Challenges and opportunities for swine nutrition

Dan Columbus, Ph.D.
Prairie Swine Centre

The issues facing pork producers and swine nutritionists moving into the future are similar to what they have been for decades, a need to increase productivity while meeting increasing demands from legislation and consumers to ensure economic, environmental, and social sustainability. While the challenges are the same, the methods with which we tackle these issues are evolving, and nutritional sciences will necessarily include additional aspects, such as physiology, metabolism, and microbiome, among others, to advance the field. There will also be a shift in focus to consider not only the impact of nutrition on growth, but on animal health and welfare as well, and to incorporate the impact of feed decisions on the environmental impact, and specifically the carbon footprint, of pork production. Our understanding of the complex interactions of the competing and symbiotic relationships between feedstuffs and animals as well as the incorporation of advancing technology, such as improved growth models and precision feeding, will be crucial for the advancement of the industry.

Introduction

"Pig producers will need to cope with higher feed costs, more pressure from legislation and, at the same time, more expectations from consumers." I think most people would agree that this would characterize very well the challenges facing the pork industry today. This statement, however, is from an article by Matheiu Cortyl written in 2014 for WattPoultry magazine. This seems to be a very accurate prediction, but I think it more reflects the challenges the industry has always faced. Indeed, these challenges are numerous and complex, including disease outbreaks, market fluctuations and trade, cost of production, animal welfare and environmental impact concerns, and labour shortages, among others (Eadie, 2023). While the specific issues may change over time, this demonstrates a highly resilient and adaptable industry.

Cortyl goes on to say, "Improving feed efficiency will be the key for success, and for this we need to remember the basics." While this is generally true, as the main determinant of profitability and sustainability is feed efficiency and, by extension, feed costs, we need to move beyond the basics of nutrition if we wish to continue to grow to meet an ever-increasing demand for pork in an economically, environmentally, and socially sustainable manner.

More than growth: feeding pigs for optimal health and development

One of the most significant changes the industry has faced in the last decade is the banning of the use of in-feed antimicrobials for growth promotion because of increasing fear of contributions to antimicrobial resistance as well as decreasing consumer acceptance of antibiotic use. While the outcome of sub-therapeutic antibiotic inclusion in the diet was improved growth performance, the reason for this effect was largely due to decreased disease pressure. This is still evident as, even though overall antibiotic usage has been decreasing, the proportion of in-feed antimicrobial use identified as for disease prevention increased from 50% in 2015 to 74% in 2019 (CIPARS, 2019). It is widely known that disease-challenged animals grow slower, are less efficient, and have greater mortality resulting in reduced profitability and welfare concerns. In addition, Woods (2023) estimated that poor health was one of the biggest contributors to emissions from pork production. Efforts to identify how nutrition can support animal health in addition to growth will not only improve profitability, but also aid in efforts to reduce antimicrobial use and improve public perception of pork production.

It's no secret, we feed animals for optimal growth, with feed formulations, and the requirements on which these are based, are determined for healthy, growing animals with little or no attention given to the requirements of other outcomes (e.g., gastrointestinal development, immune status) other than inclusion in the black box of 'maintenance' requirements. The reduction in performance during disease challenge has largely been attributed to a reduction in feed intake, however, it has been demonstrated that both reduction in nutrient supply (i.e., feed intake) and nutrient utilization (i.e., maintenance requirements) both contribute to the reduced growth, with the proportion dependent on the specific challenge. Several studies have demonstrated an increased requirement for amino acids for growth during disease challenge (Rodrigues et al., 2022a, 2021a), and others have shown clear benefits to growth, health status, and intestinal function when amino acids, such as methionine, threonine, and tryptophan, are included above requirements for growth (Rodrigues et al., 2021b; Wellington et al., 2019).

In addition to requirements for health, it has been suggested, not surprisingly, that amino acid requirements are dependent on the specific outcome to be maximized. In many cases, requirements for some outcomes may be greater than for growth, with traditional growth requirement models being inadequate to determine these requirements. For example, the requirement for lysine in sows to maximize piglets born is greater than required for nitrogen-retention, the valine requirement for survival rate is greater than for nutrient retention efficiency in tilapia, and the methionine requirement in broilers is greater for maximum immune status (i.e., immunoglobulin titer) than for weight gain (Ramirez-Camba and Levesque, 2023).

