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Review Article

Precision feeding in pig production: A review

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Abstract

Pig production system has reached high-performance level over the last few decades. However, there is still space for improvement when it comes to their environmental sustainability and cost of production. This issue is even more relevant due to the growing demand for food by human population since this food production needs to be met at an affordable cost with minimum impact on the environment. Precision pig feeding involves the exercise of feeding techniques that permit the accurate amount of feed with the accurate composition to be provided at the accurate time to each pig in the population. In the farming of growing-finishing pigs, nutritional programmes are planned to maximize the responses of animals at minimum cost of feeds. Implementation of precision feeding models which are currently in use, through their improvement, can further reduce the environmental footprint of the swine industry with reductions of feed cost, nitrogen and phosphorus excretion and greenhouse gas emissions. Recent advances in precision feeding depend on the improvement of sound nutritional concepts and inclusive biological models to more precisely estimate individual real-time nutrient requirements. Precision feeding with real on-farm implementation in pig or pork production still necessitates superior understanding of variability among individual animals corresponding to their behavioral, physiological, nutritional and production responses. All types of latest scientific know-how in animal sciences need to be incorporated with information and communication technologies for further development and regular application of precision feeding in pig production.

Keywords: Environment, Nutrient, Pig, Pork, Precision feeding

Highlights

- This review will serve as a valuable source of information regarding the present status of the precision feeding system in pig production.
- This will help to understand the ways to reduce environmental impacts by optimizing the use of dietary nutrients and nutrient utilization efficiency by individualized pig feeding leading to less nutrient excretion.
- Precision feeding method with its many positive nutritional responses at the farm condition will draw interest for further research.
- This will be helpful for further advancement of precision feeding system for its on-farm implementation in pigs.
- This article will give significant insight to develop a standard precision feeding method with the prospects for nutritionists and pig production experts to increase pig production to the optimal level.

INTRODUCTION

Pork, i.e., meat of pigs, is one of the world's most consumed meat products with 110 million tons of meat produced annually (FAO Stat, 2020). Pork or pig production system has reached high-performance level over the last few decades. Still, there is space for upgrading while it comes to their sustainability in relation to the environment. This area is even more relevant due to the rising requirement for food by human population since this food production needs to be met at an affordable cost with minimum impact on the environment (Andretta *et al.*, 2021). Feed cost is considered the maximum input cost in pork production (65-75%), and nutritional efficiency has an

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immense impact on productivity. In pigs, feeding programmes are proposed to optimize herd responses at minimal feed costs. Precision pig feeding is intended to attain completely automatic feeding management of pigs, stressing on every individual pig, by means of scientific progress as part of the management process. It can potentially improve feed efficiency, performance, animal welfare and decrease emission of livestock. Thus it influences the financial viability and sustainability of animal production by reducing farm costs, environmental loads, monitoring quality and improving animal welfare (Gaillard *et al*., 2021).

Precision feeding allocates diets tailored daily to the requirements of the animals. Though nutrient requirements differ greatly among the pigs of a given herd (Pomar *et al.*, 2003; Brossard *et al.*, 2009; Hauschild *et al.*, 2010) and for each pig, these requirements alter over time following individual patterns. The aim of precision feeding is the building up a system which is competent to measure as well as supply, at the right time, a diet or ration with an amount and nutrient composition precise to the daily nutrient requirement of every animal (Gaillard *et al*., 2020). Precision pig feeding involves the exercise of feeding techniques that permit the accurate amount of feed with the accurate composition to be provided at the accurate time to each pig in the population. Using this approach, it has been estimated that feeding costs can be reduced by more than 4.6%, and nitrogen and phosphorus excretion can both be reduced by more than 38% (Pomar *et al.*, 2009). This is acknowledged as information intensive nutrition or personalized nutrition also. Nowadays main challenges for pig farming and industry are to maximize feed efficiency while minimizing production costs and environmental impacts. Feeding pigs requires tremendous amounts of feed resources, with several studies indicating it as an important source of environmental impact (McAuliffe *et al.*, 2016). As well, pigs excrete huge quantities of nitrogen as well as phosphorus into the environment every year, which influences the sustainability of pig production in these chains (Lovatto *et al*., 2005).

