Swine Innovation Porc

PRAIRIE SWINE CENTRE

Sow Lameness, Longevity & Temperament

A workshop dedicated to those involved in the breeding and selection of sows for the future. Providing the latest research and understanding in sow lameness, longevity and temperament and how that can affect a selection strategy.

AGRICULTURE COUNCIL OF SASKATCHEWAN INC.

Agriculture et Agroalimentaire Canada

Agriculture and Agri-Food Canada

Contents:

Glossary of Terms:

Caudal = *posterior*

Ambulatory = Walking

globally observed = Observed from all sides

Kinetics = The study of motion and its causes

Latency is a measure of time delay experienced in a system

Contacts

Jennifer Brown, Ph.D.
Research Scientist – Ethology

Prairie Swine Centre

Phone: (306) 667-7442
Jennifer.brown@usask.ca

Yolande Seddon, Ph.D.
Post Doctural Fellow

Prairie Swine Centre

Yolande.seddon@usask.ca
Phone: (306) 667-7442

Dr. M.L. (Laurie) CONNOR

University of Manitoba

Professor and Head Director, Glenlea Research Station
Swine Research Unit Director
Ruminant Research Unit Director

Telephone: (204) 474-9219
Email: mconnor@cc.umanitoba.ca

Professor John Deen

University of Minnesota

Veterinary Population Medicine

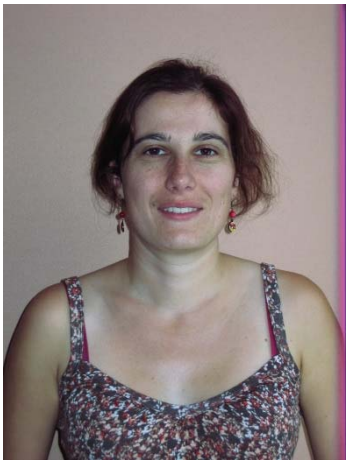
Contact Information:
Phone: 612-625-7784
Email: deenx003@umn.edu

Dr. Nicolas Devillers

Research Scientist, Swine Behaviour and Welfare
Agriculture and Agri-Food Canada

Telephone: 819-780-7223

Email: nicolas.devillers@agr.gc.ca



Dr Sabine Conte

Post Doctural Fellow
Agriculture and Agri-Food Canada [Dairy and Swine R&D Centre,

Phone: 819-780-7227

Sabine.Conte@agr.gc.ca

Executive Summary of the Cluster Research Program.

Assurance of sow welfare and economic viability of commercial operations are essential for pork producers to be competitive in the local, national and international market. This research used conventional and new technologies to identify and evaluate factors such as social characteristics, sow temperament, lameness, calcium and phosphorus balance and early reproduction management that may impact sow welfare and longevity in the sow herd. Lameness was assessed in over 500 sows in four group housing systems using several methods of evaluating locomotion.

Sow temperament traits associated with active-passive and confidence-fearful dimensions showed significant differences between breeds and between housing systems. In free-access housing sow breed line and age, but not floor type or pen configuration affected temperament measures. In the ESF systems, flooring type and age (parity) influenced sow behaviour response in temperament tests. However, within the management and group housing systems investigated, there were only minor effects of temperament on production variables. There were relationships between body injury score and temperament which differed between the two ESF systems. Flooring in the ESF systems was associated with the incidence of lameness; lameness was significantly higher on the partial-slatted flooring system and in that system only, there was a relationship between injury score and lameness. These observations are very important considerations for sow longevity associated with housing system.
A sow simulation model was validated and refined using data sets from two group housing systems. Information gathered from two other group housing systems will be analyzed early in 2013 utilizing lameness, other physical reasons and productivity culling function and the impact of different group housing systems will be determined and compared. It appears that, as expected, the model can determine the optimal time for culling a sow from an economic standpoint.

The infra-red thermography (IRT) technology is currently cost prohibitive for routine on-farm diagnostics. Limb conformation, weight and parity effected the IRT temperatures. However, IRT was effective when compared to visual scores and may be a useful method of detecting early signs of inflammation and injury in the lower limbs and hooves of sows in the future.

Bone turnover and Ca balance are influenced by and affect sow productivity, bone strength and presumably lameness and longevity in the herd. Preliminary results of investigations on the effect of dietary Ca concentrations revealed that current recommended dietary Ca levels appear appropriate. However, group housed sows gained more weight during gestation and had numerically larger litter sizes and heavier piglets than did sows in stalls.

How to estimate your own cost of lameness

John Deen
University of Minnesota

The cost of lameness, in our hands, has been inaccurate and underestimated. Almost invariably we have underestimated the associated improvements in economic outcomes associated with reductions in lameness. This can be due to a few factors but these are our most likely candidates:

- The change in prevalence due to interventions is higher than measured due to underestimation of beginning prevalence
- Lameness is affecting more variables then we have measured at the individual sow level
- Our models of sow removal are too simplistic

Along with this we have two major observations of initial response to the existence of lameness in the sow. We have found that if a lame sow is retained in the herd it reduces pigs per sow per year. If a lame sow is removed from the herd it reduces pigs per sow space per year. The former is readily recognized as we have often seen a relationship between pigs per sow per year and lameness through effects on open sow days and farrowing rate as is shown in one of our studies in figure 1. However we often find when modeling sow farm output that it is the irregular removal of sows, especially after initial meeting that has the major effect upon herd productivity. When we model reduced herd output in an already underperforming herd we find that this is often more than 50% of the effect.

A simple beginning economic model is to focus on this lost output as the indicator. Costs such as replacement of gilts and cull sow value are important but about 20%

Table 1: Productivity effects

	Not Lame	Lame	*P* Value
Pigs born/day	**0.049**	**0.028**	**< 0.00005**
Survival at 350 days, %	**51**	**33**	**< 0.00005**
Total days in herd	**215**	**147**	**< 0.00005**

Calcium and Phosphorus Requirements for Bone Strength

Bone turnover and Ca balance are influenced by and affect sow productivity, bone strength and presumably lameness and longevity in the herd. Preliminary results of investigations on the effect of dietary Ca concentrations revealed that current recommended dietary Ca levels appear appropriate.

Current Recommendations are attached from the National Swine Nutrition Guide version 1.2.

Version 1.2

National Swine Nutrition Guide

National Swine Nutrition Guide Tables on Nutrient Recommendations, Ingredient Composition, and Use Rates

A collaboration among universities, agri-businesses, and the U.S. Pork Center of Excellence.

USB
UNITED SOYBEAN BOARD
Making Your Checkoff Pay Off.

U.S. Pork Center of Excellence
Communities of National Cooperation

The National Swine Nutrition Guide was produced by the U.S. Pork Center of Excellence in collaboration with:

University of Illinois at Urbana-Champaign
Iowa State University
Kansas State University
University of Minnesota
University of Missouri
University of Nebraska-Lincoln
North Carolina State University
Purdue University
South Dakota State University

Dr. David J. Meisinger - Editor

National Swine Nutrition Guide

National Swine Nutrition Guide Tables on Nutrient Recommendations, Ingredient Composition, and Use Rates[1,2]

Introduction

Swine nutrition and feeding management is a complex process. Feed is the largest single item among the costs of producing pork, historically accounting for about 60% of all costs in farrow-to-finish systems. Pork producers are encouraged to employ a comprehensive feeding program based on sound principles and tailored to the operation. The National Swine Nutrition Guide (NSNG), which includes the Diet Formulation and Evaluation CD to allow direct application of its contents to practical feeding situations, provides the basis for the development and management of such swine feeding programs.

