Swine NRC revisions

The 11th revised edition of "Nutrient Requirements of Swine" was released in July and represents a significant revision from the 10th edition.

By HANS H. STEIN

THE 10th revised edition of the National Research Council's (NRC) "Nutrient Requirements of Swine" was published by the National Academy Press in 1998.

Computer model

As was the case for the 10th revised edition of the swine NRC, a computer model to calculate the requirements of nutrients and energy for growing/finishing pigs, gestating sows and lactating sows was also developed for the 11th revised edition. However, nutrient requirements for pigs weighing less than 20 kg are not generated by the model.

The basis for the model is described in Chapter 8, and model inputs are provided. Due to differences in protein deposition among intact males, gilts and barrows (Figure 1), energy and nutrient requirements are calculated for each gender (Figure 2).

Effects of using ractopamine or immunization against gonadotropin-releasing hormone are included in the model. The model uses values for metabolizable energy (ME), standardized ileal digestible (SID) amino acids and standardized total tract digestibility (STTD) of phosphorus as the basis for all calculations, but values for digestible energy (DE) and net energy (NE) can also be calculated from the model.

Likewise, requirements for amino acids and phosphorus can be converted to values for apparent ileal digestibility and apparent total tract digestibility, respectively. The requirement for total calcium is assumed to be 2.15 x STTD phosphorus and is also calculated by the model.

To estimate requirements of nutrients, expected levels of energy intake and animal performance need to be specified by the user. The model will then estimate protein deposition, lipid deposition and bodyweight changes. In gestating sows, these changes will be estimated for several pools, including the sow, the fetuses and the reproductive tissue. In lactating sows, litter weight gain and sow weight change are also estimated. Requirements for SID amino acids, STTD phosphorus and total calcium are then calculated.

The model can also be used to calculate retention values for nitrogen, phosphorus and carbon, and by expressing these values relative to intake values, the efficiency of utilization of nitrogen, phosphorus and carbon is calculated. Retention values for carbon are calculated by assuming that retained protein and lipid contain 53% and 76% carbon, respectively.

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A detailed user guide and a tutorial have been developed to assist users in understanding and using the model.

Ingredients, contaminants

As noted in Part 1, the statement of task included a charge to the committee to include information about new feed ingredients from the corn and soybean industries.

The background for this charge is that since publication of the 10th revision, the biofuel industry has expanded, and feed ingredients originating from this industry are now commonly available in the U.S. and many other countries in the world. Likewise, the soybean industry has undergone considerable change, and many new ingredients from this industry are now available.

The committee responded to this charge by writing Chapter 9, which specifically describes each of the feed ingredients that are generated from the corn and soybean industries. Origin, definition, nutrient concentration and energy, amino acid and phosphorus digestibilities are described for 11 corn co-products and nine soybean products. Differences between related feed ingredients are described (i.e., dried distillers grains versus dried distillers grains with solubles, corn germ versus corn germ meal, soy protein concentrate versus soy protein isolate, enzyme-treated soybean meal versus fermented soybean meal, etc.).

This chapter, therefore, provides a comprehensive and detailed description of co-products from the corn and soybean industries. This information is intended to increase the understanding of using these ingredients in diets fed to swine.

Chapter 10 contains an overview of non-nutritive feed additives that may be included in diets fed to pigs. The additives discussed include antibiotic growth promoters, anthelmintics, acidifiers, direct-fed microbials, non-digestible oligosaccharides, plant extracts, exogenous enzymes (i.e., carbohydrases and phytase), feed flavors, mycotoxin binders, antioxidants, pellet binders, flow agents and ractopamine.

For each additive, a short definition, description of products in the category, inclusion rates and expected effects are described. For antibiotic growth promoters, anthelmintics and ractopamine, usage is regulated by the Food & Drug Administration, and allowable inclusion rates and required withdrawal periods are mentioned if relevant.

Chapter 11 describes harmful contaminants that may be present in feed ingredients or diets. The fact that this chapter was included in the 2012 NRC does not indicate that there is a problem with feed contaminants in the U.S. However, frequent reports about the presence of contaminants in the feed supply in Europe and Asia indicate that contaminants may potentially be included in feed ingredients, so the chapter provides an overview of contaminants that feed manufacturers and swine producers need to be aware of.

The feed contaminants described in this chapter include chemical, biological and physical contaminants. Potential chemical contaminants include pesticides, mycotoxins, heavy metals, melamine and dioxins. Biological contaminants include bovine spongiform encephalopathy, chronic wasting disease, *Bacillus* spp., *Clostridium* spp., *Escherichia coli*, *Mycobacterium* spp., *Pseudomonans* spp., *Salmonella enterica* and *Staphylococcus* spp. Physical contaminants include plastic, glass, metal and vermin carcasses that may accidentally end up in the feed supply.