Objectives of precision feeding in pigs

The followings are the main objectives of precision pig feeding-

1. Effective utilization of feeds and nutrients
2. Optimizing productivity
3. Reduction of feed cost
4. Increasing profitability
5. Reduction of environmental pollution

Principles of precision pig feeding

With aiming to optimize nutrient utilization, robust and flexible feed formulation are required to be developed while fine-tuning these three steps- 1) estimation of the nutritive value of the feed ingredients considering modulating factors, (2) accurate measurement of nutrient requirements of animals and (3) precise feeding systems (Chassé *et al.*, 2021). Therefore, following parameters have to be considered for precision feeding of pigs-

- Precise nutrient analysis of feed
- Estimating the real-time nutrient requirements of individual pig
- Formulating balanced rations accurately at minimal cost to minimize nutrient deficiency or excess
- Providing individual pigs with daily modified or customized diets

Precise nutrient analysis

Nutritional analysis of the ingredients used in pig ration and finished feeds can be done by conventional methods and advanced techniques. Following criteria are considered for precise nutrient analysis-

- Precise nutrient composition of the ingredients of the diet
- Presence of anti-nutritional factors in ingredients
- Bio-availability of nutrients

Nutritional requirements of pigs

Factorial methods, such as BIS (1986)

(reaffirmed 2001) or NRC (2012), are traditionally used to measure the nutrient requirements of pigs fed in large groups that are given the same feed for extended periods throughout their production period (Pomar and Remus, 2019). Different non-nutritional factors can affect the estimation of pigs' nutrient requirements to be used for precision feeding (Gaillard *et al*., 2021).

Limiting excess nutrients through precision pig feeding

Improving nutrient efficiency is vital owing to the challenges linked with the likely increase in the human population, limited arable land, and the environment related problems which are often connected with livestock production (Niemann *et al*., 2011). The high significance of environmental excess of some nutrients has forced pig producers and nutritionists around the world to re-evaluate the nutritional and feeding programmes presently in use. One of the most important approaches is to formulate balanced diets for animals. It involves regular collection and monitoring of data about body weight, physiological status, production pattern, nutrient utilization efficiency, nutritional composition of the dietary ingredients and finished feeds, effects of anti-nutritional components of the dietary ingredients, etc. All these data can be used through balanced feed formulation software or models to formulate such diets that would accurately meet the nutrient requirements of the animals without any deficiency or excess of the nutrients. Nutrient excretion can be decreased by giving an individual pig with its nutrients in the concentrations required daily through precision feeding method. Factors that influence feed utilization efficiency in animals include feed spillage, feed digestibility, composition of gained body mass, feed intake as well as nutrient utilization. Choosing the proper form of diet or feed as well as the proper density and supply of nutrients, and decreasing the negative effects of environment related factors ought to improve nutrient utilization and feed efficiency in pigs (Gaillard *et al*., 2020). Dietary crude protein concentration can be decreased by using supplemental synthetic amino acids. Pigs fed precisely with daily customized diets require less crude protein than traditionally fed pigs (Remus, 2018). Lowering crude protein intake significantly reduces nitrogen excretion and environmental impacts. The optimal amino acid ratio differs between precision and conventionally fed pigs (Remus, 2018). Precision fed pigs have different metabolic responses than conventionally fed ones (Brossard *et al*., 2009). Precision feeding increase the amino acids' utilization compared to conventional feeding system as conventionally group fed pigs receive the amino acids in higher amount than individually precision fed pigs (Remus *et al*., 2020). This feeding method causes reduction of amino acid intake from 17% (Remus *et al*., 2019a, 2019b) to 27% (Andretta *et al*., 2014, 2016b).

Excretion of the excess phosphorus can be curtailed by formulating pig feeds on the basis of the digestible phosphorus as well as adding exogenous phytase. The economic and environmental effects of phytase in the production of livestock have been widely acknowledged. Various researches have demonstrated that phytase is a highly efficient hydrolic enzyme to release phosphorus in phytic acid, which improves the utilization rate of minerals including phosphorus and amino acids in pigs (Yuanfeng *et al*., 2020). Efficient feed additives, for instance, enzymes, probiotics, prebiotics and others that increase nutrient utilization in animal feeds can also have considerable impacts on cost of production and negative ecological consequences. Using highly bio-available sources of phosphorus and trace minerals and avoiding excesses of these nutrients during the diet formulation can minimize excess mineral contents in manure. The feeding, as well as nutritional strategies, should be planned to trigger mineral synergies and homeostasis, not only with phosphorus but also including other nutrients, thereby significantly reducing the formations of the insoluble-phytate-mineral-complexes that impede mineral solubility for absorption. These strategies may consist of the use of microbial phytase to release phytate-phosphorus, use of low-phytate crop varieties or cultivars, and improving diets based on the use of true digestible calcium to true digestible P ratio (Johnson and Ogbamgba, 2021). All these mechanisms integrated in precision feeding method can limit excess nutrients and supply precise amount and proportion of highly bio-available nutrients to every pig within a farm.