The purpose of the NSNG is to enhance the understanding of basic nutrition, feeding principles and related management practices and to serve as a reference for pork producers, students, educators and allied industry personnel. Users of the NSNG will be able to estimate the nutritional needs of pigs by considering specific factors that affect nutrient recommendations.

The NSNG consists of 35 factsheets and the Diet Formulator CD. For those seeking only nutrient recommendations for various classes of swine and ingredient composition and use rates, we prepared this summary. More details regarding nutrient recommendations, ingredient composition, formulating diets, and feeding program management are presented in the factsheets and on the Diet Formulator CD.

General explanation of nutrient recommendations

Nutrient requirements established by the 1998 National Research Council (NRC) and research results published since then were used as the basis for nutrient recommendations in the NSNG. Values published by the NRC do not include any intentional surpluses; they are the committee's best estimates of minimum requirements for nutrients. Those requirements are based on pigs fed corn and soybean meal-based diets under experimental conditions that normally provide ideal growing conditions. In commercial production situations, a margin of safety is added to the published nutrient requirements; in the NSNG those levels are referred to as "recommendations". A margin of safety was applied to each nutrient in order to establish a recommendation for that nutrient in the NSNG. Margins of safety are necessary to account for any number of factors that affect nutrient needs (see PIG Factsheet # 07-01-07, Factors Affecting Nutrient Requirements) and variability in nutrient composition and in nutrient bioavailability of feed ingredients (see PIG factsheet #07-07-09, Composition and Usage Rate of Feed Ingredients for Swine Diets). Nutrient cost and environmental issues surrounding nutrient excretion were also considered when determining safety margins.

Nutrient recommendations in the NSNG were established according to predetermined pig performance standards; for example, daily weight gain, feed intake, carcass lean gain, litter size and litter weaning weight. Those standards accompany the nutrient recommendations in the NSNG to provide transparency and to allow individuals to tailor recommendations to specific situations.

The nutrient recommendations presented herein should result in a "best cost" feeding strategy for most pork producers the majority of the time. However, certain conditions (i.e., specific genetic populations, economics, environmental conditions, nutrient availability, nutrient profile, and nutrient interactions) may

exist that require significant deviations from the recommendations presented.

Although crude protein values still appear on feed labels and in some feeding recommendations, we did not list dietary protein recommendations because pigs do not require protein in their diet. Instead they require amino acids, which are found in protein. Recommended levels for six of the most critical amino acids are provided in Tables 1 to 10. Lysine is the first limiting amino acid in grain soybean meal based diets. Lysine recommendations are provided on a total and a standardized ileal digestible (SID) basis. Recommendations for total lysine are applicable to corn-soybean meal based diets only. Formulating diets on a SID basis allows one to account for differences in the usable amino acids present in the diet and more closely meets the pig's amino acid needs while minimizing excess nitrogen excretion.

The recommendations for threonine, methionine, methionine+cysteine, tryptophan, isoleucine and valine are also expressed on an SID basis. These recommendations were derived from an optimal pattern or ratio among amino acids that we established (see PIG Factsheet # 07-02-03, Understanding Swine Nutrient Recommendations).

Recommendations for phosphorus are expressed on a total, available and digestible basis. Like amino acids, a certain proportion of the phosphorus in a feedstuff cannot be utilized by pigs. In order to more closely meet the pig's phosphorus requirements while minimizing phosphorus excretion, swine diets should be formulated on an available or digestible phosphorus basis. The total phosphorus recommendations presented in this factsheet should be used as a guideline only; those recommendations may not be obtained when formulating practical diets on an available or digestible basis. Also, the total phosphorus recommendations in this factsheet will not be achieved when phytase is included in the diet.

Amino acid, calcium and phosphorus recommendations are expressed both as percentage of the total content of the diet and amount relative to dietary metabolizable energy concentration. When expressing nutrient recommendations on a percentage of the diet basis, dietary energy density or feed intake must be considered. Otherwise, it is likely that the animal's nutrient needs will not be met as intended. Expressing nutrient recommendations relative to dietary energy ensures nutrient concentrations are altered in accordance to changes in dietary energy density, for example when fat is added to the diet.

Recommendations for trace mineral and vitamin additions to swine diets are shown in Table 11. The values represent our best estimate of trace mineral and vitamin needs of pigs in practical situations. These values are based on NRC requirements to which a safety margin has been added. While there are vitamins and trace minerals in grain and protein sources, it is necessary to fortify swine diets with additional quantities of several vitamins and trace minerals to ensure deficiencies do not occur.

Information gaps exist in trace mineral and vitamin nutrition of pigs, making it difficult to establish firm recommendations. Therefore, we feel it is important to offer feed manufacturers and producers some flexibility in preparing and utilizing products based on our recommendations. Thus, we established ranges for recommended additions of salt, trace mineral and vitamin additions to swine diets (see PIG Factsheet #07-02-06, Trace Minerals and Vitamins for Swine Diets).

Tables 12 to 15 contain nutritional information for the manufacturing of basemixes and premixes for swine diets. The recommended trace mineral and vitamin additions shown in Table 11 are met or exceeded with the trace mineral premix and three vitamin premixes shown.

[1]This booklet of tables was compiled to provide users with a quick reference to all the tables from the National Swine Nutrition Guide (NSNG). The NSNG is a perfect example of collaboration made possible by the US Pork Center of Excellence (USPCE) which has as its mission to add value to the pork industry by facilitating research and learning for U.S. pork producers through national collaboration. The steering committee can be very proud of this work. This tables booklet, the NSNG book and the Diet Formulation and Evaluation CD will be widely accepted and utilized by the pork industries in the US and, indeed, around the world. This national collaboration could only be possible with the input, writing, reviewing, commitment and a lot of hard work by several people including many academic and industry swine nutritionists. I have attempted to list all of these individuals who have contributed so much of their time to make this effort a success. The Steering Committee would like to extend a special thank you to Katie Beeler, communications specialist with the US Pork Center of Excellence, for all her hard work in staffing the Committee and in formatting all the fact sheets for publication.

David J. Meisinger
Executive Director
US Pork Center of Excellence

Steering Committee

Duane Reese, University of Nebraska (Chair of Development)
Bob Thaler, South Dakota State University (Chair of Outreach)
Brian Richert, Purdue University (PIG Swine Nutrition Domain Leader)
Scott Carter, Oklahoma State University
Garland Dahlke, Iowa State University
Joel DeRouchey, Kansas State University
John Patience, Iowa State University
Marcia Carlson Shannon, University of Missouri
Hans Stein, University of Illinois
Eric van Heugten, North Carolina State University
Mark Whitney, University of Minnesota
Charlotte Kirk Baer, USDA/NIFA ex-officio

Authors

All of the Steering Committee members were involved as authors of NSNG fact sheets. In addition, the following individuals also contributed as authors or co-authors on several papers:

Gary Allee, University of Missouri
Jason Apple, University of Arkansas
Justin Benz, Kansas State University
Gary Cromwell, University of Kentucky
Steve Dritz, Kansas State University
Bob Goodband, Kansas State University
Lee Johnston, University of Minnesota
Claire Masker, Iowa Corn Growers Association
Gretchen Myers Hill, Michigan State University
Jim Nelssen, Kansas State University
Allan Schinckel, Purdue University
Jerry Shurson, University of Minnesota
Alan Sutton, Purdue University
Ken Stalder, Iowa State University
Mike Tokach, Kansas State University
Theo van Kempen, Provimi