Potential damaging effects of each of these contaminants are described, and preventive measures are proposed, where appropriate.

Feed processing

The effects of feed processing on energy and nutrient utilization are discussed in Chapter 12. Feed processing such as extrusion, expander processing, pelleting, gelatinization, grinding, micronization and hydrothermal treatment may improve the digestibility and fermentability of non-starch polysaccharides and other nutrients and thereby increase energy utilization of feed ingredients.

Heat treatment may also inactivate anti-nutritional factors in the feed, which has the potential to improve energy and nutrient digestibility. This may result in improved feed conversion rates of pigs, although that is not always the case. However, extrusion and expander processing of feed results in improved pellet quality, which, in itself, may contribute to improved feed efficiency.

Pelleting usually results in improved feed conversion rates, but interactive effects of simultaneously using several different processing technologies are poorly understood, although feed companies often combine more than one feed processing technology. More research in this area is, therefore, needed.

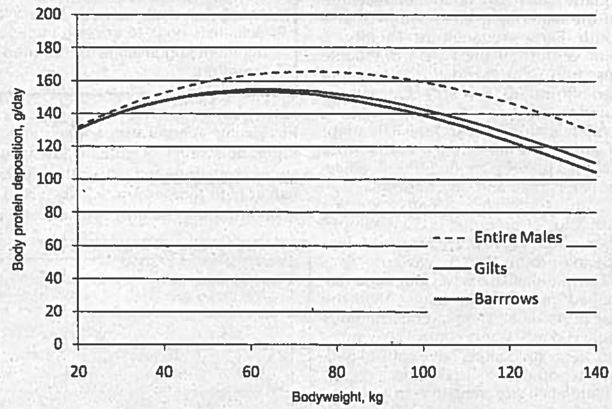
Digestibility

Chapter 13 describes theoretical aspects of determining energy and nutrient digestibility in feed ingredients. For amino acids, it was concluded that diets are most correctly formulated using values for SID of amino acids because those values in different feed ingredients are additive in mixed diets, which is not always the case for values for apparent ileal digestibility.

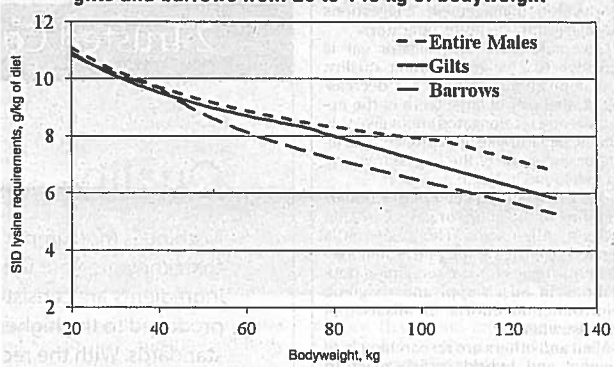
The feed composition tables in the 2012 NRC, therefore, contain values for SID of amino acids, and requirements are also expressed as SID of amino acids.

Values for SID of amino acids are determined by correcting values

1. Estimated whole-body protein deposition from 20 to 140 kg of bodyweight for entire males, gilts and barrows



2. Estimated SID lysine requirement for entire males, gilts and barrows from 20 to 140 kg of bodyweight



explained: Part 2

for apparent ileal digestibility of amino acids for basal endogenous losses. Because basal endogenous losses of amino acids are relatively variable among experiments, it was recommended that these values be determined in each experiment in which apparent ileal amino acid digestibility is measured. Values for calculating SID of amino acids are then calculated using the following equation (Stein et al., 2007): SID (%) = apparent ileal digestibility (%) + [(basal endogenous losses/dietary amino acids) x 100].

Basal endogenous losses and dietary amino acids are expressed as grams per kilogram of dry matter intake.

For lipids, values for total tract digestibility are influenced by microbial synthesis of lipids in the hindgut, and it is, therefore, more accurate to use values for ileal digestibility. As is the case for amino acids, values for apparent ileal digestibility are not additive in mixed diets. However, values for basal endogenous losses of lipids have not been determined, whereas values for total ileal endogenous losses of lipids are available. These values can, therefore, be used to determine the true ileal digestibility of lipids, and it is recommended that where values for lipid digestibility are used, true ileal digestibility values should be determined.