Effects of precision pig feeding on environment

The precision feeding is a capable feeding method to diminish the ecological footprint of swine production (Gerber *et al.*, 2013). As far as environmental impacts are concerned, the problem lies chiefly with the excretion of nitrogen and phosphorus, which is achieving disturbingly soaring points in the majority of the swine production regions. Pig manure contains 5% nitrogen and 3% phosphorus. Precision feeding methods in growing pig farming can notably lessen feed or cost of production (>8%), intake (25%) and excretion (40%) of phosphorous, lysine and protein, and emissions (6%) of the greenhouse gases by escalating nutrient utilization efficiency of individual animals (Andretta *et al.*, 2014; Andretta *et al.*, 2016b; Andretta *et al.*, 2018; Pomar and Remus, 2019). Lessening such negative environment related effects is important because high levels of nitrogen, phosphorus and trace minerals in manure that are applied to croplands can cause soil concentrations of these nutrients to exceed crop removal rates. The protein in the pig feed, which is not included in the animal products, is expelled from the body and can result in environment related troubles such as nitrate pollution of aquifers and surface water pollution with problems like blooming of algae (Pomar and Remus, 2019). Nitrate can leach through soils and contaminate ground water supplies, and is considered to be a major pollution concern from livestock farms including pig farms. Methane and nitrous oxide gas formed in manure add to the emission of greenhouse gas, and volatilization of ammonia causes acid rain that has harmful effects on trees and vegetation. Higher concentration of phosphorus released through pig manure in the environment may contribute to environmental contamination, deterioration and degradation leading to eutrophication by excess of phosphorus (de Souza Oliveira Filho *et al.*, 2020; Johnson and Ogbamgba, 2021). Phosphorus may go into surface waters through soil erosion and amplify augmentation of algae and other aquatic vegetation, which reduces dissolved oxygen that can cause fish death. Additionally, too much trace minerals (e.g., copper and zinc) accretion in soil can increase the risk of toxicity of plants and micro-organisms (Dourmad *et al.*, 1999).

Precision feeding strategies for growing swine are a promising solution to diminish the nutrient excretion by adjusting the nutrient supply to each individual animal at different points in time (Gaillard *et al.*, 2020). The losses of energy and nutrients in relation to the conversion of feed nutrients to animal products add to cost of production and the environmental load relating to nitrogen, phosphorus, trace elements, carbon as well as methane (Pomar and Remus, 2019). Switching from a conservative feeding programme to the precision feeding method during the growing and finishing phase would have a prospective environmental effect on pig production. Environmental impacts were estimated as per the life cycle assessment (LCA) standards through the approach described by Guinée *et al.* (2002) based on four interconnected steps-goal and scope definition, life-cycle inventory, life-cycle impact assessment as well as interpretation. Precision feeding programmes cause minimization of nutrient excretion plus odour and gas emissions from confinement pork production facilities (Lu *et al.*, 2017). Environmental cost grain used for swine diets is also minimized in precision feeding system.

Improvements of available precision feeding models may additionally lessen the environmental footprint of pig farming with projected cutback of feed cost of >12%, excretion of nitrogen and phosphorus > 60%, and emissions of greenhouse gas >12% (Pomar and Remus, 2019).

Precision feeding models in production of pigs

Several precision feeding models which were developed to improve production efficiency of pigs are described below.

Whittemore: Whittemore and Fawcett (1976) pioneered the development of the mechanistic pig growth models simulating growth in pigs representing the essential elements of protein and energy utilization. The model has been frequently updated (Whittemore, 1983; Whittemore, 1986; Whittemore, 1995; Green and Whittemore, 2003) and is proposed today for real-time control of the pig growth through integrated management systems (Green and Whittemore, 2003; Green and Whittemore, 2005; Parsons *et al.*, 2007). This model has inspired many of the existing deterministic pig growth models.