Reviewers

All of the Steering Committee members provided critical reviews of the fact sheets for the NSNG. In addition, many other academicians and industry representatives assisted with input, modifications and helpful advice in their critical reviews. They are listed as follows:

Samuel Baidoo, University of Minnesota
Eric Berg, North Dakota State University
Bart Borg, Murphy Brown LLC
R. Dean Boyd, The Hanor Company
Mike Brumm, Brumm Consulting
Tom Burkey, University of Nebraska
Wayne Cast, Production Input Solutions
Donnie Campbell, DSM Nutritional Products
Kevin Cera, Akey
Joe Crenshaw, APC Functional Proteins
Mark Crenshaw, Mississippi State University
Tommy Crenshaw, University of Wisconsin
Dustin Dean, International Ingredients Corp.
Robert Dove, University of Georgia
Jerry Faber, ADM Alliance Nutrition
Tim Fakler, Kerber Milling
Jason Frank, University of Arkansas
Aaron Gaines, The Maschhoffs
John Goihl, Agri-Nutrition Services, Inc.
Bob Goodband, Kansas State University
Gene Gourley, Swine Graphics Enterprises
Ross Hamilton, Darling International
Gretchen Myers Hill, Michigan State University
Palmer Holden, Iowa State University
Chris Hostetler, South Dakota State University
Roger Johnson, Farmland Foods
Brian Kerr, USDA/ARS /SOMMRU
David Kirstein, Darling International
Don Levis, University of Nebraska
Merlin Lindemann, University of Kentucky
Dennis Liptrap, Ralco Nutrition
Leland McKinney, Kansas State University
Charles Maxwell, University of Arkansas
Terry Meyer, Land O' Lakes Purina Feed LLC
Phil Miller, University of Nebraska
Ronny Moser, JBS United, Inc.
Rob Musser, Soda Ingredients
Betsy Newton, Akey
Rob Payne, Evonik Degussa Corporation
Scott Radcliffe, Purdue University
Dale Rozeboom, Michigan State University
Kari Sadorris, Akey
Tom Sauber, Pioneer
Wayne Schiefelbein, Elite Swine Program
Allan Schinckel, Purdue University
Jerry Shurson, University of Minnesota
Jim Smith, Hubbard Feeds
Joel Spencer, JBS United, Inc.
Charles Stark, North Carolina State University
Dave Stender, Iowa State University
Alan Sutton, Purdue University
Mike Tokach, Kansas State University
W. Randy Walker, DPI Global
Bryan Wiegand, University of Missouri
Noel Williams, PIC
Gawain Willis, Land 0' Lakes Purina Feed LLC
Mark Wilson, Zinpro Corporation
Bob Woerman, Woerman's Animal Nutrition Consulting LLC
Ruurd Zijlstra, University of Alberta

[2]At the outset of the project, the NSNG Steering Committee queried the feed industry to obtain their input on a number of questions in a survey including their willingness to be involved in some aspect of reviewing the individual fact sheets. The response was 100% from these polled individuals. The names of these responders who provided the initial guidance for the program outline were as follows:

Bart Borg, Murphy Brown LLC
Stewart Galloway, Hubbard Feeds
Bruce Aversman, Kent Feeds
Wayne Cast, Production Input Solutions
Ken Ferrell, MFA
Chris Sparks, ADM
Wayne Schiefelbein, Elite Swine Program
Janet Snow, Exseed Genetics
Craig Maloney, Seaboard Foods
John Eggert, Monsanto
Dale Kavan, Akey
Bob Woerman, Woerman's Animal Nutrition Consulting LLC
Neil Allen, Goldsboro Milling
John Sondermann, DanBred NA
Ronny Moser, JBS United Feeds
John Goihl, Agri-Nutrition Services
Dean Koehler, Vita Plus
David Funderburke, Cape Fear Consulting
Patrick O'Quinn, Prestage Farms
Dustin Kendall, Murphy Brown LLC
John Thompson, Wilson Milling

Table 1. Amino acid, calcium and phosphorus recommendations for nursery pigs (as-fed basis)[a]				
Type of diet	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**
Body weight, lb	**9 to 11**	**11 to 15**	**15 to 25**	**25 to 45**
Assumed daily feed intake, lb	**0.35**	**0.55**	**1.10**	**2.20**
Assumed daily gain, lb	**0.32**	**0.45**	**0.80**	**1.25**
Dietary metabolizable energy, Mcal/lb	**1.59**	**1.58**	**1.50**	**1.50**
	----------% of diet ----------			
Lysine, total	1.70	1.65	1.44	1.38
Standardized ileal digestible				
Lysine	1.56	1.51	1.31	1.25
Threonine	0.97	0.94	0.81	0.78
Methionine	0.44	0.42	0.37	0.35
Methionine + cysteine	0.90	0.88	0.76	0.73
Tryptophan	0.27	0.26	0.22	0.21
Isoleucine	0.86	0.83	0.72	0.69
Valine	1.01	0.98	0.85	0.81
Calcium	0.90	0.85	0.85	0.75
Phosphorus, total[c]	0.75	0.70	0.70	0.65
Phosphorus, available	0.60	0.55	0.45	0.37
Phosphorus, digestible	0.57	0.53	0.40	0.33
	---------- g/Mcal ME[b] ----------			
Lysine, total	4.85	4.74	4.35	4.17
Standardized ileal digestible				
Lysine	4.45	4.34	3.96	3.78
Threonine	2.77	2.70	2.45	2.36
Methionine	1.26	1.21	1.12	1.06
Methionine + cysteine	2.57	2.53	2.30	2.21
Tryptophan	0.77	0.75	0.67	0.64
Isoleucine	2.45	2.38	2.18	2.09
Valine	2.88	2.81	2.57	2.45
Calcium	2.57	2.44	2.57	2.27
Phosphorus, total[c]	2.14	2.01	2.12	1.97
Phosphorus, available	1.71	1.58	1.36	1.12
Phosphorus, digestible	1.63	1.52	1.21	1.00

[a]All diets are full-fed under thermoneutral conditions; see PIG factsheet #07-01-08 (Nursery Swine Nutrient Recommendations and Feeding Management) for more details.
[b]Recommended amount relative to dietary metabolizable energy (ME) density; energy values of ingredients from PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) were used in the calculations.
[c]Total phosphorus values will be reduced with increasing levels of added phytase in each diet. However, P release from phytase is reduced 30% when growth promoting levels of Zn are added.

