Variation of performance of a growing pig population as affected by lysine supply and feeding strategy

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Abstract. Based on the performance data of a population of 192 pigs, the InraPorc® model was used to determine lysine requirement curves for individual pigs. The consequence of using different feeding strategies (i.e., 1, 2, 3 or 10 diets, with a change of diet determined by the age of the pigs) and lysine supply (ranging from 70 to 130 % of the mean requirement of the population) on performance was tested by simulation modelling. For each diet used, the lysine content in the diet was set to meet the highest mean requirement during the period. The percentage of pigs for which the lysine requirement was met increased concomitantly with increasing lysine supply, but decreased when the number of diets increased. Daily gain increased and feed conversion ratio decreased with increasing lysine supply according to a curvilinear-plateau relationship. The best performance was obtained with the supply met or exceeded 110 % of the mean requirement of the population and did not depend on the number of diets. The coefficient of variation of daily gain was 10%, which was inherent to this population. At lower lysine supplies, performance decreased and variability of daily gain increased with an increasing number of diets. The use of multiphase feeding system may be a means to reduce nutrient input (and excretion). However, if the nutrient supply is insufficient, this may lead to increased variability in performance. Knowledge of nutrient requirements becomes more critical when a greater number of diets is used.

Keywords: Pig, Modelling, Variability, Lysine Requirement, Growth

Introduction

Feeds offered to a growing pigs group are formulated to optimise growth performance at the lowest cost. This implies the knowledge of the nutrient requirements of the animals such as lysine (Warnants *et al.*, 2003; Quiniou *et al.*, 2006). The lysine requirement is function of animal (genetic, sex, weight), environmental conditions or feeding factors (Noblet and Quiniou, 1999). Even though some of these factors may be controlled, the lysine requirement varies between individual pigs (Bertolo *et al.*, 2005). Formulating feeds for the mean requirement of a group implies that the requirements of some animals will not be covered and that their potential performance will not be realized. Consequently, the average performance of the group will be lower than that expected from the mean animal, "representative" of this group (Pomar *et al.*, 2003; Wellock *et al.*, 2004). Increasing the lysine supply to cover the requirements of a greater part of the population may be worthwhile if the performance gain compensates for the additional feed cost. The number of feeds used during the growing-finishing period varies depending on the technical possibilities, with consequences on performance. The aim of the present study was to quantify the performance response of a population of growing pigs to varying lysine supply (based on the average requirement of the population) and varying feeding strategies (i.e., number of diets). Based on actual performance data of a population of 192 pigs, the InraPorc® model was used to determine lysine requirement curves for each pig. The consequence of using different feeding strategies applied to the population (i.e., 1, 2, 3 or 10 diets, with a change of diet determined by the age of the pigs) and lysine supply (ranging from 70 to 130 % of the average requirement of the population) on performance was tested by simulation modelling.

Material and methods

Data set description

Data used in this study were obtained from a population of 192 pigs (100 gilts and 92 barrows, P76 x (Large White x Landrace)) (Brossard *et al.*, 2006). Growth and *ad libitum* intake kinetics of each animal of this population were characterized between 65 d of age and 110 kg BW by a set of five parameters following the procedure described by Brossard *et al.* (2006). This procedure allows summarizing each individual growth curve by three parameters: BW at 65 d of age (**BW_{65d}**), the shape parameter of the growth curve ($B_{Gompertz}$) and average daily gain between 65 d of age and 110 kg BW (**$ADG_{65d\text{-}110kg}$**). The shape parameter $B_{Gompertz}$ (called 'precocity' in the InraPorc software) indicates whether pigs are early- or late maturing. For a given BW_{65d} and $ADG_{65d\text{-}110kg}$, a high value of $B_{Gompertz}$ indicates an early maturing animal, whereas a low value represents a late maturing animal. The *ad libitum* daily feed intake (**DFI**) is characterized by two parameters: the expected DFI (kg/d) at 50 kg BW (**DFI_{50}**) and a shape parameter of the feed intake curve (**b**). For a value of 0 for b, DFI is constant (independent of BW), whereas a value of 1 characterizes a DFI proportional to BW. Between these values, a low b indicates an early DFI relative to BW, i.e. increasing rapidly at the beginning of the growth.

Simulation method

The consequence of using different feed sequence plans and lysine supply on performance from 65 days of age to slaughter at 110 kg BW was tested by simulation modelling.