Auspig: Auspig is a computer-based model of advanced decision support system for the present day Australian pig producers. It was initially developed based on a deterministic pig growth model made by Black *et al.* (1986). This model has been deeply updated and extended to integrate the latest research findings to assist producers with improving productivity and maximizing returns (Black *et al.*, 1993) till date.

PorkMaster: A first deterministic, dynamic and mechanistic biological model was developed by Moughan and Smith (1984) to predict dietary protein utilization in pig as well as used to evaluate dietary protein quality. This model was updated and extended (Moughan *et al.*, 1987; Moughan and Verstegen, 1988; Moughan, 1989; Moughan and Fuller, 2003) and used by Ralston Purina International Company to predict biological and economical animal responses to genetic and dietary changes. This model was the base for other models such as the TMV (TMV modelling group, The Netherlands) as well as Pork Master (University of Guelph, Canada) and others (Birkett and de Lange, 2001; de Lange *et al.*, 2003) and has been used to improve profitability in pig farms (Morel *et al.*, 2010; Morel *et al.*, 2012). The Pork Master software includes a decision support system to help users to optimize the systems of swine production.

PorcExpert: PorcExpert was a deterministic, dynamic and mechanistic model predicting growth and body composition of boars, barrows and gilts in relation to their genotype, feed as well as management (Pomar *et al.*, 1991). This model was combined at the whole-animal level with three main components of body composition including total body DNA, total body protein mass and total body mass of lipids, with total protein determining the secondary components of ash and moisture. An updated version of this model has been integrated into the Pork Expert software.

NRC: The National Research Council of the USA introduced in 1998 (NRC, 1998) the modelling approach in determining the requirements of nutrients using the factorial approach for the growing-cum-finishing swine, and gestating and lactating sows. In grower pigs, daily requirement of lysine is estimated by the addition of maintenance as well as protein accretion. This model was updated in 2012 (NRC, 2012) to estimate the requirements of the standardized ileal digestible amino acids as well as nitrogen, standardized total track digestible phosphorous and total calcium of one swine in the 20-140 kg body weight interval. This updated model is dynamic, deterministic and mechanistic representing the biology of the pigs at the whole-animal level.

Lovatto: A dynamic, mechanistic and

deterministic model of homeorhetic as well as homeostatic controls of swine growth was proposed by Lovatto and Sauvant (2003). The homeorhetic principles were based on changes in time of fractional rates of tissue metabolism (anabolism as well as catabolism). The homeostatic principles combine information on the plasma kinetics as well as nutrients partitioning between anabolism and catabolism of the body tissues as well as endogenous losses with the integument and into the gut. The main features of the model are two levels of organization (tissue and plasma) and three body tissues (visceral proteins, carcass proteins and body lipids).

Schinckel: Research data was used by Schinckel to develop a dynamic, empirical and stochastic model describing the daily growth with composition of pigs fed the ractopamine (Schinckel *et al.*, 2003). This model permits the outcome of ractopamine to be supplemented to farm specific growth curves of pigs. It can be applied to assess the approaches to maximize the ractopamine use, incorporating duration of feeding and ractopamine concentration as well as dietary lysine concentration. Similar move was exercised to reproduce the non-linear relationships that exist between birth, weaning and nursery-exit weights to later grow-finish body weight, body composition and lysine requirements (Schinckel *et al.*, 2009; Schinckel *et al.*, 2010). The model empirical equations were obtained from serial grow-finish body weight measurement of the barrows as well as gilts using a mixed model generalized Michaelis-Menten equations in which two random effects were introduced.

Watson: Watson is a ration optimization programme developed by Nutreco Canada to match the feed offered to the animals with their specific requirements of nutrients in order to optimize production, health as well as production efficiency. This software includes a stochastic mathematical model (Ferguson *et al.*, 1994; Ferguson, 2006) based in the concepts earlier developed by Emmans (1981) to predict feed intake, and the partitioning rules and other elements (Kyriazakis and Emmans, 1995). The Watson model allows producers to see the outcome of potential changes before they actually make them, and can help producers determine what improvements they should make to optimize their production system. The same concepts used in this feeding model had been used to simulate pig population responses by other authors (Knap, 2000; Pomar *et al.*, 2003; Wellock *et al.*, 2003).