Table 2. Amino acid, calcium and phosphorus recommendations for HIGH[a] lean gain lines of growing-finishing swine (as-fed basis)[b]														
Type of diet	**Phase 1**		**Phase 2**		**Phase 3**		**Phase 4**		**Phase 5**		**Phase 5 + RAC[c]**		**Phase 6+ RAC[c]**	
Body weight, lb	**45 to 90**		**90 to 135**		**135 to 180**		**180 to 225**		**225 to 270**		**225 to 270**		**270 to 315**	
Estimated lean gain, lb/d (protein deposition, g/d)	**0.70 (125)**		**0.76 (135)**		**0.87 (155)**		**0.84 (150)**		**0.76 (136)**		**1.01 (180)**		**0.91 (162)**	
Sex[d]	**B**	**G**	**B**	**G**	**B**	**G**	**B**	**G**	**B**	**G**	**B**	**G**	**B**	**G**
Assumed daily feed intake, lb	**3.1**	**3.1**	**4.2**	**4.0**	**5.1**	**4.7**	**5.8**	**5.3**	**6.2**	**5.7**	**6.2**	**5.7**	**6.4**	**5.9**
Dietary metabolizable energy, Mcal/lb	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**
	----------% ----------													
Lysine, total	1.24	1.24	1.06	1.11	0.93	1.01	0.82	0.90	0.73	0.79	0.94	1.02	0.83	0.90
Standardized ileal digestible														
Lysine	1.10	1.10	0.93	0.98	0.81	0.88	0.72	0.78	0.63	0.69	0.83	0.90	0.72	0.79
Threonine	0.69	0.69	0.59	0.61	0.52	0.56	0.47	0.51	0.42	0.46	0.55	0.60	0.49	0.53
Methionine	0.32	0.32	0.27	0.28	0.24	0.26	0.21	0.23	0.19	0.21	0.25	0.27	0.22	0.24
Methionine+cysteine	0.64	0.64	0.54	0.57	0.49	0.53	0.43	0.47	0.39	0.43	0.51	0.56	0.46	0.50
Tryptophan	0.18	0.18	0.15	0.16	0.13	0.14	0.11	0.13	0.10	0.11	0.13	0.14	0.12	0.13
Isoleucine	0.60	0.60	0.51	0.54	0.45	0.49	0.39	0.43	0.35	0.38	0.45	0.49	0.40	0.43
Valine	0.71	0.71	0.60	0.63	0.53	0.57	0.47	0.51	0.41	0.45	0.54	0.58	0.47	0.51
Calcium	0.71	0.71	0.61	0.65	0.56	0.61	0.52	0.57	0.49	0.53	0.51	0.55	0.48	0.52
Phosphorus, total[e]	0.71	0.71	0.61	0.65	0.56	0.61	0.52	0.57	0.49	0.53	0.51	0.55	0.48	0.52
Phosphorus, available	0.32	0.32	0.26	0.28	0.23	0.25	0.20	0.22	0.19	0.20	0.21	0.22	0.19	0.20
Phosphorus, digestible	0.33	0.33	0.27	0.28	0.23	0.25	0.19	0.21	0.16	0.18	0.22	0.24	0.19	0.20
	----------g/Mcal ME[f]----------													
Lysine, total	3.70	3.70	3.16	3.31	2.78	3.01	2.45	2.69	2.18	2.36	2.81	3.04	2.48	2.69
Standardized ileal digestible														
Lysine	3.28	3.28	2.78	2.92	2.42	2.63	2.15	2.33	1.88	2.06	2.48	2.69	2.15	2.36
Threonine	2.06	2.06	1.76	1.82	1.55	1.67	1.40	1.52	1.25	1.37	1.64	1.79	1.46	1.58
Methionine	0.95	0.95	0.81	0.84	0.72	0.78	0.63	0.69	0.57	0.63	0.75	0.81	0.66	0.72
Methionine+cysteine	1.91	1.91	1.61	1.70	1.46	1.58	1.28	1.40	1.16	1.28	1.52	1.67	1.37	1.49
Tryptophan	0.54	0.54	0.45	0.48	0.39	0.42	0.33	0.39	0.30	0.33	0.39	0.42	0.36	0.39
Isoleucine	1.79	1.79	1.52	1.61	1.34	1.46	1.16	1.28	1.04	1.13	1.34	1.46	1.19	1.28
Valine	2.12	2.12	1.79	1.88	1.58	1.70	1.40	1.52	1.22	1.34	1.61	1.73	1.40	1.52
Calcium	2.12	2.12	1.82	1.94	1.67	1.82	1.55	1.70	1.46	1.58	1.52	1.64	1.43	1.55
Phosphorus, total[e]	2.12	2.12	1.82	1.94	1.67	1.82	1.55	1.70	1.46	1.58	1.52	1.64	1.43	1.55
Phosphorus, available	0.95	0.95	0.78	0.84	0.69	0.75	0.60	0.66	0.57	0.60	0.63	0.66	0.57	0.60
Phosphorus, digestible	0.98	0.98	0.81	0.84	0.69	0.75	0.57	0.63	0.48	0.54	0.66	0.72	0.57	0.60

[a]>0.80 lb of fat-free lean/day from 45 to 270 lb.
[b]All diets are full fed under thermoneutral conditions; see PIG factsheet #07-01-09 (Growing-Finishing Swine Nutrient Recommendations and Feeding Management) for more details.
[c]Ractopamine hydrochloride (Paylean®).
[d]B = barrows and G = gilts.
[e]Total phosphorus recommendations should be used as a guideline only; those recommendations may not be obtained when formulating practical diets on an available or digestible phosphorus basis which is recommended. Also, total phosphorus recommendations will not be achieved when phytase is included in the diet.
[f]Recommended amount relative to dietary metabolizable energy (ME) density; energy values of ingredients from PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) were used in the calculations.

