
Nitrogen retention, kg/pig	2.17	2.08	2.08	2.06	0.02	0.64
Nitrogen excretion, kg/pig	4.04^{a}	3.52^{b}	3.54^{b}	3.17^{b}	0.07	<0.001

[1] Within a row, means without a common superscript differ (P<0.05) according to Tukey's test.

Table 4. Performance, feeding costs and nitrogen balance of pigs fed in three-phase feeding system (3P) or multi-phase feeding system (MP) provided individually considering 110%, 100%, 90% or 80% of the estimated nutritional requirements (trial 2).

Response	Treatments[1]					SEM	*P* value
	3P	MPI110	MPI100	MPI90	MPI80		
Daily feed intake, kg/day	2.44	2.43	2.53	2.57	2.33	0.03	0.52
Daily weight gain, kg/day	1.05^{a}	1.05^{a}	1.03^{a}	1.00^{ab}	0.93^{b}	0.01	<0.01
Gain:Feed ratio, kg/kg	0.43	0.43	0.41	0.39	0.40	0.01	0.05
Daily protein gain, g/day	167^{a}	167^{a}	166^{a}	158^{ab}	148^{b}	3.10	<0.01
Daily lipid gain, g/day	256	263	245	256	235	2.74	0.55
Final BW, kg	119^{a}	118^{a}	116^{ab}	114^{ab}	108^{b}	1.21	0.02
Final backfat thickness, mm	15.6	17.0	15.5	16.1	15.2	0.36	0.37
Final loin muscle depth, mm	72.4^{a}	74.1^{a}	69.7^{ab}	64.6^{b}	64.6^{b}	0.87	<0.01
Daily crude protein intake, g/day	380^{a}	331^{b}	318^{b}	302^{bc}	262^{c}	4.00	<0.01
Daily SID lysine intake, g/day	22.4^{a}	18.1^{b}	16.5^{bc}	15.0^{c}	12.5^{d}	0.38	<0.01
Nitrogen retention, kg/pig	2.25^{a}	2.24^{a}	2.24^{a}	2.13^{ab}	1.99^{b}	0.01	<0.01
Nitrogen excretion, kg/pig	2.66^{a}	2.04^{b}	1.87^{bc}	1.78^{bc}	1.41^{c}	0.02	<0.01

[1] Within a row, means without a common superscript differ (P<0.05) according to Tukey's test.

Intake and balance of nutrients

In trial 1, the use of MPI feeding program allowed reducing (P<0.05) the intake of crude protein by 16% and SID lysine by 27% in relation to 3P feeding program. Still in relation to 3P treatment, feeding pigs on MPI program allowed reducing (P<0.05) the ratio between ingested SID lysine and retained protein by 24% in MPI program (data not shown). In the trial 2, the use of MPI100 diets reduced (P<0.05) by 16% the intake of crude protein and by 26% the intake of SID lysine in relation to 3P treatment.

As the nutritional requirements were properly satisfied, nitrogen retention was not affected by feeding treatments in trial 1. Similar results were also obtained for nitrogen retention in the treatments 3P, MPI110, MPI100 and MPI90 of the second trial.

By better adjusting the supply to the nutrient requirements, feeding pigs in MPI program allowed reducing (P<0.05) the estimated excretion of nitrogen by 22% in relation to conventional 3P feeding program of the trial 1. Likewise, in the trial 2, the nitrogen excretion was reduced (P<0.05) by 24% in MP110, by 30% in MPI100, by 33% in MP90 and by 47% in MP80 treatment in relation to 3P group. The reached reduction is lower than the 38% estimated by Pomar et al.

(2010) because pigs were fed in these trials according to lysine requirements and the lysine/crude protein ratio was different in premixes A and B. In this context, further reduction could be reached by improving formulas' amino acids balances.

Conclusion

Innovative feeding systems controlled by effective decision support systems are being developed and this technology will be soon available as a sustainable tool to enhance competitiveness of the swine industry.The method used to estimate real-time daily lysine requirements, that is, tracking the pigs' feed intake and growth patterns, allowed a significant increase in nutrient efficiency throughout the entire growing-finishing period. The results of this study clearly indicate that precision feeding is an effective approach for reducing nutrient excretion in pig production systems. Improving nutrient use efficiency may also represent a significant decrease in feeding cost.

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