REGRESAR AL MENU

Selected Strategies for the Development of Feeding Programs to Optimize Pig Performance and Maximize Net Income

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INTRODUCTION

The global situation for feed ingredients is getting much tighter than it has been in the past, resulting in higher prices and in some cases, difficulty accessing adequate supplies. As a consequence, pork producers and feed companies are more actively seeking to develop feeding programs that both reduce cost and increase the predictability of pig performance.

Few nutritionists formulate individual pig diets in isolation; rather, diets are formulated to serve as one component of an overall feeding program. This approach recognizes that the composition of one diet may impact that of a following diet. In other words, pork production is a continuum of phases, including gestation, lactation, nursery and growout, and diet formulation simply recognizes this interrelationship. The concept of developing feeding programs, as opposed to individual diets, also helps to emphasize the simple reality that feed is only one component of a successful pork farm. Most critically, the objectives imbedded in the feeding program must reflect the overall objectives of that farm. For example, if the farm requires a certain minimum growth rate to achieve required barn throughput, the feeding program cannot have as its objective maximizing return over feed cost; the two objectives will conflict with one another and result in the failure to meet farm objectives.

Feeding programs must be dynamic in nature, because the financial circumstances of pork production are forever changing. Thus, a feeding program that maximizes net income when market prices are high and feed costs are low may not be the best feeding program when the situation is reversed. In order to maximize net income, feeding programs should be reviewed whenever market economic conditions change. Of course, it must be acknowledged that raising pigs is a process that takes many months; optimizing the feeding program must recognize that chasing very short-term situations in the marketplace could have long-term effects in the barn. Thus, the "context" of feeding program development is very important as well. Consequently, the science of nutrition is constantly evolving to develop new ways to achieve increasingly complex financial objectives.

While there are many issues involved in the development of individual diets within the feeding program, feed intake may be the most critical and is certainly one of the most challenging. Pigs with large appetites will grow very well on lower cost feeds, because daily intake will ensure the adequate supply of essential nutrients. If feed intake is reduced, then the diet must be formulated to be more nutrient dense. This will help to overcome limitations in the amount of feed consumed in order to achieve targets for the daily supply of nutrients. Many factors will affect ad libitum feed intake in the barn, including nutrient balance in the diet, pig genotype, health status, housing density, body weight, barn temperature, rate of passage and gut capacity. While beyond the scope of this presentation, the reader is encouraged to review a recently released book on the subject, to obtain a more thorough discussion of the subject (Torrallardona and Roura, 2009).

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We know that feed intake varies by at least 35% among farms. This tells us that a feeding program that is optimal for one farm may not be ideal for a neighboring farm. While feed intake is very difficult to predict, it can certainly be managed. However, understanding the many factors that influence feed intake is required in order to manage it on individual farms. There are big rewards to pork producers who focus on feed intake, and implement practices to ensure that it is maximized on their farm.

DIET FORMULATION

While the mechanics of diet formulation have remained relatively unchanged over the past 3 decades, the science behind it has changed a great deal. The evolution of diet formulation has been driven by a desire to meet the pig's requirement for nutrients at the lowest possible cost in order to maximize net income.

However, coincident with this overall objective is the need to achieve predictable animal performance. For example, if the economics of feed supply or hog market prices dictate a change in nutrient profile, or if a new ingredient is being introduced into the feeding program, can the nutritionist make appropriate changes to the diet that will result in an expected performance outcome? Because the consistency and predictability of pig performance is becoming increasingly important in our industry, the expectations of nutritionists are also increasing.

Diet formulation requires the proper balancing of more than 60 individual nutrients. None can be ignored, but due to their cost, the greatest attention is paid to energy and amino acids. Time does not provide an opportunity to deal with consideration of vitamins and minerals, but this should not be interpreted to mean that they deserve no attention; nothing could be further from the truth. Nonetheless, I will focus my comments in energy and amino acids.