Table 3. Amino acid, calcium and phosphorus recommendations for MEDIUM[a] lean gain lines growing-finishing swine (as-fed basis)[b]														
Type of diet	**Phase 1**		**Phase 2**		**Phase 3**		**Phase 4**		**Phase 5**		**Phase 5 + RAC[c]**		**Phase 6+ RAC[c]**	
Body weight, lb	**45 to 90**		**90 to 135**		**135 to 180**		**180 to 225**		**225 to 270**		**225 to 270**		**270 to 315**	
Estimated lean gain, lb/d (protein deposition, g/d)	**0.60 (107)**		**0.65 (116)**		**0.75 (133)**		**0.73 (129)**		**0.66 (117)**		**0.87 (155)**		**0.78 (139)**	
Sex[d]	**B**	**G**	**B**	**G**	**B**	**G**	**B**	**G**	**B**	**G**	**B**	**G**	**B**	**G**
Assumed daily feed intake, lb	**3.1**	**3.1**	**4.2**	**4.0**	**5.1**	**4.7**	**5.8**	**5.3**	**6.2**	**5.7**	**6.2**	**5.7**	**6.4**	**5.9**
Dietary metabolizable energy, Mcal/lb	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**
	----------% ----------													
Lysine, total	1.06	1.06	0.92	0.96	0.82	0.88	0.72	0.79	0.64	0.69	0.82	0.89	0.71	0.77
Standardized ileal digestible														
Lysine	0.93	0.93	0.80	0.84	0.71	0.77	0.62	0.68	0.55	0.59	0.71	0.78	0.61	0.67
Threonine	0.59	0.59	0.51	0.53	0.45	0.49	0.41	0.44	0.37	0.40	0.48	0.52	0.42	0.45
Methionine	0.27	0.27	0.23	0.24	0.21	0.22	0.18	0.20	0.16	0.18	0.21	0.23	0.19	0.21
Methionine+cysteine	0.54	0.54	0.47	0.49	0.43	0.46	0.37	0.41	0.34	0.37	0.44	0.48	0.39	0.42
Tryptophan	0.15	0.15	0.13	0.13	0.11	0.12	0.10	0.11	0.09	0.10	0.11	0.12	0.10	0.11
Isoleucine	0.51	0.51	0.44	0.46	0.39	0.42	0.34	0.38	0.30	0.33	0.39	0.43	0.34	0.37
Valine	0.60	0.60	0.52	0.55	0.46	0.50	0.41	0.44	0.35	0.39	0.46	0.50	0.40	0.43
Calcium	0.71	0.71	0.61	0.65	0.56	0.61	0.52	0.57	0.49	0.53	0.51	0.55	0.48	0.52
Phosphorus, total[e]	0.71	0.71	0.61	0.65	0.56	0.61	0.52	0.57	0.49	0.53	0.51	0.55	0.48	0.52
Phosphorus, available	0.32	0.32	0.26	0.28	0.23	0.25	0.20	0.22	0.19	0.20	0.21	0.22	0.19	0.20
Phosphorus, digestible	0.29	0.29	0.24	0.25	0.20	0.22	0.17	0.19	0.14	0.15	0.19	0.20	0.15	0.17
	----------g/Mcal ME[f]----------													
Lysine, total	3.16	3.16	2.75	2.86	2.45	2.63	2.15	2.36	1.91	2.06	2.45	2.66	2.12	2.30
Standardized ileal digestible														
Lysine	2.78	2.78	2.39	2.51	2.12	2.30	1.85	2.03	1.64	1.76	2.12	2.33	1.82	2.00
Threonine	1.76	1.76	1.52	1.58	1.34	1.46	1.22	1.31	1.10	1.19	1.43	1.55	1.25	1.34
Methionine	0.81	0.81	0.69	0.72	0.63	0.66	0.54	0.60	0.48	0.54	0.63	0.69	0.57	0.63
Methionine+cysteine	1.61	1.61	1.40	1.46	1.28	1.37	1.10	1.22	1.01	1.10	1.31	1.43	1.16	1.25
Tryptophan	0.45	0.45	0.39	0.39	0.33	0.36	0.30	0.33	0.27	0.30	0.33	0.36	0.30	0.33
Isoleucine	1.52	1.52	1.31	1.37	1.16	1.25	1.01	1.13	0.90	0.98	1.16	1.28	1.01	1.10
Valine	1.79	1.79	1.55	1.64	1.37	1.49	1.22	1.31	1.04	1.16	1.37	1.49	1.19	1.28
Calcium	2.12	2.12	1.82	1.94	1.67	1.82	1.55	1.70	1.46	1.58	1.52	1.64	1.43	1.55
Phosphorus, total[e]	2.12	2.12	1.82	1.94	1.67	1.82	1.55	1.70	1.46	1.58	1.52	1.64	1.43	1.55
Phosphorus, available	0.95	0.95	0.78	0.84	0.69	0.75	0.60	0.66	0.57	0.60	0.63	0.66	0.57	0.60
Phosphorus, digestible	0.87	0.87	0.72	0.75	0.60	0.66	0.51	0.57	0.42	0.45	0.57	0.60	0.45	0.51

[a]0.65 to 0.80 lb of fat free lean/day from 45 to 270 lb.
[b]All diets are full fed under thermoneutral conditions; see PIG factsheet #07-01-09 (Growing-Finishing Swine Nutrient Recommendations and Feeding Management) for more details.
[c]Ractopamine hydrochloride (Paylean®).
[d]B = barrows and G = gilts.
[e]Total phosphorus recommendations should be used as a guideline only; those recommendations may not be obtained when formulating practical diets on an available or digestible phosphorus basis which is recommended. Also, total phosphorus recommendations will not be achieved when phytase is included in the diet.
[f]Recommended amount relative to dietary metabolizable energy (ME) density; energy values of ingredients from PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) were used in the calculations.

Table 4. Amino acid, calcium and phosphorus recommendations for LOW[a] lean gain lines of growing-finishing swine (as-fed basis)[b]														
Type of diet	**Phase 1**		**Phase 2**		**Phase 3**		**Phase 4**		**Phase 5**		**Phase 5 + RAC[c]**		**Phase 6+ RAC[c]**	
Body weight, lb	**45 to 90**		**90 to 135**		**135 to 180**		**180 to 225**		**225 to 270**		**225 to 270**		**270 to 315**	
Estimated lean gain, lb/d (protein deposition, g/d)	**0.50 (89)**		**0.55 (97)**		**0.62 (111)**		**0.60 (107)**		**0.55 (97)**		**0.72 (129)**		**0.65 (115)**	
Sex[d]	**B**	**G**	**B**	**G**	**B**	**G**	**B**	**G**	**B**	**G**	**B**	**G**	**B**	**G**
Assumed daily feed intake, lb	**3.1**	**3.1**	**4.2**	**4.0**	**5.1**	**4.7**	**5.8**	**5.3**	**6.2**	**5.7**	**6.2**	**5.7**	**6.4**	**5.9**
Dietary metabolizable energy, Mcal/lb	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**
	----------% ----------													
Lysine, total	0.87	0.87	0.78	0.82	0.70	0.76	0.62	0.68	0.54	0.59	0.69	0.75	0.59	0.64
Standardized ileal digestible														
Lysine	0.76	0.76	0.68	0.71	0.61	0.66	0.53	0.58	0.46	0.50	0.60	0.65	0.51	0.55
Threonine	0.48	0.48	0.43	0.45	0.39	0.42	0.35	0.38	0.31	0.34	0.40	0.44	0.34	0.37
Methionine	0.22	0.22	0.20	0.21	0.18	0.19	0.15	0.17	0.14	0.15	0.18	0.20	0.16	0.17
Methionine+cysteine	0.44	0.44	0.39	0.41	0.36	0.39	0.32	0.35	0.29	0.31	0.37	0.40	0.32	0.35
Tryptophan	0.12	0.12	0.11	0.11	0.10	0.11	0.09	0.09	0.07	0.08	0.10	0.10	0.08	0.09
Isoleucine	0.42	0.42	0.37	0.39	0.33	0.36	0.29	0.32	0.25	0.28	0.33	0.36	0.28	0.30
Valine	0.49	0.49	0.44	0.46	0.39	0.43	0.35	0.38	0.30	0.33	0.39	0.42	0.33	0.36
Calcium	0.71	0.71	0.61	0.65	0.56	0.61	0.52	0.57	0.49	0.53	0.51	0.55	0.48	0.52
Phosphorus, total[e]	0.71	0.71	0.61	0.65	0.56	0.61	0.52	0.57	0.49	0.53	0.51	0.55	0.48	0.52
Phosphorus, available	0.32	0.32	0.26	0.28	0.23	0.25	0.20	0.22	0.19	0.20	0.21	0.22	0.19	0.20
Phosphorus, digestible	0.24	0.24	0.20	0.21	0.17	0.19	0.14	0.16	0.12	0.13	0.16	0.17	0.12	0.13
	----------g/Mcal ME[f]----------													
Lysine, total	2.60	2.60	2.33	2.45	2.09	2.27	1.85	2.03	1.61	1.76	2.06	2.24	1.76	1.91
Standardized ileal digestible														
Lysine	2.27	2.27	2.03	2.12	1.82	1.97	1.58	1.73	1.37	1.49	1.79	1.94	1.52	1.64
Threonine	1.43	1.43	1.28	1.34	1.16	1.25	1.04	1.13	0.93	1.01	1.19	1.31	1.01	1.10
Methionine	0.66	0.66	0.60	0.63	0.54	0.57	0.45	0.51	0.42	0.45	0.54	0.60	0.48	0.51
Methionine+cysteine	1.31	1.31	1.16	1.22	1.07	1.16	0.95	1.04	0.87	0.93	1.10	1.19	0.95	1.04
Tryptophan	0.36	0.36	0.33	0.33	0.30	0.33	0.27	0.27	0.21	0.24	0.30	0.30	0.24	0.27
Isoleucine	1.25	1.25	1.10	1.16	0.98	1.07	0.87	0.95	0.75	0.84	0.98	1.07	0.84	0.90
Valine	1.46	1.46	1.31	1.37	1.16	1.28	1.04	1.13	0.90	0.98	1.16	1.25	0.98	1.07
Calcium	2.12	2.12	1.82	1.94	1.67	1.82	1.55	1.70	1.46	1.58	1.52	1.64	1.43	1.55
Phosphorus, total[e]	2.12	2.12	1.82	1.94	1.67	1.82	1.55	1.70	1.46	1.58	1.52	1.64	1.43	1.55
Phosphorus, available	0.95	0.95	0.78	0.84	0.69	0.75	0.60	0.66	0.57	0.60	0.63	0.66	0.57	0.60
Phosphorus, digestible	0.72	0.72	0.60	0.63	0.51	0.57	0.42	0.48	0.36	0.39	0.48	0.51	0.36	0.39