Automatic and intelligent precision feeding (AIPF) system: New modelling approaches have been recently proposed to develop automatic and intelligent systems of precision pig feeding with the objective of feeding each pig with customized diet daily (Pomar *et al.*, 2009; Pomar and Pomar, 2012). For this purpose, a mathematical model predicting real-time daily requirements of amino acids of each growing-finishing pigs was developed including empirical and mechanistic components (Hauschild *et al.*, 2012; Rivest *et al.*, 2012). The empirical component estimates feed intake per day, body weight changes as well as gain in body weight per day based on individual animal information composed in real time. On the basis of this data, the mechanistic element applies classic factorial equations to determine the optimum level of the amino acids which must be served daily to each animal of the herd to fulfill its amino acid requirement. The basic concepts used to develop this model have been described (Pomar and Pomar, 2012; Pomar *et al.*, 2014). The effectiveness of this model has been evaluated in recent studies (Andretta *et al.*, 2014), and the model has been calibrated (Zhang *et al.*, 2012; Cloutier *et al.*, 2015).

InraPorc: The contemporary status of know-how was integrated in InraPorc model for grower pigs as well as for the sows to make it accessible as a software device to end-users, mainly nutritionists involved in the pig nutrition and production. A decision support tool was developed from a set of equations, with additional modules to describe animal's characteristics and adjust some model parameters to account for variations in genotypes and performance. This tool could be used to estimate the requirements of energy and amino acids of sows as per production objectives or to envisage the changes in body composition according to a given feeding strategy (Dourmad *et al*., 2008). Under this, a dynamic, mechanistic and deterministic model developed to appraise the effect of using different nutritional strategies like performance and carcass characteristics on nutrient utilization of growing pig (15-150 kg body weight) was proposed by van Milgen *et al.,* (2008). This model was based on the conversion of feed nutrients to the body protein and lipid which were then used to calculate body weight, lean body mass as well as backfat thickness. The InraPorc model was extended to represent the variation in response between pigs using a stochastic approach (Brossard *et al*., 2009). This technique was developed to allow end-users of InraPorc to easily characterize their animals based on observed data and then use the model to test different scenarios. Further improvements have been made, in which a common covariance pattern of growth model parameters through different groups has been suggested and validated (Vautier *et al*., 2013). The predictive models of nutrient requirements as well as excretion, for instance, InraPorc, have been made and applied to choose the best strategies of feeding (Gaillard *et al*., 2020).

Other models: In automated precision feeding method of pigs a mathematical model predicting real-time daily requirements of amino acids of each growing-finishing pigs was developed including empirical and mechanistic components (Hauschild *et al*., 2012). Hansen *et al*. (2014) studied to build a mathematical model to explain the partitioning of the energy and nutrient as well as forecast the excretion and composition of the manure and the methane emissions on a daily basis in sows during reproduction phase. The model was prepared to include gestation and lactation modules, which could be run singly or sequentially, with outputs from the gestation module used as inputs to the lactation module. The model was assessed using independent data sets from the literature using root mean square prediction error (RMSPE) and concordance correlation coefficients. However, the authors observed that though the model gave a framework, further refinements and improvements in precision of prediction (particularly urine nitrogen) were necessary before the model could be used to appraise environmental mitigation options from sow production.

Models for estimation of mineral requirements: Jondreville and Dourmad (2005) applied a factorial approach to determine digestible phosphorus requirements for maintenance as well as production under different physiological stages of pigs. Based on this approach and the reviews of NRC (2012) and Bikker and Blok (2017), the estimation of phosphorus and calcium requirements was adapted for gestating sows and incorporated in the nutritional model shown in Gaillard *et al.* (2019). The model makes it feasible to adjust dietary phosphorus supplies to sow and litter performance. However, using this model, phosphorus requirements for growth are determined with certain limitations. More mechanistic models have recently been developed, in which mineral concentrations (phosphorus and calcium) can vary independently of protein and lipid mass (Letourneau-Montminy *et al*., 2015), but until now, they had been built in support of growing pigs only. Lautrou *et al*. (2020) developed a mechanistic type of model for phosphorus and calcium requirements of grower pigs and compared it to the recognized factorial models, INRA (Jondreville and Dourmad, 2005) and NRC (NRC, 2012). In the future, it might be interesting to formulate diets based on the amino acids as well as mineral requirements simultaneously and therefore mix three diets instead of two diets (Gaillard *et al*., 2021).