For carbohydrates, the apparent ileal digestibility is used to determine digestibility of monosaccharides, disaccharides and starch, because monosaccharides are absorbed only in the small intestine. However, for oligosaccharides and non-starch polysaccharides, fermentation takes place in the large intestine, and therefore, values for apparent total tract digestibility of these nutrients are calculated.

In contrast to amino acids, lipids and phosphorus, no endogenous losses of carbohydrates have been demonstrated, so it is not necessary to correct values for carbohydrate digestibility for endogenous losses. As a consequence, values for apparent digestibility can be used to characterize the digestibility of carbohydrates.

For phosphorus, values for STTD are used, and these values are calculated by correcting values for apparent total tract digestibility for basal total tract endogenous loss of phosphorus using the following equation (Almeida and Stein, 2010): STTD (%) = [phosphorus intake - (phosphorus output - basal endogenous loss) x 100].

Phosphorus intake and phosphorus output are expressed in grams per day, and basal endogenous loss of phosphorus is expressed in grams per kilogram of dry matter intake. However, from more than 10 experiments, it was demonstrated that basal endogenous losses of phosphorus from pigs are relatively constant, so it is not necessary to measure the basal endogenous loss of phosphorus in all experiments in which phosphorus digestibility is determined. Instead, a constant value of 190 mg/kg of dry matter intake can be used to correct values for apparent total tract digestibility of phosphorus to calculate values for STTD phosphorus.

Principles for calculating DE and ME are described, and specific procedures to conduct experiments to determine DE and ME in feed ingredients are outlined. It was emphasized that where the total collection procedure of feces is used to calculate DE of feed ingredients, start and stop markers need to be used for accurate fecal collection.

It was concluded that there is no evidence of differences among commercial breeds of pigs in their ability to utilize energy from feed ingredients and diets. Pigs will, however, increase energy digestibility if the particle size of ingredients or diets is reduced, and it was recommended that a particle size between 400 and 600 microns be used in experiments in which energy digestibility is determined.

Nutrient excretion

The influence of nutrition on nutrient excretion is discussed in Chapter 14. To reduce nutrient excretion, it was recommended that diets be frequently adjusted to match the requirements of the animals. Split-sex feeding will also allow for more accurate nutrient provision and, therefore, reduced nutrient excretion.

Use of feed ingredients that contain highly digestible nutrients can also contribute to reduced nutrient excretions but may not always be economical. However, exogenous enzymes may sometimes be used to improve the digestibility of nutrients with low digestibility, such as phosphorus in plant-based feed ingredients.

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Ingredient: Corn DDGS, >10% Oil
AAFCO #: 27.6, AAFCO 2010, p. 343
IFN #: 5-02-843

Proximate Components, %	$\bar{x}$	n	SD
Dry matter	89.31	59	1.91
Crude protein	27.33	81	1.53
Crude fiber	7.06	12	1.24
Ether extract	10.43	34	1.03
Acid ether extract	11.27	8	1.36
Ash	4.11	39	0.91
Carbohydrate Components, %			
Lactose			
Sucrose			
Raffinose			
Stachyose			
Verbascose			
Oligosaccharides			
Starch	6.73	32	1.70
Neutral detergent fiber	32.50	76	5.42
Acid detergent fiber	11.75		
Hemicellulose			
Acid detergent lignin	2.61	1	
Total dietary fiber	31.35	8	3.28
Insoluble dietary fiber			
Soluble dietary fiber			

Amino Acids, %	Total			Digestibility: AID			Digestibility: SID		
	$\bar{x}$	n	SD	$\bar{x}$	n	SD	$\bar{x}$	n	SD
Essential									
CP	27.33	81	1.53	64	40	5.19	74	35	5.83
Arg	1.16	67	0.17	74	40	5.02	81	40	5.25
His	0.71	67	0.07	74	40	4.97	78	40	4.75
Ile	1.02	77	0.09	72	40	5.03	76	40	4.87
Leu	3.13	67	0.46	82	40	4.09	84	40	4.00
Lys	0.77	68	0.12	55	40	10.76	61	40	8.75
Met	0.55	68	0.09	80	40	4.30	82	40	4.13
Phe	1.34	67	0.10	78	40	3.87	81	40	3.96
Thr	0.99	64	0.08	64	40	6.51	71	40	5.73
Trp	0.21	67	0.03	63	40	8.34	71	40	8.16
Val	1.35	67	0.12	71	40	5.16	75	40	4.95
Nonessential									
Ala	1.93	58	0.16	74	40	4.72	79	40	4.64
Asp	1.82	58	0.18	63	40	5.73	69	40	5.52
Cys	0.51	60	0.11	69	40	5.97	73	40	5.70
Glu	4.35	58	0.69	76	40	7.81	81	40	5.63
Gly	1.04	56	0.09	42	40	10.79	64	40	11.16
Pro	2.09	58	0.18	34	40	19.40	74	40	21.54
Ser	1.18	58	0.16	70	40	5.36	77	40	5.48
Tyr	1.04	38	0.14	78	20	4.48	81	20	3.98

