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Precision Feeding of Pigs

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Keywords

Growing pig · Sows · Modelling · Efficiency · Precision livestock farming

Definition

Precision feeding, or tailored feeding, is a strategy based on the frequent and individual (or small group) adjustment of the ration composition and quantity based on the animal's nutritional requirements. Precision feeding should improve animal efficiency and reduce feed cost and nutrient excretion.

Efficiency is defined as the ratio of outputs to inputs; for example, feed efficiency is calculated as body weight gain per unit of feed consumed.

Introduction

In animal production, feed is a major lever for improving the efficiency and economic profitability of production, reducing emissions into the environment, and guaranteeing the quality of animal products. Precise knowledge of the nutritional requirements of animals makes it possible to minimize feed costs, by adjusting the quantity and quality of the ration.

Currently, growing pigs and pregnant sows are fed based on the needs of an average animal. As a result, animals may receive certain nutrients in excess or in deficit relatively to their own requirements. The objective of precision feeding, more recently renamed "tailored feeding," is to develop systems that estimate and deliver, at the right time, a ration with a quantity and composition adapted to the production needs of a group or of each animal. This concept was raised at the end of the 2000s at both group and individual levels and has been well studied theoretically and experimentally since; however, it is still under development for its practical application (Pomar et al. 2019). Precision feeding should improve feed efficiency while reducing feed costs and emissions, in particular of nitrogen and phosphorus (Pomar et al. 2019). To apply such an adapted feeding strategy, four steps are necessary: data collection, data processing before their use in algorithms and mathematical models, and implementation through automation. New technologies like automatons (e.g., feeders) and sensors (e.g., to measure physical activity or room temperature) are required to measure individually and continuously the production and reproduction performances of the animals and parameters of the rearing environment. Indeed, with the increased number of pigs per farm over the past decades, automation of data collection is mandatory to work at the individual

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level. This high amount of data must also be handled (i.e., cleaned and analyzed) to be processed automatically, and possibly in real-time, by models to estimate the daily individual nutritional requirements and, from there, provide instructions (i.e., plans indicating feed quantity and quality to be given to the group or to each individual) to feeders able to provide tailored diets.

In the following sections, first the variability of the nutrient requirements over time and among pigs and sows will be highlighted through a modelling approach to understand the need for a new feeding strategy based on the individual. Then the different technologies needed to apply such a feeding strategy will be presented. Finally, the results of several on-farm experiments applying precision feeding will be summarized.

Principles

Nutritional Requirements Variability

To supply the right amount of feed and nutrients to each animal, there is a need to estimate the individual requirements over time and to understand the potential factors that influence these requirements.

Models Used to Estimate Nutritional Requirements

The first tools used to predict nutrient requirements were developed for growing pigs and were based on simple empirically derived responses to nutrient supply that can be used to model their growth. These empirical responses were calculated from the average response of the animals, so the extrapolation of this approach to other conditions than the initial experimental trial was biased. Therefore, nutrient requirement estimations based on a representation of physiological mechanisms were proposed, integrating internal and external factors, and interactions between them, as well as the known empirical response curves. Ingested nutrients are partitioned between maintenance requirements (including also endogenous losses and a minimum protein turnover rate) and requirements for protein and lipid deposition and their corresponding efficiencies. Body weight and carcass traits are determined from these depositions. For example, among the several models existing for growing pigs (Brossard et al. 2017), the InraPorc model (van Milgen et al. 2008), easily used through a software tool, summarizes the phenotypic potential of a growing pig (i.e., growth potential and ad libitum feed intake) by five model parameters. These parameters are estimated through a statistical routine using on-farm recorded data (body weight and feed intake, feed composition, and feed allowance). InraPorc can be used to estimate nutrient and energy requirements and utilization, to evaluate the consequences of different feeding strategies, and to identify feeding strategies that improve performance traits such as feed efficiency.