Applying precision feeding method in pigs

Providing each pig with customized diets daily is the motto of precision feeding method. New feeding technologies (e.g., sensors and feeders) permit the group-housed pigs to be fed depending on their individual nutrient requirements, which would improve group performances (Gaillard *et al.*, 2020). This feeding system includes the methods that supply pigs with feeds modified consistent with the production. The purposes are to deal with environmental effects and swine welfare concerns. In this feeding method feeding to each animal is practised. To do this, the alteration in requirements of nutrients occurring over the time as well as individual variation in animals are considered. Exact determination of accessible nutrients in the ingredients of diets, accurate ration formulation and estimation of the requirements of nutrients of each pig or a group of pigs should be incorporated in the preparation of precision feeding methods (van Kempen and Simmins, 1997; Pomar *et al.*, 2009).

Execution of the system of precision feeding management in commercial pig farms needs the assimilation of three sorts of actions - automatic data collection, processing of data as per established control tactics and action pertaining to the control method of the entire system (Aerts *et al.*, 2003; Banhazi *et al.*, 2012b). Hence, the gathering of data, processing of data and control system of feeding are necessary for individual pigs in the farm where this system would be applied.

Data collection: Sensors and automatons are being developed, thus allowing an automatic and real-time data collection, which leads to ration adjustments for pigs in a farm (Gaillard *et al.*, 2021). The data can be gathered by the cameras – CCTV, infra-red, thermal, etc. – as well as real-time analysis systems, microphones and sound analysis system, or any other sensor within the production unit or on the animal such as accelerometers, radio frequency identification device (RFID) sensors, etc. (Arulmozhi *et al.*, 2021; Tzanidakis *et al.*, 2021). Measurements of several parameters of the animals, the diets and the environment related components are vital for precision feeding, and these parameters are required to be estimated directly and repeatedly (Pomar and Remus, 2019). Important estimation related to precision feeding in grower pig rearing comprises feed intake plus body weight or body weight gain. The accessibility and the fast advances of latest gadgets and rising sensor technologies present immense possibilities for other measurements, e.g., physical activity of animals, interactions among the animals plus composition of animal body. The RFID ear tags in monitoring pig movement helps in further accurate determination of requirements and real-time animal monitoring. Camera-based computer vision techniques can be used as a more promising solution for pig monitoring, because such techniques offer a low cost, non-invasive and non-attached application. Three-dimensional (3D) video cameras (top view with depth sensors) ought to be used to observe pigs. However, three major problems may be generally observed with video-based detection and tracking of individual pigs- (1) light fluctuation. e.g., abrupt light changes that may take place in the sheds of the pigs, together with various illuminations at the time of the day and night (light-on and light-off), which can cause a change in the camera imaging model (Zhang *et al.*, 2019), (2) very comparable appearances of pigs and varying status of the background and (3) the object deformations as well as the occlusions. Two dimensional (2D) and 3D video camera-based systems are also used for individual pig detection and tracking without the need to manually mark or physically identify the pigs, working under different environmental conditions such as, daylight and/ or night (Zhang *et al.*, 2019). Various data related to pigs, which are collected by using different sensors, can be employed for nutrition, welfare, health and ultimately in support of precision feeding of pigs (Cornou and Kristensen, 2013; Matthews *et al.*, 2016; Gaillard *et al.*, 2021).

Processing of data: Data collected about pigs are processed consistently with the goals of farm production. If feeds are offered *ad libitum* to the animals, the main approach to regulate intake of nutrients should be altering the composition of feeds to be offered. By this way, different type of variations like between-animal variation and time-dependent nutrient requirement variation can be regulated. On the contrary, if the animals are kept under restricted feeding regime the quantity and the composition of the feed can be regulated without difficulty (Pomar and Remus, 2019). Mathematical modelling is a method applied to realize and measure complex biological happenings concerned with livestock production and it is the basis for processing of data in precision feeding methods. Mathematical models prepared in support of precision feeding need to be planned to work in real-time situation using real-time system measurements. Consequently, these are structurally dissimilar from conventional nutritional or feeding models that are built up to operate in a retrospective way as well as to simulate known production condition (Pomar and Remus, 2019). The first mathematical model formed for determination of nutrient requirements of each pig in real-time setup was predicted by Hauschild *et al.* (2012). Lysine concentration required per day is anticipated in this model by using information of body weight and feed intake of individual animal. By means of these data, an empirical model element determines the anticipated feed intake, body weight gain and body weight for the next day, while a mechanistic model element exercises these estimated variables to compute with a factorial technique the optimum level of lysine, which should be served on that day to every pig in the group to fulfill its lysine requirement. Other amino acids as well as the nutrient requirements are implicit regarding lysine requirements (Pomar and Remus, 2019).