Model parameterisation and calculation of lysine requirement. In the InraPorc® model, the five parameters described above are the input parameters required to define an animal profile (for potential growth and feed intake). Using this profile, the InraPorc® model allows simulating actual growth for a defined feeding strategy and to calculate nutrients requirements for each day of the simulation (van Milgen *et al.*, 2007). In a first step, previously obtained values of the model parameters were entered in InraPorc® to define a profile for each pig. The changes with age in BW and in the requirement of standardized ileal digestible lysine (**dLys**) were obtained for each pig by using a feeding strategy that allowed maximal growth. The mean dLys requirement of the population was calculated daily.

Feed sequence plans and lysine supply. Within the software, four feed sequence plans were defined depending of the number of diets used (one, two, three or ten diets for the one-phase, two-phase, three-phase and ten-phase plans, respectively). The criterion to change diets in the multiphase plans was the age of the animal. Thus, all the animals of the population received the same diet during the same period of age. To determine the age at which diets were changed, the mean age at which animals reached a defined BW was calculated using the individual growth kinetics previously obtained (i.e. the mean age at 65 kg for the two-phase strategy, the mean age at 50 and 75 kg for the three-phase strategy, and the mean age at 38, 46, 54, 62, 70, 78, 86, 94 and 102 kg for the ten-phase strategy). For each phase of the four feed sequence plans, a lysine level was then defined as the maximal mean requirement for the corresponding period of age (i.e., typically the mean requirement at the beginning of a feeding phase). Diets were then formulated for each phase to provide 70, 80, 90, 100, 110, 120 or 130% of this defined level of lysine. The diets for the different phases, feed sequence plans and level supply were identical in EN (10.59 MJ/kg), CP (19 %) and digestible amino acids (except lysine) content. The AA content was formulated to be non-limiting irrespective of the lysine level. Only the dLys level varied between diets.

Simulations of lysine supply effect and calculations. Feed intake and growth were simulated individually using the InraPorc® model from 65 d of age to 110 kg BW and for each feed sequence plan and lysine supply. Individual ADG, average DFI (**ADFI**), feed conversion ratio (**FCR**) and ingested quantities of lysine were calculated. The percentage of pigs for which the lysine requirement was met (**PRM**) was calculated at the start and end of each phase. A mean PRM was then calculated at the start and end of phase for all phases of each feed sequence plan.

Statistical analysis. Simulated performance (ADG, ADFI, FCR, total ingested lysine) was analysed by the GLM procedure (SAS, 1999). Feed sequence plan and level of lysine supply were included in the model as main effects and their interaction were also included in the model. Data on PRM were analysed using the χ^2 tests of the FREQ procedure (SAS, 1999).

Results

Evolution of lysine requirement with age, and percentage of animals with covered requirement

The lysine level of each diet and ages at diet changes according to the feed sequence plan are shown in Table 1. The mean requirement of lysine of the population decreased along the growth.

At anticipated, for each feed sequence plan and for a lysine supply lower than 130 % of the mean requirement, the PRM was higher at the end than at the start of diet distribution (Figure 1; $P < 0.001$). At the start of phase, PRM differences were non significant between feed sequence plans ($P > 0.1$). Furthermore, PRM increased with increasing of lysine supply ($P < 0.001$), with values of 0, 56 and 100 % with a supply corresponding to 70, 100 and 130 % of the mean requirement, respectively. At the end of the phase, and for a given lysine supply lower than 130 % of the mean requirement, PRM decreased with increasing number of phases ($P < 0.001$) but it increased with increasing lysine supply ($P < 0.001$). With a supply corresponding to 70 % of the mean requirement, PRM was of 0 and 89 % for ten-phase and one-phase sequence plans, respectively. With a supply corresponding to 100 % of the mean requirement, PRM was of 74 % for ten-phase sequence plan and higher than 94 % for other plans. With a supply corresponding to 130 % of the mean requirement, requirement of entire population was met irrespective of the feed sequence plan. For the three multiphase sequence plans, the shape of the PRM evolution curve was similar.

Table 1. BW and age at diet change and standardized digestible lysine (dLys) supply per phase.

Feed sequence plan	Phase	Target BW (kg) at diet change	Age (d) at diet change	dLys supply (g/kg feed)
one-phase	-	-	-	8.95
two-phase	1	65	101	8.95
	2	-	-	7.82
tri-phase	1	50	87	8.95
	2	75	110	8.43
	3	-	-	7.36
ten-phase	1	38	75	8.95
	2	46	83	8.80
	3	54	91	8.58
	4	62	98	8.32
	5	70	106	7.97
	6	78	113	7.62
	7	86	120	7.26
	8	94	127	6.83
	9	102	135	6.47
	10	-	-	6.24

Table 2. Effect of lysine supply (as % of lysine mean requirement) and feed sequence plan on ADG, ADFI, FCR and total ingested lysine.