Energy

Energy is the most expensive component of the diet, representing about 75% of the total cost. Yet, it may be one of the least understood. While it is generally agreed that adjustments in the amino acid composition of the diet will result in fairly predictable changes in pig performance or carcass composition, the same cannot be said for energy. However, I am encouraged by the increasing attention being paid to energy by researchers in North America, which will ultimately lead to improvements in our knowledge and capabilities.

Part of the challenge in dealing with energy is the fact that, unlike amino acids, vitamins and minerals, there is more than one dietary constituent involved. For example, energy can be supplied by amino acids that are not required for protein synthesis, fat, starch and complex carbohydrates. The manner in which the pig uses energy depends on the source of that energy and on the function for which the energy will be used. For example, CVB (Rijnen et al., 2004) has determined the net energy value, the heat increment and the partial efficiency of various diet components involved in supplying energy to the pig (Table 1). It can be seen that fats have the highest energy value while fiber has the lowest, with starches, sugars and proteins being intermediate. The net energy system has an advantage over the DE and ME systems, because it acknowledges the differing quantity of energy available to the pig for productive purposes, depending on its source.

Most nutritionists in the United States prefer the ME or the modified ME system, while in Canada, the DE and ME systems are being gradually supplanted by the NE system that was developed in Europe over the past 4 decades.

Nonetheless, there remains uncertainty as to whether or not the NE system provides greater accuracy in diet formulation than DE, ME or the so-called modified ME system. Energy systems fill two purposes, the first in characterizing the relative energy content of ingredients, and the second in defining the quantity of energy that is to be provided by a specific diet. The NE system does a superior job of assigning relative economic values to ingredients, as compared to DE or ME. This is because NE accounts for the metabolic cost of converting sources of energy in the diet into common forms of energy that can be used by the pig. It is not a perfect system in this regard, but it has advantages over DE and ME.

The ability of the NE system to predict pig performance better than DE or ME under commercial conditions commonly found in North America remains uncertain. We have observed in a number of experiments that NE is superior in predicting fat accretion, but is not superior to DE in predicting average daily gain or feed efficiency (Table 2; Oresanya et al., 2008). As our familiarity and use of the NE system increases, we will have a greater opportunity to evaluate its strengths and weaknesses under commercial conditions, which differ somewhat in North America as compared to Europe. I should hasten to add that in our experience, the NE system has never resulted in poorer pig performance, so nutritionists should be comfortable in earning the benefits of the NE system in pricing ingredients without impairing performance outcomes, if, of course, the NE system is correctly implemented.

Perhaps the greatest advantage of the NE system is its focus on the pig, and how the pig uses energy, by removing as many factors related to diet composition as possible. Thus, adoption of the NE system will help us focus – indeed it will force us to focus - on how the pig is using dietary energy. Logically, this should lead to improvements in our understanding of energy metabolism, ultimately supporting greatly improved efficiency in pork production.

Amino Acids

Next to energy, amino acids are the most costly class of nutrients in the diet. Nutritionists have considerable flexibility on how they meet the pig's amino acid requirements, using either intact protein, such as soybean meal, or synthetic amino acids, such as lysine HCl or dl-methionine. The challenge of formulating diets rests in meeting the pig's requirement for a specific production target, and doing so at the lowest possible cost.

<u>Availability</u>

Practical diets are, or at least should be, formulated according to standardized ileal digestible amino acids (SID), as opposed to total amino acids or apparent ileal digestible amino acids (AID; Stein et al., 2007). This is the most precise estimate of the bioavailability of amino acids that is widely available at the present time for most common ingredients, and thus should be used to achieve the most precise overall diet formulation.