[a]< 0.65 lb of fat-free lean/day from 45 to 270 lb.
[b]All diets are full fed under thermoneutral conditions; see PIG factsheet #07-01-09 (Growing-Finishing Swine Nutrient Recommendations and Feeding Management) for more details.
[c]Ractopamine hydrochloride (Paylean®).
[d]B = barrows and G = gilts.
[e]Total phosphorus recommendations should be used as a guideline only; those recommendations may not be obtained when formulating practical diets on an available or digestible phosphorus basis which is recommended. Also, total phosphorus recommendations will not be achieved when phytase is included in the diet.
[f]Recommended amount relative to dietary metabolizable energy (ME) density; energy values of ingredients from PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) were used in the calculations.

Table 5. Amino acid, calcium and phosphorus recommendations for gestating swine fed higher energy diets (as-fed basis)[a]				
	Parity 0 and 1[b]		Parity 2 or greater[c]	
Litter size, total born	**10.5**	**12.5**	**12**	**14**
Assumed daily feed intake, lb[d]	**4.6**	**4.7**	**4.1**	**4.2**
Assumed total weight gain, lb	**115**	**125**	**80**	**90**
Dietary metabolizable energy, Mcal/lb	**1.50**	**1.50**	**1.50**	**1.50**
	----------% of diet ----------			
Lysine, total	0.68	0.70	0.58	0.60
Standardized ileal digestible				
Lysine	0.58	0.60	0.50	0.52
Threonine	0.44	0.46	0.38	0.40
Methionine	0.16	0.16	0.14	0.14
Methionine+cysteine	0.41	0.42	0.35	0.37
Tryptophan	0.11	0.11	0.09	0.10
Isoleucine	0.33	0.34	0.29	0.30
Valine	0.40	0.41	0.34	0.36
Calcium	0.90	0.90	0.85	0.85
Phosphorus, total[e]	0.80	0.80	0.75	0.75
Phosphorus, available	0.45	0.45	0.40	0.40
Phosphorus, digestible	0.39	0.39	0.35	0.35
	----------g/Mcal ME[f]----------			
Lysine, total	2.04	2.10	1.76	1.82
Standardized ileal digestible				
Lysine	1.76	1.82	1.51	1.57
Threonine	1.34	1.38	1.15	1.19
Methionine	0.48	0.49	0.42	0.42
Methionine+cysteine	1.23	1.27	1.06	1.10
Tryptophan	0.32	0.33	0.27	0.29
Isoleucine	1.00	1.04	0.86	0.89
Valine	1.20	1.24	1.03	1.07
Calcium	2.72	2.72	2.57	2.57
Phosphorus, total[e]	2.42	2.42	2.27	2.27
Phosphorus, available	1.36	1.36	1.21	1.21
Phosphorus, digestible	1.18	1.18	1.06	1.06
	---------- Calculated daily intake, g ----------			
Metabolizable energy, Mcal	6.90	7.05	6.15	6.30
Lysine, total	14.3	15.0	10.8	11.4
Standardized ileal digestible				
Lysine	12.2	12.8	9.3	9.9
Calcium	18.8	19.2	15.8	16.2
Phosphorus, total	16.7	17.1	14.0	14.3
Phosphorus, available	9.4	9.6	7.4	7.6
Phosphorus, digestible	8.1	8.3	6.5	6.7

[a]All diets are limit-fed under thermoneutral conditions; see PIG factsheet #07-01-11 (Gestating Swine Nutrient Recommendations and Feeding Management) for more details.
[b]Parity 0 = first gestation period (female has not farrowed a litter); parity 1 = second gestation period (female has farrowed one litter previously).
[c]Parity 2 = third gestation period (female has farrowed two litters previously).
[d]Adjust to achieve a desired body condition or weight gain.
[e]Total phosphorus recommendations should be used as a guideline only; those recommendations may not be obtained when formulating practical diets on an available or digestible phosphorus basis which is recommended. Also, total phosphorus recommendations will not be achieved when phytase is included in the diet.
[f]Recommended amount relative to dietary metabolizable energy (ME) density; energy values of ingredients from PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) were used in the calculations.

Table 6. Amino acid, calcium and phosphorus recommendations for gestating swine fed lower energy diets (as-fed basis)[a]				
	Parity 0 and 1[b]		Parity 2 or greater[c]	
Litter size, total born	**10.5**	**12.5**	**12**	**14**
Assumed daily feed intake, lb[d]	**5.1**	**5.2**	**4.6**	**4.7**
Assumed total weight gain, lb	**115**	**125**	**80**	**90**
Dietary metabolizable energy, Mcal/lb	**1.35**	**1.35**	**1.35**	**1.35**
	----------% of diet ----------			
Lysine, total	0.62	0.64	0.52	0.53
Standardized ileal digestible				
Lysine	0.53	0.54	0.44	0.46
Threonine	0.40	0.41	0.33	0.35
Methionine	0.14	0.15	0.12	0.12
Methionine+cysteine	0.37	0.38	0.31	0.32
Tryptophan	0.10	0.10	0.08	0.08
Isoleucine	0.31	0.31	0.25	0.26
Valine	0.36	0.37	0.30	0.31
Calcium	0.81	0.81	0.76	0.76
Phosphorus, total[e]	0.72	0.72	0.67	0.67
Phosphorus, available	0.41	0.41	0.35	0.35
Phosphorus, digestible	0.36	0.36	0.31	0.31
	----------g/Mcal ME[f]----------			
Lysine, total	2.08	2.15	1.75	1.78
Standardized ileal digestible				
Lysine	1.78	1.81	1.48	1.55
Threonine	1.35	1.38	1.12	1.18
Methionine	0.48	0.49	0.40	0.42
Methionine+cysteine	1.25	1.27	1.04	1.08
Tryptophan	0.32	0.32	0.27	0.28
Isoleucine	1.01	1.03	0.84	0.88
Valine	1.21	1.23	1.01	1.05
Calcium	2.72	2.72	2.56	2.56
Phosphorus, total[e]	2.42	2.42	2.25	2.25
Phosphorus, available	1.38	1.38	1.18	1.18
Phosphorus, digestible	1.21	1.21	1.04	1.04
	---------- Calculated daily intake, g ----------			
Metabolizable energy, Mcal	6.88	7.02	6.21	6.34
Lysine, total	14.3	15.0	10.8	11.4
Standardized ileal digestible				
Lysine	12.2	12.8	9.3	9.9
Calcium	18.8	19.2	15.8	16.2
Phosphorus, total	16.7	17.1	14.0	14.3
Phosphorus, available	9.4	9.6	7.4	7.6
Phosphorus, digestible	8.3	8.5	6.5	6.6