Parameter	Feed sequence plan	% of lysine mean requirement 70	80	90	100	110	120	130	r.m.s.e[1]	Statistics[2]
ADG (kg/d)	one-phase	0.912	0.991	1.042	1.065	1.071	1.072	1.072	0.1135	F***
	two-phase	0.863	0.957	1.028	1.062	1.070	1.072	1.072		L***
	three-phase	0.842	0.938	1.018	1.060	1.070	1.072	1.072		FxL***
	ten-phase	0.796	0.895	0.988	1.050	1.068	1.071	1.072		
ADFI (kg/d)	one-phase	2.332	2.344	2.361	2.372	2.375	2.376	2.376	0.2481	-
	two-phase	2.348	2.353	2.363	2.372	2.375	2.376	2.376		
	three-phase	2.354	2.357	2.364	2.372	2.375	2.376	2.376		
	ten-phase	2.373	2.374	2.373	2.374	2.376	2.376	2.376		
FCR (kg/kg)	one-phase	2.56	2.37	2.27	2.23	2.22	2.22	2.22	0.092	F***
	two-phase	2.73	2.46	2.30	2.24	2.22	2.22	2.22		L***
	three-phase	2.80	2.52	2.33	2.24	2.22	2.22	2.22		FxL***
	ten-phase	3.00	2.67	2.41	2.27	2.23	2.22	2.22		
Total ingested lysine (kg)	one-phase	1.31	1.39	1.50	1.64	1.79	1.95	2.12	0.084	F***
	two-phase	1.28	1.33	1.40	1.52	1.66	1.81	1.96		L***
	three-phase	1.26	1.31	1.37	1.48	1.61	1.75	1.90		FxL***
	ten-phase	1.23	1.28	1.33	1.41	1.53	1.66	1.80		

[1] r.m.s.e: root mean standard error

[2] F: feeding strategy effect; L: lysine percentage effect; FxL: interaction feeding strategy x lysine percentage;***: P<0.001

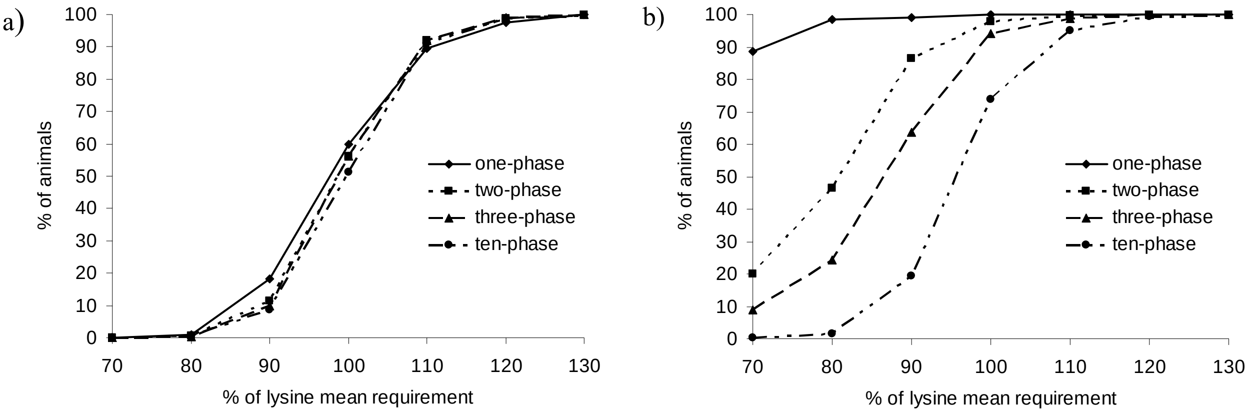

Figure 1. Effect of lysine supply (as % of lysine mean requirement) and feed sequence plan on percentage of pigs for which the lysine requirement was met (PRM) at the beginning (a) or at the end of the phase (b).