Ileal digestibility has some short-comings, the most notable of which is the influence of heat treatment during processing on the bioavailability of lysine. Estimates based on ileal digestibility in heated products over-estimate true bioavailability, due to the formation of reducing sugar-lysine complexes, called Amadori products. These Amadori products render the lysine largely unavailable to the pig (Finot, 1990). Because these carbohydrate-lysine complexes are converted back to free lysine during analysis using acid hydrolysis, the true bioavailability of lysine is overestimated (Gabert et al., 2001). Other amino acids may be similarly affected, including proline, tryptophan and arginine, but the chemical nature of these reactions is less well defined (Rutherford and Moughan, 2007). It therefore behooves all nutritionists to apply SID amino acid values with appropriate caution, understanding their short-comings in the case of ingredients exposed to rigorous heat treatment, such as fish meal, meat and bone meal and quite possibly ethanol co-products.

The other issue associated with the use of available amino acid values is related to endogenous secretions of amino acids into the gut of the pig, primarily as digestive enzymes but also as sloughed off cells. The adoption of SID values helps to address this issue, and is therefore clearly superior to the use of AID values. There is no logic to formulating diets using total amino acid values, with the possible exception of early phase starter diets, where SID values of specialized ingredients may not be widely available.

Requirements

Amino acid requirements can be defined in two very different ways: empirical or factorial. The empirical approach basically establishes requirements as a percent of the diet; adjustments may be made for pigs differing in their genetic potential for lean gain, so that "higher quality" pigs will have higher amino acid requirements. For example, the NRC (1998) defines the TID lysine requirement to be 0.52% for an 80 to 120 kg barrow with a lean gain of 350 g/d; the same barrow with a lean gain of 300 g/d would have a TID lysine requirement of 0.45%.

While adjustment for genetic capacity for gain is important, there are many other variables that can affect the amino acid requirements of a growing pig. One of the most significant, in a practical circumstance, is daily feed intake. Feed intake can vary among farms by at least 35% (Patience et al., 1995). The significance of feed intake in defining the lysine requirement of finishing pigs is illustrated in Table 3 (Ross, 2009). In experiment 1, the pigs on the lowest level of lysine (0.58% SID lysine) consumed 23 g lysine per day and gained 1.4 kg/d. In experiment 2, pigs consuming the exact same feed, but eating less, gained 1.1 kg/d and received only 19 g SID lysine per day. Increasing the level of lysine in experiment 1 did not improve average daily gain or average daily feed intake ($P > 0.10$), but it did improve feed efficiency ($P < 0.05$). In experiment 2, increasing lysine levels increased average daily gain, average daily feed and feed efficiency ($P < 0.05$). Because feed intake differed between the two experiments, even though the diets were identical, daily lysine intake also differed, explaining the differential response.

The factorial approach can be used in two ways. If feed intake for the barn is not known ahead of time, it can later be measured and the daily lysine intake estimated. Using well accepted calculations for the maintenance requirement of lysine, and the quantity of lysine required per unit of gain, the adequacy of the diet can be determined and adjustments made if necessary. If feed intake is known, then one can estimate the daily lysine requirement and convert it to percent of the diet by using the same formulas. It has often been said that diets for weanling pigs and growing pigs, the so-called "energy dependent phases" of production, should be formulated according to a ratio to energy; formulating diets for lysine on a "grams per day" basis is typically restricted to finishing pigs. My personal experience suggests that until I better understand the pig's response to energy, I am more comfortable formulating on a "grams per day" basis for all classes of swine.

ALTERNATIVE INGREDIENTS

The use of alternative feed ingredients offers many possibilities to pork producers, the most important of which is the reduction in feed costs. However, with the benefit of lower feed costs may come increased risks, especially if information about, or experience with, the new ingredient is limited. In most markets, the more widely an ingredient is used, the lower the financial benefit accruing from its use. Markets tend to discount ingredients when there is more risk associated with their use. Thus, as is commonly the case, increased risk leads to at least the potential for increased reward. However, even when an ingredient is new to the marketplace, risk associated with its use can be mitigated.