> "Disease challenged pigs grow slower are less efficient, with higher mortality"

Of necessity, in addition to re-evaluating amino acid requirements, an improved understanding of how dietary nutrient content supports proper gastrointestinal development and function and immune response. In other words, the functional value of nutritional ingredients. This includes the ever-evolving understanding of how dietary protein and fibre content affect animal health. For example, while low dietary protein is considered beneficial for weaned pig gut health, the results of reducing protein are inconsistent. It has been suggested that the indigestible protein fraction of dietary protein is more highly correlated with negative outcomes than total protein (Babatunde et al., 2023). Likewise, historically, dietary fibre was considered an anti-nutrient, especially in the post-weaning period, however, more recent studies have indicated that inclusion of fibre, both soluble and insoluble, have benefits to gut health and growth of nursery pigs.

Overall, the evidence indicates a necessary shift in our view of nutrient requirements and the functional aspects of nutrition. Further, determination of requirements will need to be based on the desired outcome, which, in some instances, is not growth.

Environmental impact: feed efficiency and beyond

There has been significant discussion on climate change and, rightly or wrongly, intense focus on agriculture's contribution to emissions. Through great strides in areas such as genetics, nutrient requirements, feed processing, and management, animal agriculture in general, and pork production specifically, have much less environmental impact today than before. It is also important to note that the Canadian pork industry is largely export-oriented, being in the top 3 exporters in the world, behind the USA and China (not including the EU; USDA, 2023). It could be argued that, given our high efficiency, low emission production, Canada will play a large role in reducing global emissions while meeting an ever-increasing need for high quality protein foods. Indeed, decreasing production in high efficiency countries will result in an overall increase in emissions as production shifts to low efficiency countries (CAPI, 2023). Advances in our understanding of nutrient utilization and feeding management will allow the industry to make further improvements in efficiency.

An understanding of the variability in animal growth, and by extension their requirements and efficiency, will be critical to improving efficiency. We can't improve what we don't measure, but even basic measures of pig growth and feed use are not commonly determined. Out of necessity, and practicality, nutrition programs are based largely on population dynamics, and decisions around what proportion of the pigs will be provided diets that meet (and largely exceed) their requirements. Consider that body weight can range from 2.4 to 9.2 kg at 19 days of age to 74.6 to 125.2 kg at 140 days, with an average of 5.4 and 104.0 kg, respectively (Patience, 2023). Given this information, what pig do you feed for? Feeding for the average means half the pigs receive feed that is below requirements and feeding for the maximum results in most pigs receiving above requirements. Either way, this results in waste, in nutrient excretion or reduced growth potential. There are methods available to help reduce variability, but variation in body weight will be a constant. Advances in technology, specifically the use of individual precision feeding, provide an opportunity to manage variability.

Traditionally, phase-feeding, the provision of multiple diets over pigs' lifetime, has been used to more closely match feed provision to the animals' requirements. As such, the more diets you have the more closely you can match to requirements. However, provision of multiple diets requires multiple feed formulations and more equipment for diet storage and supply. Moreover, even with changes in diets over time, each phase consists of periods of over- and under-supply of nutrients, in addition to the issues mentioned above with respect to population-based feeding and feeding to the 'average' pig. Precision feeding is the practice of feeding pigs, either individually or as a group, a diet tailored to meet their requirements daily. These systems also use real-time data (i.e., feed intake, body weight gain) to predict nutrient requirements, allowing for more dynamic estimation of requirements for growth and

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adjustment of diets (Pomar and Remus, 2023). By extension, and more so for individual than group precision feeding, these systems aid in managing pig variability by tailoring diets to account for differences in growth and efficiency of individual pigs. In addition to requiring only two diets over the entire grower-finisher period, simplifying formulation and milling requirements, precision feeding can reduce feed costs by 10%, nitrogen and phosphorus excretion by 30%, and greenhouse gas emission by up to 32% (Pomar and Remus, 2023; Pomar et al., 2021). While precision feeding represents one of the largest potential advancements in pork production, its implementation will be dependent on the development of equipment that is cost-effective and reliable and the training of personnel in its use. Further, additional information will be required with respect to nutrient requirements and nutrient efficiencies of individual pigs, as opposed to the current group values (Pomar and Remus, 2023; Remus et al., 2019). It also remains to be seen if there are any negative effects of such precise provision of nutrients based on growth requirements, such as on immune status of precision fed pigs (Remus et al., 2019).