Only a few models describing nutrient utilization in reproductive sows have been developed. Two mechanistic models, InraPorc (Dourmad et al. 2008) and the model by Hansen et al. (2014), describe energy and nutrient partitioning on a daily basis using a similar structure. Concerning InraPorc, two models, one for the gestation and one for the lactation, evaluate the animal’s requirements regarding the nutrient use by the different body compartments. The factorial approach consists of determining for each nutrient the expenses related to maintenance and production. Maintenance expenditure results from physiological functions that allow the animal to stay alive without having to draw on its body reserves. They cover basal metabolism, moderate physical activity, and thermoregulation in the thermal comfort zone. Production requirements are specific to each physiological stage. During lactation, expenses are due to the synthesis and secretion of milk, while during gestation, they are caused by the development of the uterus, fetuses, and the udder. Therefore, the use of nutrients between the different body compartments changes during the reproductive cycle. In addition, the body reserves of the sow play a buffer role. The energy and excess nutrients in the feed help to build up the sow’s body reserves, and in case of a deficit, these reserves are mobilized.

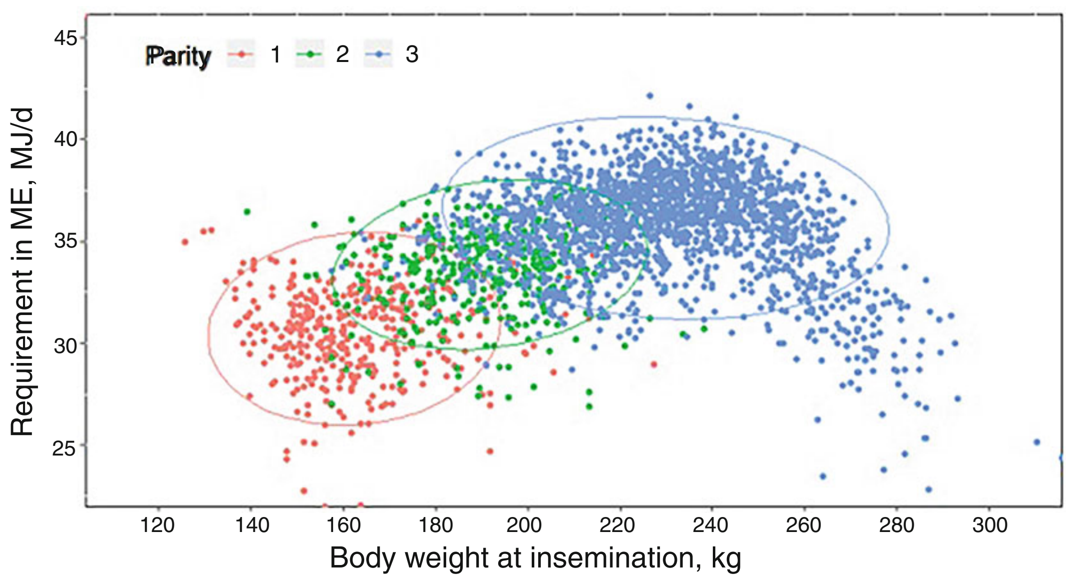
Variability of Nutrient Requirements

The models presented above are mainly deterministic, i.e., they consider an average animal and a unique prediction for a specific set of input parameters. Brossard et al. (2017) or Pomar et al. (2019) summarized some arguments indicating the importance to account for individual variation in models used to estimate nutrient requirements. For instance, between-animal variation determines the precision, the amplitude, and the shape of the response of a population to the level of nutrient supply and, therefore, the overall efficiency of nutrient utilization and optimal nutrient levels. To illustrate this, using the InraPorc models described above to calculate the nutrient requirements, the individual variability of nutritional requirements was assessed using different datasets in order to identify the main variation factors.