Control system of feeding: The data gathered and processed is utilized to manage the pig feeding system. Automatic feeders for precision feeding are used to give each pig with the accurate quantity and composition of the diet or feed at a particular time. Plastic button tag with passive transponders (RFID) is attached in the ear of every pig. This specialized tag is used for the identification of pigs. Minimum two feeds (such as feed 1 and feed 2) are prepared considering the energy like net energy, amino acids like standardized ileal digestible amino acids as well as any other critical nutrients. These two diets or feeds are required for precision feeding method. Feed 1 (highly nutrient dense diet) is prepared for the most demanding or growing pigs at the beginning of the growing phase. Feed 2 (low nutrient dense diet) is prepared in support of the less demanding or growing pigs at the end of the finisher phase. Mixing feed 1 and 2 at varying proportion permits the feeders to supply individual animals with the accurate diet (Pomar and Remus, 2019). In every feeder, precision Archimedes' screw conveyor puts and mixes volumetric quantities of two diets kept in independent two feed containers. When the pig enters its head into the feeder, the feeder recognizes each animal, two diets or feeds (feed 1 and 2) are mixed, and mixed feed is delivered as per the pig demand as per the predicted optimal level of lysine. Daily ration is delivered in several servings. A serving consists of the quantity of diet delivered as per every effective serving demand by a pig in automatic feeder. A time interval is obligatory to make sure that animals eat all feeds of previous serving before requesting a new serving of the feed. Serving size is gradually augmented and it ranges from 15-25 g (Pomar *et al.*, 2011). Weekly measurement of feed density should be done and this data should be used to calculate feed weight from feed volume.

Pomar *et al.* (2014) used a real-time modelling-control procedure to manage the time-dependent difference of group housed pigs served feed *ad libitum*. They mentioned that protein intake could be decreased by 7% and nitrogen excretion could be decreased by 12% by comparing between traditional three-phase feeding system and daily-phase feeding system of pigs. If the time-dependent as well as individual animal variations are controlled, intake and excretion of nutrients can also be reduced. It can be predicted that cost of feed would be reduced by 1-3% by regulating the time-dependent variation only. However, 8-10% drop in feed cost could be attained by controlling both of the sources of variation, i.e., time-dependent variation and individual animal variation. Nitrogen excretion can be cut by almost 30% if pigs are supplied with daily customized diets (Pomar and Remus, 2019).

Conclusion

The precision feeding method in pigs is likely an essential means to augment sustainability and competitiveness in the pig farming and industry. It can reduce environmental impacts by optimizing the utilization of nutrients and nutrient utilization efficiency by individual animals resulting in nutrient excretion in less amount. Various mathematical models designed for precision pig feeding practice need to be applied in real-time setup using system measurements. For next level improvement in precision feeding technique in pig production, it is required to make our actual understanding of several animal metabolic processes better. Each pig is able to transform the growth and body composition consistent with the levels of the available amino acids. Recent progresses in precision feeding of pigs depend on the improvement of concrete concepts of nutrition as well as inclusive biological models to further accurately determine real-time nutrient requirements of each pig. The innovative idea of metabolism plus nutrition of individual animal would help the animal science to progress, opening up new prospects in support of individualized pig feeding as well as nutrition. Advances in precision feeding techniques would also comprise latest knowledge regarding the genetic potential of each pig to proficiently utilize the nutrients and incorporate this in daily evaluation of optimal nutrient requirements of each pig, relations between feeding patterns, composition of diet as well as digestive and metabolic dynamic accessibility of the nutrients. All of these would eventually augment sustainable productivity along with profitability of safe and environment friendly pig or pork production. Precision feeding with real on-farm implementation in the system of pig production still necessitates superior comprehension of variability among individual pigs corresponding to their behavioral, physiological, nutritional as well as production responses. All types of latest scientific know-how in the field of animal sciences need to be incorporated with information technology as well as communication technology for further development and regular practice of precision feeding in pig production. The success of precision feeding technique in the system of pig production would depend on the integration of precision feeding of the pigs into the pig farming system, as well, the adaptability and training of the farmers to use the precision pig feeding systems in farms.

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