The discussion with respect to the contribution of livestock to greenhouse gas emissions is dominated by carbon. However, the livestock industry contributes approximately one-third of human-induced global nitrogen emissions, with nitrous oxide emissions the predominant greenhouse gas produced from pig manure. While nitrous oxide is present in the atmosphere at much lower concentration than methane or carbon dioxide, its warming potential is 10 and 300 times greater than methane and carbon dioxide, respectively (Shurson and Kerr, 2023). The utilization of nitrogen in pigs is an inherently inefficient process, with generally around 50% retention (NRC, 2012). As Shurson and Urriola (2023) outline, strategies to improve dietary nitrogen utilization include the use of diet formulation to prevent overfeeding, precision feeding to match nutrient provision to the individual nutrient requirements of individual pigs, and feeding low-protein diets supplemented with adequate amounts of essential amino acids. Indeed, efficiency was greatly improved over the last decades as our understanding of essential amino acid requirements improved and the availability of crystalline amino acids increased, allowing for more precise diet formulations. As mentioned above, precision feeding also results in reduced nitrogen waste. There is also a trend to provide reduced protein diets that are supplemented to meet essential amino acid requirements. This strategy has been shown to increase N and AA utilization efficiency and reduce N excretion into the environment, however, the results have been inconsistent and may result in reduced performance and increased carcass fatness (Wang et al., 2018). Current essential amino acid requirements are the result of studies in which a traditional level of dietary protein was used (NRC, 2021). These recommendations, therefore, may not reflect requirements in low protein, amino acid supplemented diets.

One area of study that may aid in improving nitrogen utilization is examining the pig's requirements for total nitrogen, and how dietary nitrogen content affects essential amino acid requirements. It has been suggested that after meeting the requirements for the essential amino acids, protein (or nitrogen) may become limiting, reducing the production of non-essential amino acids and limiting the utilization of essential amino acids (Siegert et al., 2018; Wang et al., 2018; Wu et al., 2022). The essential amino acid-nitrogen:total nitrogen (E:T) ratio has been suggested as a means to determine nitrogen sufficiency in diets for multiple species, including swine (Heger, 2003). Indeed, at extreme E:T values, nitrogen utilization efficiency is reduced, suggesting an optimal amount of nitrogen needs to be included to maximize efficiency. Recent work has shown that lean gain and lysine requirement are reduced when diets are nitrogen-deficient, and that both gain and the requirement are increased when a supplemental source of nitrogen, either as intact protein (i.e., soybean meal) or non-protein nitrogen (i.e., ammonium phosphate) are included in the diet, while maintaining essential amino acid content (Camire et al., 2023; Buchinski et al., 2024). While this research is still in the preliminary stages, it suggests that efforts to further understand nitrogen metabolism in the pig will aid in efforts to improve production efficiency and reduce environmental impact.

Small pigs, big problems

Average litter size has increased significantly resulting in an increased number of pigs marketed per sow per year and increased profitability of pork producers. A consequence of increased litter size, however, is a reduction in average birth weight (~37 g for each additional pig born; Beaulieu et al., 2010), increased variation in birth weight (Milligan et al., 2002), and significantly more piglets born with low birth weights (Beaulieu et al., 2010; Rutherford et al., 2013). It has been estimated that low birth weight pigs are present in up to 75% of litters and can be up to 25% of the pigs in a litter (Bovey et al., 2014). The selection for increased litter size, which results in more low birth weight pigs, may not be beneficial unless programs are developed which support growth and development of these pigs (Milligan et al., 2002).

Birth weight and weaning weight are two critical indicators of lifetime performance in pigs, with smaller pigs generally demonstrating slower growth performance, altered gut development, higher mortality, and increased days to market (Rodrigues et al., 2020). Overall, slow growth performance represents an increased cost to producers through increased feed costs as well as inefficient use of pig space. Indeed, Lopez-Verge et al. (2018) estimated that > 20% of variation in final weight is due to variation in performance during lactation

and nursery, indicating a critical time for intervention. While the incidence of low birth weight pigs has increased, it must also be taken into account that an increase in sow prolificacy results in a concurrent decrease in average birth weight and an increase in within-litter variation in birth weight (Quiniou et al., 2002; Blavi et al., 2021). For example, increasing litter size from 7 to 16 piglets decreases average birth weight from 1.8 to < 1.0 kg and increases the number of pigs weighing less than 1 kg from 4 – 16% (Martineau and Badouard, 2009), with up to 30% of piglets in large litters being considered low birth weight (i.e., intrauterine growth restricted) (Blavi et al., 2021).

"Birth and weaning weight are two critical factors related to lifetime performance of pigs."