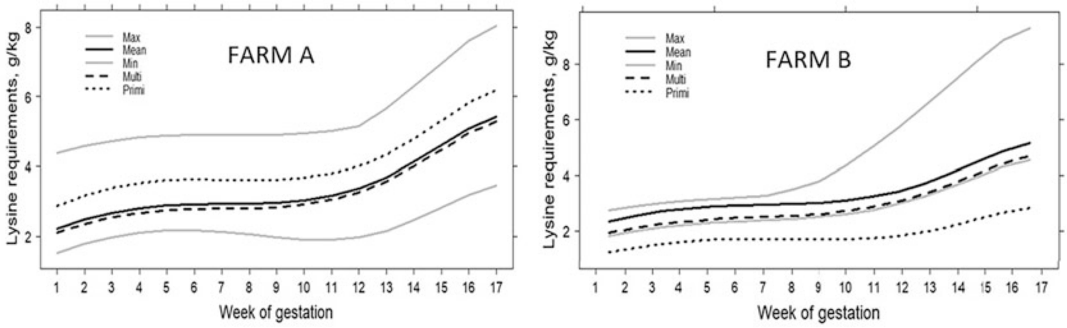
For gestating and lactating sows, the two InraPorc models were tested on two Canadian databases comprising 2511 gestations of 540 sows for one, and 1450 lactations of 633 sows for the other. The week of gestation or lactation, parity, and breeding conditions (farm) significantly affected the daily nutrient requirements of sows and their performance (Figs. 1 and 2, Gaillard et al. 2019, 2020; Gauthier et al. 2019). These factors should therefore be taken into account when predicting nutritional requirements.

For growing pigs, the nutrient requirements are also dependent on the week, the sex, and the breed (Fig. 3). For pigs fed 90–95% of the ad libitum level, compared to uncastrated males, castrated pigs have a lower daily protein deposition and a higher lipid deposition, inducing a lower protein requirement and a higher energy requirement. Females' protein requirement is between that of castrated and uncastrated males.

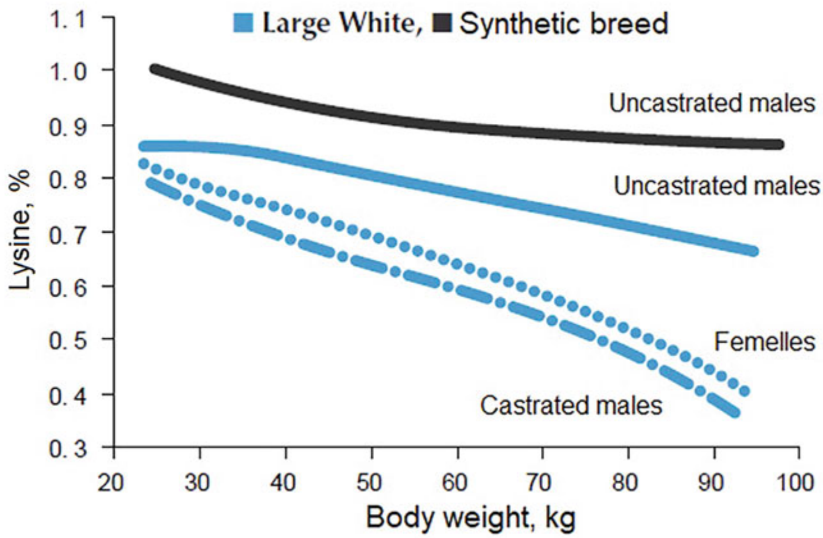
Brossard et al. (2009) used InraPorc to simulate individual responses of 192 pigs to different feeding strategies (1, 2, 3, or 10 successive diets with decreasing nutrient supply) and lysine supply (from 70% to 130% of the mean requirement of the population). As for sows, they showed that the standardized ileal digestible lysine requirement varies between pigs in a population and that the percentage of pigs for which the requirement was met can vary greatly with the feeding strategy (i.e., the number of successive diets) and the growth period. Simulated daily gain and feed efficiency increased with increasing lysine supply according to a curvilinear–plateau relationship.



Precision Feeding of Pigs, Fig. 1 Variability in energy (MJ metabolizable energy (ME)/d) requirements between gestating sows of different parity. (From Gaillard et al. (2019))



Precision Feeding of Pigs, Fig. 2 Evolution of estimated requirements in digestible lysine (in g/kg) during sows' gestation from two farms (farm A on the left and farm B on the right). (From Gaillard et al. (2020))



Precision Feeding of Pigs, Fig. 3 Effect of the type of pig, breed, and body weight on the digestible lysine requirement (% of a feed at 13.4 MJ of digestible energy per kg of feed). (From Noblet et al. (1994) and Noblet and Quiniou (1999))

Thus, simulated performance was close to maximum when the lysine supply was 110% of the mean population requirement.