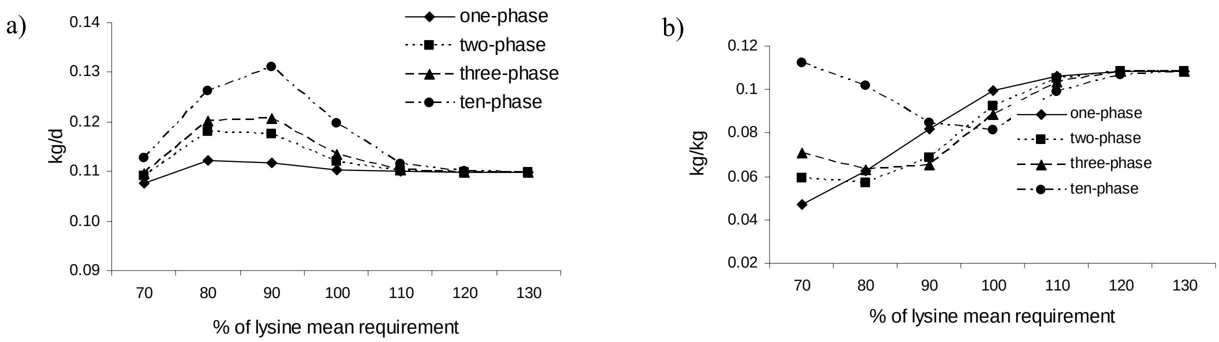

Figure 2. Effect of lysine supply (as % of lysine mean requirement) and feed sequence plan on coefficient of variation of ADG (a) and FCR (b)

Effect of lysine supply and feed sequence plan on mean and variability of performance

No significant effect of feed sequence plan or lysine supply was observed on ADFI (P > 0.1; Table 2). With a supply corresponding to 70 % of the mean requirement, ADFI was of 2.33, 2.35, 2.35 and 2.37 kg/d for the one, two, three and ten-phase sequence plans, respectively. For the ten-phase sequence plan, ADFI is constant irrespective of the level of lysine. For the other feed sequence plans, ADFI increased numerically with increasing lysine supply from 70 to 100 % of the mean requirement and was constant at 2.38 kg/d for higher supplies. The mean total quantity of ingested digestible lysine increased with increasing lysine supply (P < 0.001) and decreased with increasing number of phases (P < 0.001). Total digestible lysine intake varied from 1.31 to 1.23 kg with a supply at 70 %, from 1.64 to 1.41 kg with a supply at 100 % and from 2.12 to 1.80 kg for a supply at 130 %, for one and ten-phase sequence plans, respectively.

With a supply from 70 to 100 % of the mean requirement, ADG decreased and FCR increased with increasing number of phases (P < 0.001; Table 2). In contrast, ADG increased and FCR decreased with increasing lysine supply (P < 0.001). With a higher supply, performance was similar between feed sequence plans and lysine supplies (P > 0.1). With a supply corresponding to 70 % of the mean requirement, population mean ADG varied from 0.912 kg/d to 0.796 kg/d for one-phase and ten-phase sequence plans, respectively. With a supply corresponding to 100 % of the mean requirement, population mean ADG was of 1.065 kg/d and 1.050 kg/d for one-phase and ten-phase sequence plans, respectively. With a higher lysine supply, mean ADG reached 1.072 kg/d for the four feed sequence plans. The increase in ADG in response to the increasing lysine supply became more marked with an increasing number of phases in the sequence plan. With a supply corresponding to 70 % of the mean requirement, FCR was of 2.56, 2.73, 2.80 and 3.00 kg/kg for feed sequence plans including one, two, three and ten phases, respectively. The FCR decreased with the increasing lysine supply and became constant at 2.2 kg/kg for lysine supply higher than 100 % of the mean requirement.

Variability of performance between animals was estimated by the standard deviation of the calculated criteria ADG and FCR (Figure 2). For the feed sequence plan with one phase, the standard deviation of the ADG was constant at 0.11 kg/d and independent on the lysine supply. For the multiphase feed sequence plans, the standard deviation of the ADG increased with increasing number of phases for a lysine supply between 70 and 100 % of the mean requirement. It also increased with decreasing lysine supply from 110 to 90 % and thereafter decreased for lower supplies. The effect of the feed sequence plan on the standard deviation of the FCR varied with increasing lysine supply. With a supply corresponding to 70 % of the mean requirement, the standard deviation of the FCR increased with increasing number of phases. This relationship was inversed for a supply corresponding to 100 % of the mean requirement and no difference was observed for a supply higher than 110 %. For the feed sequence plan with one phase, the standard deviation of the FCR increased with increasing lysine supply. For the multiphase feed sequence plans, this criterion decreased for a supply between 70 and 80-90% of the mean requirement and thereafter increased with increasing lysine supply.

Discussion

The maximum of the mean lysine requirement of the population during a phase was chosen to define the lysine supply in each feed. As the lysine requirement (in g/kg feed) typically decreases during growth, the maximum of the mean requirement corresponded to the mean requirement at the start of a feeding phase. At the start of a feeding phase, the PRM is approximately 50%. Because of the declining requirement, this increased with time within a phase. By increasing the number of phases, the PRM increased less between the beginning and the end of the phase. This is particularly the case when the lysine supply is relatively low (i.e., 70 to 100 % of the mean requirement). By increasing the lysine supply to 110 % or more, the requirement of a greater proportion of animals will be met both at the beginning of a phase (90 % or more) and at the end of a phase (95%).