Due to decreased access to nutrition in the suckling period, low birth weight pigs are more likely to have lower weaning weight than their heavier littermates. Although several factors have been linked to poor post-weaning growth performance, the underlying physiological mechanisms involved in variability in growth performance among piglets of different birth weight are not well understood. In general, it is believed that inadequate nutrient supply due to poor intake is the largest contributor to reduced growth performance in the pre- and post-weaning period, however, variability in performance may be due to an altered physiological or metabolic response to nutrient intake in low birth weight pigs (Wellington et al., 2023). For example, in a recent study, while functional amino acid supplementation was effective at improving performance of normal birth weight weaned pigs during disease challenge, there was little benefit observed in low birth weight pigs (Rodrigues et al., 2022b). In our recent work (Rodrigues et al., 2020), we characterized the effects of birth weight and neonatal undernutrition on growth in the suckling and nursery period. In this study we found that both birth weight and category (low vs. normal) and neonatal nutrient availability (fully fed vs. restricted) impacted pig growth to weaning, however, it appeared that all pigs were able to recover from nutrient restriction once they returned to normal feed access while LBW pigs remained small. In addition to the overall effects on growth, there were significant effects of birth weight and nutrient restriction on organ development (Wellington et al., 2021; McPeek et al., 2023; Morton et al., 2022), suggesting that organ function may be impacted, irrespective of recovery in growth. These results suggest that the reduced performance in low birth weight pigs is largely physiological in nature, that is, we cannot just treat these pigs as small pigs that require more feed and instead need to re-evaluate how they are fed. Overall, birth weight represents both a challenge and an opportunity for the pork industry, and it will be critical to understand the contribution of physiological factors versus nutrient supply that lead to differences in how low and normal birth weight piglets respond to nutrition interventions to develop effective nutrition programs to support piglet performance.

As mentioned previously, sow prolificacy has increased significantly in the past decade, however, little to no progress has been made with respect to the nutritional management of sows. This is not only in response to potential changes in nutrient requirements to support increased litter sizes and lactation demands, but also in 'current' nutrient requirements (e.g., NRC, 2012) based on limited data (i.e., empirical studies) and/or assumptions (e.g., digestibility coefficients, utilization efficiency, amino acid ratios) that may not be valid. Moreover, suggested requirement values may not appropriate for all potential outcomes (e.g., fetal development, litter

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size, colostrum and milk yield, mammary development). For example, recent work has shown that while current lysine recommendations may be sufficient to maximize fetal growth, additional lysine is required to maximize mammary development in first parity gilts (Farmer et al., 2022, 2023). The availability and increased use of electronic sow feeding (ESF) represents a significant opportunity to not only evaluate individual sow nutrient requirements, but also to provide individualized diets to sows to better optimize performance. With these systems, phase-feeding of gestating and lactating sows will not only be possible but will become a necessity. To properly implement phase-feeding, however, significant research is required to properly evaluate and characterize nutrient requirements of the sow throughout all stages of the reproductive cycle (Theil et al., 2022; Tokach et al., 2019).

Everything but the kitchen sink

If there is one benefit of animal agriculture, it is the ability to turn low-quality products (i.e., those that are not fit for human consumption) into high-quality nutrient sources, especially as sources of protein. In other words, a main goal of animal agriculture should be the use of feedstuffs that do not compete with use for human nutrition. The use of alternative ingredients leads to increased sustainability and reduced environmental impact (Feed Strategy, 2024), and aids in the overall reduction of greenhouse gas emission (White and Hall, 2017). The use of alternative ingredients also generally represents a cost-effective strategy for inclusion of energy and protein sources in diets. In addition to use of alternative ingredients, feed additives will continue to play an important role in maintaining and improving the sustainability of pork production.

While it is generally agricultural by-products/co-products, those products derived from processing of primary crops, that come to mind when thinking of alternative ingredients, the use of all potential feedstuffs should necessarily be included in the discussion. This is highlighted in the US Environmental Protection Agency's Food Recovery Hierarchy for reducing food waste, where use of 'food scraps' to animal feed falls under source reduction (e.g., volume reduction) and feeding of hungry people (e.g., food donation) and above industrial uses, composting, and landfill. While this hierarchy specifically highlights streams for use of extra human food, I believe it should also extend to all food production, such as downgraded crops, and feed regulations should reflect this need. As mentioned in the CAPI (2023) report, "Canada's regulatory system, which is respected globally, can be slow in approving and making available new animal health products." It can also limit the use of potential alternative ingredients and feed additives, reducing competitiveness and sustainability of agriculture. For example, the use of downgraded crops due to mycotoxin contamination is strictly regulated, with limits put on both the use of these crops and the use of feed additives to mitigate the risk. This is despite research that has shown that the use of these feedstuffs could potentially be incorporated into feeding programs without risk to animal or human health (Wellington et al., 2020, 2021b).

Summary

While the swine industry faces numerous challenges, including increased costs and regulatory, environmental, and social requirements, the industry has proved to be resilient and adaptable. There are many opportunities to ensure the continued success of the industry, however, both additional knowledge on nutrient requirements and a shift in how we view nutrition will be needed. We will also need to continue to incorporate alternative ingredients into nutrition programs and advocate for a regulatory environment that ensure the competitiveness of the pork industry in Canada.

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