A Step Forward in Models to Account for Individual Variability

Models presented above allow to study nutritional requirements. However, they require an a priori knowledge of animal performance on the entire studied period to be calibrated and applied. They are used in a retrospective manner to predict the animal response (nutrient use, growth performance), for instance, to a change in the nutritional composition of feed, and thus evaluate and test different nutritional strategies (Pomar et al. 2019). Moreover, even if variability between individuals has been introduced in such models (e.g., Brossard et al. 2009), they use a reference population or profile to describe the potential of animals. This impairs a real-time use that requires a dynamic adaptation to the actual performance of animals (e.g., growth and feed intake patterns) that may differ from the expected "theoretical" patterns (Pomar et al. 2015; Brossard et al. 2017). Furthermore, an increasing flux of data is collected on animals and their environment thanks to the development of sensors (see the section "Sensors and Data Collection for New Feeding Strategies"). Once the data about animals and feeds are collected, they have to be processed in real time to allow the application of precision feeding, i.e., to calculate the concentration of nutrients and therefore the composition and quantity of feed to be provided to pigs each day. This implies to make evolve the functioning of models to be applied. Currently, mathematical models become more and more complex thanks to the development of artificial intelligence methods (e.g., artificial neural networks, machine learning) and computational power, making possible to treat the data collected on animals. This can be seen as a black box approach where models are abstract without link to biological mechanisms and continuously adapt depending on online inputs and output measurements. These models have the advantage to be more flexible to data than mechanistic models presented in part 1. As summarized by Pomar et al. (2019), there are few examples in which these models have been successfully used in PLF or precision livestock feeding applications. Firstly, they do not give indications on biological processes. Secondly, Pomar et al. (2019) indicated that the possible significant time lag between input corrections induced by the model (e.g., dietary lysine concentration) and the response of animals, which can be longer (e.g., body weight gain), can exceed the calibration capacity of these models and then generate irregularities in signals for feeding control. To take advantage of both models issued from artificial intelligence or statistics and mechanistic models, an intermediate approach combining both types of models has been developed, resulting in so-called gray-box models. This can be illustrated in growing pigs by the model of Hauschild et al. (2012), who combined a real-time statistical analysis (through time-series methods) of performances of preceding days (daily feed intake, body weight, and growth) to predict performances of the next day and a mechanistic model (using a factorial approach) calculating amino acid requirements based on predicted performances. For lactating sows, Gauthier et al. (2021) combined online forecasting of daily feed intake, based on previous days' intakes, and time-series clustering (using an unsupervised machine learning method) to better predict individual feed intake. Two types of feed intake trajectories were defined with the clustering method: the first one is characterized by a mostly continuous increase in feed intake over the course of lactation, and the second one by a plateau in feed intake starting from about the 10th day of lactation. The predicted trajectory curve is used as an input to calculate the individual dietary requirement of lysine for lactating sows following the assumption of the mechanistic model InraPorc. Predictions of requirements from such models can then be converted by a controlling system into information about the composition of the diet to be distributed, information that is transferred and used to distribute a tailored diet to the right animal through adapted feeding systems.

Sensors and Data Collection for New Feeding Strategies

As described before, it is essential to consider variability in nutritional requirements among animals to improve feed efficiency. This has led to the development of precision feeding concept. Consequently, knowledge about animals and their rearing environment is essential as a first step in precision feeding process to characterize animals and provide data for further steps. Due to the increasing number of pigs in farms, the data collection has to be as automatic as possible to be performed at an individual level with a useful frequency. Progress has been done in sensors during the last decade leading to affordable technologies, with a variety of technical solutions depending on traits to be measured. Several traits are useful for precision feeding applications and are related to performance (reproduction, feed and water intake, growth), digestive efficiency, body composition, and behavioral and health status (physical activity, feeding and drinking, interactions between animals, health and sanitary indicators). Rearing conditions can also be included in these traits (e.g., light intensity, temperature, and humidity), as well as knowledge of feed nutritional quality. Sensor technologies and applications in pigs to measure these traits have been reviewed by several authors (e.g., Cornou and Kristensen 2013; Benjamin and Yik 2019; Vranken and Berckmans 2017).