Differences observed for ADG, ADFI and FCR, at each value of lysine supply, are similar to those observed for PRM. Performance increased and variation of performance between feed sequence plans decreased with increasing lysine supply. Maximal performance was reached for a supply of 110 % of the mean requirement. At this value of supply, performance was identical for the different feed sequence plans. Leclercq and Beaumont (2000) observed the same curvilinear-plate response of ADG and FCR to increasing digestible lysine supply in a modelling study for a broiler population. In a modelling study for a pig population, Pomar *et al.* (2003) observed the same type of response of body protein deposition to increasing protein intake.

For the level of lysine supply lower than 110 % of the mean requirement, ADG and PRM decreased with an increasing number of phases. With a low PRM, a smaller proportion of pigs will be able to express their potential and thus ADG of the population decreases. The absence of a clear affect on ADFI is to be interpreted with caution. The InraPorc® model does not take into account the possibility of increased feed intake in case of a lysine deficiency. The numerically low increase in ADFI with increasing number of phases or lysine supply can be attributed to an extended growth duration (to reach the final BW) and to an increased contribution of maintenance (relative to growth).

The change in the standard deviation for ADG is related to PRM and the growth potential of pigs. For a lysine supply greater than 110% of the mean requirement, the PRM is higher than 90 % and the majority of pigs can express their growth potential. In this case, the standard deviation is close to the 'natural' phenotypic variation in a population under optimal conditions (i.e., the lysine supply is non-limiting for the entire population). As the lysine supply decreases to 100 or 90 % of the mean requirement, PRM decreases, especially for multiphase sequence plans. As the change in feeds is determined by the age, pigs with a performance lower than average will be lighter at the feed change. Consequently, they will be penalized by the feed change as they receive less lysine than required. This contributed to the increase in the variability of performance. This increase in variability of performance with feeds deficient in amino acids supply was also observed in broilers (Corzo *et al.*, 2004). For very low lysine supplies (70 %), the entire population is penalized and performance of all animals is low. Consequently, the variability in performance is also low. Results of this study underline the importance of knowing (and covering) the individual lysine requirement if a multiphase sequence plan is used. Without this knowledge, it may have a risk to observe an increase in performance variability over the intrinsic population variability. Another implication is that a less variable genotype could be cheaper to feed. The greater the variation in lysine requirement, the greater the safety margin should be to cover the needs of a large part of the population. At the same time, a greater part of the lysine supply will be 'wasted' by animals having a lower performance potential.

In the present study, the growth duration has been chosen to determine the feed change in multiphase sequence plans. This is representative of practical conditions due to the farrowing batch system. The mean BW of the population could also be chosen to determine feed change. This type of decision rule is currently not available when the InraPorc® model is applied to a population. However, it would be interesting to model the consequence of such a rule on performance and their variability. The effect of grouping animals in batches of homogeneous pigs and following specific feed sequence plans could then be studied.

The present study also presents other practical implications. The population mean requirement was chosen as a basis in feed formulation. In this case, increasing the number of phases in the sequence plan to adjust more often the lysine supply did not allow covering the requirements of a greater percentage of animals when the lysine supply was lower than 110 %. However, it reduced the total lysine supply and thus feed cost. A feed sequence plan with a unique feed across the growth period allows covering the requirement of a high proportion of the population. However, the corresponding feed cost will be high. The present study showed that a high performance and PRM could be obtained when the lysine supply corresponded to 110 % of the mean requirement of the population. Choosing the mean requirement or a higher value in feed formulation has to be evaluated economically by comparing the performance gain and associated feed cost. It is therefore essential to model the economical impact of these choices in order to optimize performance and feed costs simultaneously.

Implications

This study showed that lysine supplies corresponding to 110 % of the mean requirement of the population allowed covering the requirement a large part of the population. It also allowed reaching performance corresponding to 99% of the maximal value. However, it must be emphasised that results come from a modelling study and that animals could react differently, by example by an increased feed intake of deficient diets (currently not accounted for in the model). The present study raises the question of the practical and economical choice between performance objective, the percentage of pigs for which the lysine requirement is met, the number of feeds in the feed sequence plan and lysine quantities used in feeds. Further studies are necessary to take into account management practices with respect to animal feeding.

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