Minerals	$\bar{x}$	n	SD
Macro, %			
Ca	0.12	38	0.19
Cl			
K	0.90	22	0.12
Mg	0.29	25	0.04
Na	0.22	23	0.13
P	0.73	66	0.10
S	0.66	19	0.28
Micro, ppm			
Cr			
Cu	7.65	22	4.20
Fe	126	21	73
I			
Mn	17.92	22	10.85
Se			
Zn	65.05	21	19.62
Phytate P, %	0.26	1	
ATTD of P, %	60	17	6.49
STTD of P, %	65	17	6.54

Vitamins, mg/kg (unless otherwise noted)	$\bar{x}$	n	SD
Fat Soluble			
Beta-Carotene	3.5		
Vitamin E			
Water Soluble			
Vitamin B_6	8.0		
Vitamin B_{12}, µg/kg	0		
Biotin	0.78		
Folacin	0.90		
Niacin	75		
Pantothenic acid	14.0		
Riboflavin	8.6		
Thiamin	2.9		
Choline	2637		
Energy, kcal/kg			
GE	4849	41	113
DE	3620	16	166
ME	3407	11	190
NE	2384		

Fatty Acids, % of Ether Extract	$\bar{x}$	n	SD
E.E.			
C-12:0			
C-14:0			
C-16:0			
C-16:1			
C-18:0			
C-18:1			
C-18:2			
C-18:3			
C-18:4			
C-20:0			
C-20:1			
C-20:4			
C-20:5			
C-22:0			
C-22:1			
C-22:5			
C-22:6			
C-24:0			
SFA			
MUFA			
PUFA			
IV			
IVP			

Proper balancing of dietary digestible amino acids and use of a correct calcium-to-phosphorus ratio are also necessary to reduce nutrient excretion. Nutrient excretion can be reduced only if the requirements for nutrients in each group of pigs are known, if the chemical composition of the feed ingredients is known and if the digestibility of each nutrient in all feed ingredients is correctly assessed.

Examples of strategies that may be used to reduce nutrient excretion include use of synthetic amino acids, formulation of diets based on an ideal protein and use of microbial phytase and possibly other exogenous enzymes.

Research needs

As members of the committee reviewed the literature and established nutrient requirements for all categories of pigs, it became clear that there is a lack of information in many areas. These areas are described in Chapter 15, and the objective of including this chapter is to direct future research and research funding to the areas that are highlighted.

Among the areas where the committee realized that data are inadequate are accurate estimates of efficiency of energy and nutrient utilization by pigs, the effects of including high-fiber ingredients in diets and the effects of nutrient intake in one phase of production on requirements in subsequent phases. Data for the effects of energy intake on protein and lipid deposition are needed as well.

The committee also realized that data are needed for calculating the NE of many feed ingredients, which requires nutrient composition and nutrient digestibility in ingredients to be determined.

Requirements for amino acids in gestating and lactating sows also have been poorly studied, and research on the effects of activating the immune system on amino acid requirements is needed.

It was recommended that requirements for calcium and phosphorus be re-evaluated because modern and leaner genetic lines may have different requirements from genetic lines used in the past. Values for the digestibility of calcium in feed ingredients are also needed.

As the committee reviewed the literature to obtain data for the composition of feed ingredients and the energy and nutrient digestibility of feed ingredients, it also became clear that there is a lack of data for many ingredients and that more work in this area is needed. The increased focus on the environmental impact of swine production additionally makes it necessary to generate more information about the impact of dietary nitrogen, sulfur and fiber on emissions of ammonia and greenhouse gas.

Requirement tables

Chapter 16 contains nine tables that list the requirements for amino acids, minerals, vitamins and linoleic acid in diets fed to all categories of pigs. All requirements are provided as units per kilogram of diet and also as units per day.

Amino acid requirements are calculated for SID amino acids, apparent ileal digestible amino acids and total amino acids. The calcium requirement is provided for total calcium, and phosphorus requirements are provided for STTD phosphorus, apparent total tract digestible phosphorus and total phosphorus.

Requirements of all nutrients for weanling, growing and finishing pigs are calculated for seven separate weight groups: 5-7 kg, 7-11 kg, 11-25 kg, 25-50 kg, 50-75 kg, 75-100 kg and 100-135 kg. Requirements of all nutrients are provided for mixed-sex groups, but for pigs weighing more than 50 kg, requirements for calcium, phosphorus and amino acids are also calculated separately for gilts, barrows and entire males.