[a]All diets are limit-fed under thermoneutral conditions; PIG factsheet #07-01-11 (Gestating Swine Nutrient Recommendations and Feeding Management) for more details.
[b]Parity 0 = first gestation period (female has not farrowed a litter); parity 1 = second gestation period (female has farrowed one litter previously).
[c]Parity 2 = third gestation period (female has farrowed two litters previously).
[d]Adjust to achieve a desired body condition or weight gain.
[e]Total phosphorus recommendations should be used as a guideline only; those recommendations may not be obtained when formulating practical diets on an available or digestible phosphorus basis which is recommended. Also, total phosphorus recommendations will not be achieved when phytase is included in the diet.
[f]Recommended amount relative to dietary metabolizable energy (ME) density; energy values of ingredients from PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) were used in the calculations

Table 7. Amino acid, calcium and phosphorus recommendations for lactating swine (as-fed basis)[ab]				
	Parity 1[c]		Parity 2 or greater[c]	
Assumed sow lactation wt change, lb	**-25**	**-10**	**-10**	**+5**
Assumed sow daily feed intake, lb	**11.8**	**10.1**	**14.2**	**12.3**
Assumed daily piglet wt gain, lb	**0.49**	**0.40**	**0.49**	**0.40**
Assumed litter size weaned	**11**	**10**	**12**	**11**
Assumed litter weaning wt, lb	**145**	**115**	**160**	**125**
Dietary metabolizable energy, Mcal/lb	**1.50**	**1.50**	**1.50**	**1.50**
	----------% of diet ----------			
Lysine, total	1.13	0.95	1.04	0.88
Standardized ileal digestible				
Lysine	1.00	0.83	0.92	0.76
Threonine	0.59	0.52	0.57	0.50
Methionine	0.25	0.22	0.24	0.21
Methionine+cysteine	0.46	0.41	0.44	0.39
Tryptophan	0.18	0.16	0.17	0.15
Isoleucine	0.54	0.47	0.52	0.45
Valine	0.82	0.71	0.78	0.68
Calcium	0.90	0.90	0.85	0.85
Phosphorus, total[d]	0.80	0.80	0.75	0.75
Phosphorus, available	0.45	0.45	0.40	0.40
Phosphorus, digestible	0.39	0.39	0.35	0.35
	----------g/Mcal ME[e]----------			
Lysine, total	3.42	2.87	3.14	2.66
Standardized ileal digestible				
Lysine	3.02	2.51	2.78	2.30
Threonine	1.78	1.58	1.72	1.52
Methionine	0.76	0.68	0.72	0.64
Methionine+cysteine	1.39	1.23	1.34	1.17
Tryptophan	0.54	0.48	0.50	0.46
Isoleucine	1.63	1.43	1.59	1.36
Valine	2.48	2.16	2.36	2.05
Calcium	2.72	2.72	2.57	2.57
Phosphorus, total[d]	2.42	2.42	2.27	2.27
Phosphorus, available	1.36	1.36	1.21	1.21
Phosphorus, digestible	1.18	1.18	1.06	1.06

[a]All diets are full-fed under thermoneutral conditions; see PIG factsheet #07-01-12 (Lactating Swine Nutrient Recommendations and Feeding Management) for more details; parity 1 = first lactation period, parity 2 = second lactation period, etc.
[b]Sow performance assumptions: 21-day lactation length, initial piglet weight = 3 lb, sow weight at weaning = = 350 - 400 lb (parity 1) and 400 - 450 lb (parity 2+).
[c]Parity 1 = first lactation period; parity 2 = second lactation period.
[d]Total phosphorus recommendations should be used as a guideline only; those recommendations may not be obtained when formulating practical diets on an available or digestible phosphorus basis which is recommended. Also, total phosphorus recommendations will not be achieved when phytase is included in the diet.
[e]Recommended amount relative to dietary metabolizable energy (ME) density; energy values of ingredients from PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) were used in the calculations.

Table 8. Amino acid, calcium and phosphorus recommendations for breeding boars (as-fed basis)[a]		
Body weight, lb	**300 to 400**	**400 to 650**
Assumed daily feed intake, lb[b]	**5.4**	**6.0**
Dietary metabolizable energy, Mcal//b	**1.50**	**1.50**
	---------- % of diet ----------	
Lysine, total	0.75	0.75
Standardized ileal digestible		
Lysine	0.64	0.64
Threonine	0.47	0.47
Methionine	0.17	0.17
Methionine + cysteine	0.45	0.45
Tryptophan	0.12	0.12
Isoleucine	0.36	0.36
Valine	0.44	0.44
Calcium	0.85	0.85
Phosphorus, total[c]	0.75	0.75
Phosphorus, available	0.40	0.40
Phosphorus, digestible	0.35	0.35
	---------- g/Mcal ME[d] ----------	
Lysine, total	2.27	2.27
Standardized ileal digestible		
Lysine	1.94	1.94
Threonine	1.43	1.43
Methionine	0.52	0.52
Methionine + cysteine	1.35	1.35
Tryptophan	0.35	0.35
Isoleucine	1.10	1.10
Valine	1.32	1.32
Calcium	2.57	2.57
Phosphorus, total[c]	2.27	2.27
Phosphorus, available	1.21	1.21
Phosphorus, digestible	1.06	1.06

[a]All diets are limit-fed under thermoneutral conditions; see PIG factsheet #07-01-13 (Breeding Boar Nutrient Recommendations and Feeding Management) for more details.
[b]Adjust to achieve a desired body condition or weight gain.
[c]Total phosphorus recommendations should be used as a guideline only; those recommendations may not be obtained when formulating practical diets on an available or digestible phosphorus basis which is recommended. Also, total phosphorus recommendations will not be achieved when phytase is included in the diet.
[d]Recommended amount relative to dietary metabolizable energy (ME) density; energy values of ingredients from PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) were used in the calculations.