Measuring individual traits first requires identifying animals. Radiofrequency identification (RFID) by ear tag is commonly used in pig production for this purpose (Cornou and Kristensen 2013; Brown-Brandl et al. 2019). The ear tag is detected when the pig is close to a system equipped with a reception antenna. This technique is largely used, but some drawbacks (i.e., cost, working load to put or remove tags, sensitivity to interferences) can impair a larger commercial application. Other comparable technologies such as Bluetooth are also tested. With the rise of machine vision cameras and artificial intelligence, methods and commercial applications have been developed to track and recognize pigs individually through body shape or facial recognition (e.g., Wurtz et al. 2019; Marsot et al. 2020). As an input parameter in nutritional models and a performance indicator for pig producers, bodyweight is essential to measure. Automatic systems have been developed for commercial applications to avoid induced workload and stress, and to obtain body weight frequently, based on weighing scales or on 2D or 3D machine vision (Vranken and Berckmans 2017). These systems are currently quite limited in commercial farms but could spread in association with management systems using this information. Automatic feed intake measurement is also essential to precision feeding. This is performed using electronic feeding stations that can also control feed distribution and composition. For growing pigs, few of these systems are available, mainly in research or genetic selection facilities due to investment costs (Pomar et al. 2019). They are more widespread in commercial farms for group-housed gestating or lactating sows to control individual feed allowance. Water consumption is quite simple to measure at different levels (from barn to pen, and sometimes individually) with a connected water meter (Vranken and Berckmans 2017). Additionally to the interest in detecting health problems, for instance (Vranken and Berckmans 2017), knowledge of behavioral activity can be useful in precision feeding. Indeed, physical activity affects the energy expenditure of pigs and sows: for instance, for a pig, standing and walking are twice to several times more energy-consuming than lying (van Milgen et al. 2008). Behavioral activity can be measured, for instance, using accelerometers, but recent developments are mainly based on 2D or 3D machine vision associated with artificial intelligence treatments (Wurtz et al. 2019). General activity, postures, or specific behaviors can be determined by this way.

Concerning the more internal characterization of pigs, body composition informs on the partitioning of tissues (protein/lean, lipid/fat, and mineral/bone) within the animal and its changes during growth or reproduction stages. This information can help to adjust the analysis of nutritional requirements. Body composition is classically approached by measuring the backfat thickness in pigs, which is usually measured using ultrasound. This technique is time consuming as it is performed manually, and the equipment and skilled technicians are costly (Halachmi et al. 2019). It is therefore not suitable for automatic and frequent measurements. Imaging techniques such as dual-energy X-ray absorptiometry, computed tomography, or magnetic resonance imaging are largely used to study body composition with great precision but are limited to experimental or genetic selection facilities due to their costs and constraints (e.g., anesthesia of animals). Despite its relevance for precision feeding and some attempts to use systems based on 3D vision or bioelectrical impedance, automatic and frequent measurement of body composition remains a technical challenge. Finally, health or physiological status can be determined using different technologies (Vranken and Berckmans 2017; Halachmi et al. 2019): for instance, temperature by infrared imaging, pig behavior using machine vision as seen previously, or respiratory problems (e.g., cough) by sound analyzers. Concerning rearing environment, automatic and continuous measurement of temperature, ventilation, or humidity is frequent in commercial pig barns. Such information can be interesting for precision feeding to adapt feed quality or quantity to compensate for the effects of heat stress (Mayorga et al. 2019).

On-Farm Application of Precision Feeding: Experimental Results and Practical Considerations

The combination of devices for data collection on animals and their environment, models to treat in real time this data, and devices to apply models recommendations and adapted feeding strategies allows the application of precision feeding. This section describes some examples of application.