For pigs weighing more than 50 kg, requirements for calcium, phosphorus and amino acids are also provided separately for pigs that deposit an average of 115 g, 135 g or 155 g of protein per day to illustrate the influence of protein deposition on nutrient requirements.

For finishing pigs (i.e., pigs weighing more than 105 kg), requirements for calcium, phosphorus and amino acids are also provided for male pigs that are immunized against gonadotropin-releasing hormone.

Likewise, requirements for calcium, phosphorus and amino acids for entire male pigs or barrows and gilts fed diets containing 5 or 10 parts per million of ractopamine from 115 kg to 135 kg are also provided because inclusion of ractopamine in the diet increases nutrient requirements.

For gestating sows, separate requirements for calcium, phosphorus and amino acids are provided for sows that have a bodyweight of 140, 165, 185 or 205 kg at the time of breeding. Within each weight group, requirements are calculated for the initial 90 days of gestation and also for the final 25 days of gestation.

The requirement estimates assume that litter size is 12.5 pigs for first-parity sows and 13.5 pigs for older sows. Separate requirement estimates are also calculated for sows farrowing 15.5 pigs per litter.

For lactating sows, requirements for calcium, phosphorus and amino acids are calculated for sows that have a post-farrowing bodyweight of 175 or 210 kg. It was assumed that the average litter size is 11 for sows weighing 175 kg and 11.5 for sows weighing 210 kg. Within each weight group, requirements are calculated for sows that do not lose weight during lactation, for sows with a moderate weight loss during lactation and for sows with more than 15 kg of weight loss.

The last table in this chapter contains requirement estimates for sexually active boars.

Feed composition tables

The feed composition tables included in the 2012 NRC were generated by scanning 21 peer-reviewed journals for articles that contained information about the energy and nutrient composition of feed ingredients.

Data were organized into sections for proximate components, carbohydrates, lipids, crude protein and amino acids, vitamins, minerals and energy. With a few exceptions, only data published after 1998 were used.

Data for the digestibility of energy and nutrients in feed ingredients were also collected, but because fewer data are available for energy and nutrient digestibility than for feed composition, data that were published in the peer-reviewed literature during the last 20 years were used.

All data were entered into an Excel spreadsheet and summarized within each ingredient. The mean, the least value, the greatest value, the standard deviation and the variance were calculated for energy, dry matter and all nutrients in all ingredients. If values for certain nutrients were not available from the literature, values from other published sources were included if such values were available.

Data for a total of 122 feed ingredients were collected, but for some ingredients, data for all nutrients were not available. Likewise, digestibility information has not been published for all ingredients, and as a result, for some ingredients, digestibility values are not available.

The feed composition tables are organized with one ingredient per page, and all data for that ingredient are presented on the same page. All values are presented with a mean and a standard deviation, and the number of observations for each mean is also provided. This approach hopefully will make it easy for the user to identify the data needed. An example of the information included for each ingredient is indicated in the Table.

In addition to tables for the composition of the 122 feed ingredients, a table outlining the mineral composition of macro mineral sources is also provided, and a separate table containing information about mineral concentration, chemical formula and relative bioavailability of micro minerals is included. The fatty acid composition and the energy value of fats and oils that may be included in diets fed to pigs are also outlined in a table.

Conclusions

The 11th revised edition of "Nutrient Requirements of Swine," also known as "the new swine NRC," represents a very comprehensive review of the literature of most aspects related to nutrient requirements of swine. The contents of the chapters hopefully will provide the theoretical basis for understanding many aspects of swine nutrition and also the logic the committee followed in deciding on principles for establishing nutrient requirements.

The requirement tables will likely be used in the formulation of diets around the world — although many nutritionists undoubtedly will adjust the requirements based on their experiences, local situation and other reasons.

The model may be used to generate requirement estimates for pigs that are different from what is assumed in the printed requirement tables, and the model also provides users with an opportunity to study relationships among input factors, productivity and nutrient requirements.

The feed ingredient tables represent the most comprehensive knowledge about energy and nutrient concentrations and energy and nutrient digestibility in feed ingredients used in diets fed to pigs that can be generated from the peer-reviewed literature.

Thus, using the information included in the 2012 NRC provides users with an opportunity to formulate diets based on relevant and updated knowledge about nutrient requirements for pigs. Although the document is not perfect, it will hopefully be used and viewed as a helpful tool by everyone involved in formulating diets for pigs.

References

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