The risks associated with alternative feed ingredients can be divided into 3 categories: those related to pig performance, those related producer management and those related to product quality (carcass merit and pork eating quality).

The pig is placed at risk through the use of a new ingredient, 1) if palatability of the feed is compromised, 2) if the nutrient composition of the ingredient is not well understood, or 3) if the ingredient contains anti-nutritional factors including mycotoxins.

The producer assumes many risks from the use of alternative ingredients, with the biggest being financial. However, there are other risk that can be of great significance as well. Perhaps the most important is the physical handling properties of the ingredient. If the new ingredient causes bridging problems in the mill or in feeders, this could more than offset financial benefits from its use. Another risk is supply and delivery; no one wants to add a new ingredient to the diet when it is only available intermittently, or when delivery is not dependable.

Like pig performance, product quality is at risk if the nutrient profile of the ingredient is not well understood, such that carcass quality declines. However, there are other possible risks in this category, including the presence of compounds which will transfer into the meat or alter it in ways that are less valued by the marketplace. One example would be a different fatty acid profile which could lead to softer fat in the carcass. Ingredients can become contaminated during transport, so it is incumbent on the user to be familiar not just with the product itself, but also with how it has been handled prior to delivery to the farm.

The risks associated with the use of alternative ingredients can be mitigated by following a few important steps:

1. Undertake a complete analysis of the ingredient, including amino acids, fiber and macro minerals. This is an essential starting point in evaluating a new ingredient.
2. Analyze the ingredient for possible anti-nutritional factors or mycotoxins.
3. Understand the production, marketing and transportation of the product, in order to develop a profile of its composition, purity, consistency and risk of contamination during both production and transport.
4. Apply published values for digestibility, to adjust the “total” nutrient composition to “available” nutrient composition. If such values are not available, they may be estimated from similar ingredients for which such information is available.
5. Undertake feeding trials using graded levels of the alternative ingredient, to determine how the pig responds to increasing levels in the diet. This is an excellent way to determine if there are any palatability issues that need to be considered, and also test

to see if the nutrient profile used to formulate the ingredient into the diet is accurate. Carcass evaluation and, if possible pork evaluation, should be included in this step.

6. Depending on the level of risk associated with the ingredient, one might limit its use to growing and finishing pigs, until greater confidence can be gained from more experience. Using ingredients of uncertain palatability or nutrient profile in starter diets or lactation diets is not recommended. If there is a risk of mycotoxin contamination, the ingredient should be used with great caution in sow and starter diets. In all instances, the ingredient should be used at lower levels of the diet in order to dilute out mycotoxins if present.
7. As experience with the ingredient grows, it may be possible to use it in greater quantities in growing and finishing diets, and later expand its use into starter and sow diets.

SUMMARY

1. Diets are developed and formulated within the context of the total feeding program, and the objectives of the feeding should agree with the objectives for the total farm.
2. Feeding programs should be dynamic, meaning that they can be modified as financial circumstances in the marketplace change.
3. There is a large reward to pork producers who focus attention on maximizing feed intake in their pigs.
4. Energy is the most expensive component of the diet, and as such, deserves attention. Whether or not this means adopting the net energy system will depend on a farm's circumstances.
5. Diets should be formulated on an SID (standardized ileal digestible) basis, but recognition is required of the fact that SID values may overestimate the available amino acid content of ingredients exposed to high temperatures during production.
6. The required amino acid content of the diet will depend on the intake of the pig, so consideration should be given to daily intake (g/d) of amino acids, as well as their concentration.
7. Alternative ingredients represent a possible way to improve net income, but with this financial reward will come risks associated with their use. Ways to mitigate this risk were discussed.

REFERENCES

CVB. 2003. Table of feedstuffs. Information about composition, digestibility and feeding values. Central Veevoederbureau, Lelystad, The Netherlands.