Gestating Sows

In 2019–2020, an experiment took place at the INRAE Pig Physiology and Phenotyping Experimental Facility (doi: https://doi.org/10.15454/1.5572415481185847E12, Saint-Gilles, France), evaluating the effects of a precision feeding strategy compared to a single conventional diet during gestation on feed cost and sows' performances. The gestation rooms were equipped with two automatic feeders each, able to distribute a specific ration each day to each sow. Individual intakes and feeding behaviors (time spent at the feeder, number of visits) were also automatically recorded by the feeders. A total of 8 groups of gestating sows, representing 170 sows, were involved, and each group was housed in a room. All the sows were fed restrictively, and the quantity of feed distributed daily was calculated with the gestating sow version of the InraPorc model (Dourmad et al. 2008). The detailed approach is described in Gaillard et al. (2019, 2020). Half of the sows in each group received a conventional diet, defined as a mixture of two diets in fixed proportions: 27% of the diet low in lysine (diet L, 3.3 g of digestible lysine per kg of feed) and 73% of the diet high in lysine (diet H, 8.5 g of digestible lysine per kg of feed) to constitute a classical gestation diet (4.7 g of digestible lysine per kg of feed). The other half of the sows in each group received a precision feeding strategy, i.e., a daily individual mixture of diets L and H adjusted to individual requirements. The results indicate that precision feeding allowed a reduction of around 25% of the lysine ingested without decreasing feed intake, leading to a decrease of around 4% of feed cost per gestation (so around 3.4 € per gestation or 8 € per ton of feed). Moreover, nitrogen and phosphorus excretions were estimated to have decreased by 18.5% and 9%, respectively. These results are in agreement with previous simulation results performed using databases (Gaillard et al. 2020; Table 1).

The body weight, backfat thickness, and reproductive performances were not affected by the feeding strategy. The litter weight at birth was around 23.1 ± 0.84 kg; the total number of piglets was of 16.3 ± 0.52; the number of piglets born alive was of 15.1 ± 0.66; and the number of weaned piglets was of 11.1 ± 0.48.

Precision feeding did not affect the number of daily nutritive visits to the feeder or the time spent in the feeder. However, the sows fed with precision feeding made more nonnutritive visits to the feeder than the sows fed with conventional feeding. This last point will require more behavioral investigation through video recording or sensors. Indeed, feeding behaviors could be linked to the activity of the sows and therefore to their energy requirement. They could as well serve as indicators of health, like in the study of Weary et al. (2009), where a reduction of the nonnutritive visits to the feeder allowed the identification of the sick calves.

Precision Feeding of Pigs, Table 1 Experimental and simulation results on gestating sows comparing the effects of a precision feeding strategy on lysine supply, nitrogen and phosphorus excretion, and feed cost compared to those of a conventional feeding strategy

	Simulation results (Gaillard et al. 2020)	Experimental results (Gaillard and Dourmad 2022)
Lysine supply	↘25%	↘25%
Nitrogen excretion	↘17%	↘18%
Phosphorus excretion	↘15%	↘9%
Feed cost	↘5%	↘4%

Lactating Sows

For the sows in lactation, an experimentation similar to the one realized on the gestation sows has been done in the same experimental station on 62 lactating sows (Gauthier 2021). Sows were fed ad libitum and housed individually. Similarly to the gestating sows set up, two feeding strategies were compared: a conventional feeding strategy containing 8.6 g of digestible lysine per kg of feed (66% of a diet H rich in digestible lysine 10.57 g/kg; 34% of a diet L lower in digestible lysine 4.70 g/kg) and a precision feeding strategy with a variable content of lysine (individual and daily mixture of diets H and L, mainly regarding sow' parity, body weight, and backfat thickness at farrowing, feed intake, litter size, and weight). The two groups of sows receiving different feeding strategies had the same average parity (3.5), body weight (287 kg), and backfat thickness at farrowing (19.3 mm). The duration of the lactation was not affected by the feeding strategy (27.9 days on average) or the reproductive performances. Compared to conventional feeding, precision feeding allowed the reduction of ingested lysine by 14.3% and, therefore, the feed cost by 2.5% per ton of feed (based on ingredient prices as of July 2020). Moreover, with precision feeding, the ingestions and excretions of nitrogen (−7.7% and −19%, respectively) and phosphorus (−6.5% and −12.9%, respectively) were reduced compared with a conventional feeding strategy.

Another experiment on a commercial farm in collaboration with the group Cérès Inc. (Québec, Canada) was realized in 2020 on 479 lactating sows (240 with a conventional feeding strategy and 239 with a precision feeding strategy), based on the same principles as the one described before. In this case, precision feeding allowed the reduction of lysine ingestion by 23%, feed cost by 10% per lactation, nitrogen intake and excretion by 20% and 28%, respectively, and phosphorus intake and excretion by 19% and 42%, respectively. There was no difference in backfat thickness between the sows of the different strategies, but the sows with the precision feeding lost more weight than the sows with the conventional feeding, even though this loss is quite small (respectively −7.7 vs. −2.1 kg over the lactation). Reproductive performance after weaning was not affected by the feeding strategy. On average, when the sows had been fed with precision feeding, the growth of the litter was high (around 3 kg/d) but lower of around 3% than the litter of the sows with conventional feeding. This might be due to an underestimation of the litter's growth, leading to an insufficient supply of amino acids.

Overall, the results of these two experimentations are going to the same direction, even though the numerical values are different. There is indeed a strong herd effect and/or environmental effect to better integrate into the model estimating the nutritional requirements.

Growing Pigs

In growing pigs, the efficiency of precision feeding was tested by simulation and also confirmed by experimental studies. Pomar et al. (2010) simulated the performances of 68 pigs during 83 days (from 27.2 to 107.9 kg) while receiving an ad libitum allowance of either a classical three-phase feeding program or an individually tailored daily feeding obtained by mixing two diets. Feed intake, growth performance, and nitrogen retention were not influenced by the feeding strategy (Table 2). However, application of precision feeding reduced feed costs by 10.5%, nitrogen intake by 25%, and nitrogen excretion by 38%, while nitrogen efficiency was increased by 30%.

Experimental studies applied precision feeding by comparing conventional feeding programs (two- or three-phase feeding) to individual precision feeding. Targeted feed composition in precision feeding was obtained by blending two diets (with a high and a low nutrient concentration) using automatic feeders, and weight was obtained individually by frequent manual weighing or daily by an automatic weigh scale. For instance, Andretta et al. (2016) found that an individual feeding strategy reduced standardized ileal digestible Lys intake by 26%, nitrogen excretion by 30%, and feed cost by 10% compared to those of a group feeding strategy. Compared to a two-phase feeding strategy, Brossard et al. (2019) observed a reduction of standardized ileal digestible Lys intake by 11%, of nitrogen intake by 9%,

Precision Feeding of Pigs, Table 2 Simulation results on growing pigs comparing feed intake, growth, feed costs, and nitrogen intake, retention, excretion, and efficiency according to a conventional three-phase feeding strategy or a precision feeding strategy

Parameter	Three-phase feeding program	Individually daily tailored diets
Average daily feed intake (kg/d)	2.49	2.49
Average daily gain (kg/d)	0.97	0.97
Feed costs/average daily gain ($/kg)	1.02	0.97
Nitrogen intake (kg)	5.69	4.29
Nitrogen retention (kg)	2.08	2.08
Nitrogen excretion (kg)	3.61	2.21
Nitrogen efficiency (%)	37	48

From Pomar et al. (2010)

and of nitrogen excretion by 14% during the growing phase (before 65 kg of bodyweight). As summarized by Pomar et al. (2019), other systems using automatic feeding systems, visual analysis to estimate body weight, and models to optimize growth, amount of feed, crude protein or amino acid content, and/or reduce ammonia emission were tested to apply daily precision feeding or multiphase feeding at the individual or pen scale. They conclude on the interest of this technique, for instance, to control growth and optimize costs and return on investment.