Finot, P.A. 1990. Metabolism and physiological effects of Maillard reaction products. In. *The Maillard Reaction in Food Processing, Human Nutrition and Physiology*. pp. 259-271. (P.A. Filot, H.U. Aeschbacher, R.F. Hurrell and R. Liardon, eds.) Basel, Switzerland: Burkhauser.

Gabert, V.M., H. Jorgensen and C.M. Nyachoti. 2001. Bioavailability of amino acids in feedstuffs for swine. In. *Swine Nutrition*. pp 151-186. (A.J. Lewis and L.L. Southern, eds). CRC Press, Boca Raton, FL.

NRC. 1998. Nutrient requirements of swine. 10^{th} ed. National Academy Press, Washington, DC.

Oresanya, T.F., A.D. Beaulieu and J.F. Patience. 2008. Investigations of energy metabolism in weanling barrows: The interaction of dietary energy concentration and daily feed (energy) intake. J. Anim. Sci. 86: 348-363.

Patience, J.F., P.A. Thacker and C.F.M. de Lange. 1995. Swine Nutrition Guide, 2nd Edition. Prairie Swine Centre Inc., Saskatoon, SK, pp. 274.

Rijnen, M.M.J.A., J. Doorenbos, J. Mallo and L.A. Den Hartog. 2004. The application of the net energy system for swine. Proc. 25^{th} Western Nutr. Conf., Saskatoon, SK.

Ross, K.A. Ractopamine hydrochloride and the environmental sustainability of pork production. M.Sc. thesis, University of Saskatchewan, Saskatoon. pp. 78.

Rutherford, S.M. and P.J. Moughan. 2007. Development of a novel bioassay for determining the available lysine contents of foods and feedstuffs. Nutr. Res Reviews 20:3-16.

Stein, H.H., B. Sève, M. F. Fuller, P. J. Moughan and C. F. M. de Lange. 2007. Amino acid bioavailability and digestibility in pig feed ingredients: Terminology and application. J. Anim. Sci. 85:172-180.

Torrallardona, D. and E. Roura. 2009. Voluntary Feed Intake in the Pig. Wageningen Academic Pubishers, Wageningen, The Netherlands. pp. 365.

Table 1. Net energy, heat increment and partial efficiency of various diet components

Digestible nutrient	NE Value	Heat Increment	Partial Efficiency
	Mcal/kg	Mcal/kg	%
Crude fat	8.63	0.83	91
Starch	3.27	0.94	78
Sugars	2.96	0.83	78
Crude protein	2.58	3.06	46
Dietary fiber	2.29	1.92	54

Source: CVB, 2003, as adapted by Rijnen, 2004

Table 2. Correlation between DE intake and NE intake and various production parameters

Parameter	DE intake	NE intake
A.D.G.	0.92	0.90
A.D.F.	0.99	0.96
G:F	-0.14	-0.12
Carcass protein gain	0.93	0.91
Carcass lipid gain	0.80	0.85
Ratio of carcass lipid gain:protein gain	0.60	0.67

Source: Oresanya et al., 2008

Table 3. Comparison of the response to lysine by finishing pigs at two levels of feed intake

SID Lysine, %	Experiment 1				Experiment 2			
	ADG	ADFI	Feed: Gain*	Lysine Intake	ADG*	ADFI*	Feed: Gain*	Lysine Intake
	kg/d	*kg/d*		*g/d*	*kg/d*	*kg/d*		*g/d*
0.58	1.4	4.0	2.86	23	1.1	3.3	2.86	19
0.74	1.4	3.9	2.86	29	1.3	3.1	2.50	23
0.91	1.5	3.9	2.56	35	1.2	3.0	2.50	27

ADG: average daily gain; PDR, protein deposition rate; LDR: lipid deposition rate; ADFI: average daily feed intake. In both experiments, pigs were individually fed, but in experiment, pigs had free access to feed for 1 hour per day in the morning and again at night.

* Effect of lysine significant, P<0.05.

Source: Ross, 2009