Practical Considerations

On-farm application of precision feeding requires availability of all components of this technique, if possible at an individual level for an individual application: automatic data collection, data processing, and the controlling tool of the system (Wathes et al. 2008). This includes devices such as automatic blenders, automatic feeders, and animal management devices to apply decisions from support tools (Pomar et al. 2019). Thanks to the development of sensors, automates and methods, precision feeding has an increasing potential to develop in farms. Gestating sows have been reared in groups for several years now, which favored in commercial farms the use of automatic feeders to control feed allowance depending on parity, weight, and backfat thickness. Automatic feeders are also largely developing in commercial farms for lactating sows to favor intake. However, these systems often do not have the possibilities to blend diets adapted to each sow and are not associated with control systems based on nutritional models. For growing pigs, application is currently still at the group level. Feed distribution systems exist that can blend dry feeds and distribute an adapted diet to a specific pen, allowing the application of daily multiphase feeding to the pen scale. Some liquid feed systems allow also to prepare several mixtures for the different pens of a piggery. These systems are often associated with weighing systems through vision in sorting devices and large pens, for instance. Upscaling precision feeding to individual scale in growing pigs requires an automatic feeder able to control individually feed composition and/or allowance. Even if automatic feeders have existed for quite a while to measure feed intake especially in selection farms, very few allow individual control of feed allowance and composition (e.g., Pomar et al. 2011, 2015), and they are still scarcely present in commercial farms.

Pomar et al. (2019) summarized the main issues for the development and adoption of precision feeding in commercial farms. This includes the need to involve experts and stakeholders to develop adapted systems (researchers, engineers, farmers, technology suppliers, etc.), the particular focus to be done on data interpretation and control mechanisms in relation to sensors' availability, on-farm demonstration of benefits of precision feeding (in terms of economy, work, environment, etc.), a balance of decision-making between farmer and automates, an adapted support and training of farmers on these technologies, information and education for consumers and citizens to avoid a negative image of such a technology that could be seen as a further industrialization of pig farming. Therefore, even if the development of precision feeding in pig farms is on the way, it will be more complex than "just" a technological development.

Concluding Remarks

Pig production increasingly benefits from sensors and data collection on animals and their environment. As described in this chapter, this allowed the development of precision feeding components. Besides the considerations exposed for a further application in commercial piggeries, several perspectives have to be accounted for. Additionally to classical performance criteria (growth, feed intake), developments in sensors and data treatment offer possibilities to take into account information on behavior/activity and the physiology/health of animals. Conversely, a renewed interpretation of the dynamics of growth and feed and water consumption can help to quantify mechanisms such as resistance and resilience and to provide alerts on pig health status. Information from sensors would also allow for a deeper understanding of physiological mechanisms and nutritional concepts. Growth models are still considering fixed and average values for parameters such as efficiency of nutrient use (e.g., amino acid) or growth composition (protein to lipid ratio, amino acid composition of the gain). Individualizing these parameters (thanks to adapted measurements) would help to more precisely estimate individual requirements and to refine precision feeding models and real-time application. It will thus be possible to think of precision feeding as an optimization not only of zootechnical performance but also in terms of health and welfare with the intervention of more specific nutrients. All these considerations require further refinement of analysis methods by further combining data-driven (artificial intelligence) and concept-driven (mechanistic models) approaches. The evolution of precision feeding will also imply to think at a larger scale in pig farming systems. Supplying adapted feed (or premix to be blended) at different stages of production requires to conceive adapted feed storage and distribution systems, and also to manage feed formulation in an adapted way. Indeed, feed formulation of premix to be blended was already studied; it can also evolve to integrate further consideration of minerals, origin of feedstuffs, or environmental impacts of feed. Pig farming systems are also evolving with diversification in terms of feed ingredients, bedding, type of feeding (liquid or dry), size of groups, space, and outdoor access. If precision feeding can drive change in a farming system to achieve application, the data collection, models, devices, and scale of application (individual, pen, and room) will also have to be adapted to this diversity of farming systems. In conclusion, precision feeding of pigs is a valuable technique, with increasing application and still challenges to meet to scale up.

Cross-References

► Some of the relevant entries in this encyclopedia **could be added after being published online as a living chapter**.

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