Table 9. Amino acid, calcium and phosphorus recommendations for maternal-line replacement gilts (as-fed basis)[ab]							
Type of diet	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Phase 5**	**Phase 6F**	**Phase 6L**
Body weight, lb	**45 to 90**	**90 to 135**	**135 to 180**	**180 to 225**	**225 to 270**	**270 to breeding**	**270 to flush**
Assumed daily feed intake, lb	**3.1**	**4.0**	**4.7**	**5.3**	**5.7**	**5.9**	**5.0**
Dietary metabolizable energy, Mcal/lb	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**
	----------% of diet ----------						
Lysine, total	1.15	1.04	0.95	0.85	0.74	0.65	0.77
Standardized ileal digestible							
Lysine	1.02	0.92	0.84	0.74	0.64	0.56	0.67
Threonine	0.64	0.58	0.54	0.48	0.43	0.38	0.46
Methionine	0.30	0.27	0.24	0.22	0.19	0.17	0.21
Methionine + cysteine	0.59	0.53	0.50	0.45	0.40	0.35	0.42
Tryptophan	0.16	0.15	0.13	0.12	0.10	0.09	0.11
Isoleucine	0.56	0.51	0.46	0.41	0.35	0.31	0.37
Valine	0.66	0.60	0.54	0.48	0.42	0.36	0.44
Calcium	0.81	0.75	0.71	0.67	0.65	0.65	0.75
Phosphorus, total[c]	0.81	0.75	0.71	0.67	0.65	0.65	0.75
Phosphorus, available	0.38	0.34	0.32	0.29	0.29	0.29	0.34
Phosphorus, digestible	0.35	0.32	0.29	0.26	0.26	0.26	0.32
	----------g/Mcal ME[d]----------						
Lysine, total	3.43	3.10	2.83	2.54	2.21	1.94	2.30
Standardized ileal digestible							
Lysine	3.04	2.74	2.50	2.22	1.92	1.67	2.00
Threonine	1.92	1.73	1.60	1.44	1.29	1.14	1.36
Methionine	0.88	0.80	0.72	0.64	0.58	0.52	0.62
Methionine + cysteine	1.77	1.59	1.50	1.33	1.19	1.05	1.26
Tryptophan	0.49	0.44	0.40	0.36	0.31	0.27	0.32
Isoleucine	1.67	1.51	1.37	1.22	1.06	0.92	1.10
Valine	1.98	1.78	1.62	1.44	1.25	1.09	1.30
Calcium	2.42	2.24	2.12	2.00	1.94	1.94	2.24
Phosphorus, total[c]	2.42	2.24	2.12	2.00	1.94	1.94	2.24
Phosphorus, available	1.13	1.01	0.95	0.87	0.87	0.87	1.01
Phosphorus, digestible	1.04	0.95	0.87	0.78	0.78	0.78	0.95

[a]All diets are full-fed under themoneutral conditions except diet 6L, which is limit-fed and is used in place of diet 6F for limit-feeding programs; see PIG factsheet #07-01-10 (Replacement Gilt and Boar Nutrient Recommendations and Feeding Management) for more details.
[b]Sufficient data are not available to indicate that requirements for other nutrients are different from those in Table 11 for animals of these weights. Provide breeding herd levels of trace minerals and vitamins beginning at about 270 lb.
[c]Total phosphorus recommendations should be used as a guideline only; those recommendations may not be obtained when formulating practical diets on an available or digestible phosphorus basis which is recommended. Also, total phosphorus recommendations will not be achieved when phytase is included in the diet.
[d]Recommended amount relative to dietary metabolizable energy (ME) density; energy values of ingredients from PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) were used in the calculations.

Table 10. Amino acid, calcium and phosphorus recommendations for terminal-line replacement boars (as-fed basis)[ab]						
Type of diet	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Phase 5**	**Phase 6**
Body weight, lb	**45 to 90**	**90 to 135**	**135 to 180**	**180 to 225**	**225 to 270**	**270 to 300**
Assumed daily feed intake, lb	**3.1**	**4.0**	**4.7**	**5.3**	**5.7**	**5.9**
Dietary metabolizable energy, Mcal/lb	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**	**1.52**
	----------% of diet ----------					
Lysine, total	1.35	1.20	1.12	0.99	0.88	0.79
Standardized ileal digestible						
Lysine	1.20	1.07	0.99	0.87	0.77	0.69
Threonine	0.76	0.67	0.64	0.57	0.52	0.47
Methionine	0.35	0.31	0.29	0.25	0.23	0.21
Methionine + cysteine	0.70	0.62	0.60	0.52	0.48	0.43
Tryptophan	0.19	0.17	0.16	0.14	0.12	0.11
Isoleucine	0.66	0.59	0.55	0.48	0.42	0.38
Valine	0.78	0.69	0.64	0.57	0.50	0.45
Calcium	0.86	0.80	0.76	0.72	0.68	0.68
Phosphorus, total[c]	0.86	0.80	0.76	0.72	0.68	0.68
Phosphorus, available	0.46	0.39	0.34	0.31	0.30	0.30
Phosphorus, digestible	0.45	0.38	0.33	0.30	0.29	0.29
	----------g/Mcal ME[d]----------					
Lysine, total	4.03	3.58	3.34	2.95	2.63	2.36
Standardized ileal digestible						
Lysine	3.59	3.18	2.96	2.61	2.30	2.06
Threonine	2.26	2.00	1.90	1.69	1.54	1.40
Methionine	1.04	0.92	0.86	0.76	0.69	0.64
Methionine + cysteine	2.08	1.84	1.78	1.56	1.43	1.30
Tryptophan	0.57	0.51	0.47	0.42	0.37	0.33
Isoleucine	1.98	1.75	1.63	1.43	1.27	1.13
Valine	2.33	2.07	1.92	1.69	1.50	1.34
Calcium	2.57	2.39	2.27	2.15	2.03	2.03
Phosphorus, total[c]	2.57	2.39	2.27	2.15	2.03	2.03
Phosphorus, available	1.37	1.16	1.01	0.93	0.90	0.90
Phosphorus, digestible	1.34	1.13	0.98	0.90	0.87	0.87

[a]All diets are full-fed under thermoneutral conditions; see PIG factsheet #07-01-10 (Replacement Gilt and Boar Nutrient Recommendations and Feeding Management) for more details.
[b]Sufficient data are not available to indicate that requirements for other nutrients are different from those in Table 11 for animals of these weights. Provide breeding herd levels of trace minerals and vitamins beginning at about 270 lb.
[c]Total phosphorus recommendations should be used as a guideline only; those recommendations may not be obtained when formulating practical diets on an available or digestible phosphorus basis which is recommended. Also, total phosphorus recommendations will not be achieved when phytase is included in the diet.
[d]Recommended amount relative to dietary metabolizable energy (ME) density; energy values of ingredients from PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) were used in the calculations.

Table 11. Recommended dietary additions of lactose, trace minerals and vitamins from concentrates, base mixes or premixes							
Type of diet	**Nursery**	**Grower**	**Finisher-1**	**Finisher-2**	**Finisher + RAC[a]**	**Sows**	**Breeding boars**
Body weight, lb	**9 to 45**	**45 to 135**	**135 to 225**	**225 to 315**	**225 to 315**		
Dietary metabolizable energy, Mcal/lb	**1.54**	**1.52**	**1.52**	**1.52**	**1.52**	**1.50**	**1.50**
Lactose, %	23 to 0[b]	0	0	0	0	0	0
Minerals							
Sodium, %[c,d]	0.25 to 0.15	0.15	0.15	0.15	0.15	0.2	0.2
Chloride, %[c,d]	0.25 to 0.15	0.15	0.15	0.15	0.15	0.2	0.2
Copper, ppm[e]	16	12	10	8	12	16	16
Iodine, ppm	0.30	0.25	0.20	0.15	0.25	0.30	0.30
Iron, ppm	165	125	100	75	125	165	165
Manganese, ppm	10	6	5	4	6	30	30
Selenium, ppm[f]	0.3	0.25	0.20	0.15	0.25	0.3	0.3
Zinc, ppm[e]	165	125	100	75	125	165	165
Vitamins							
Vitamin A, IU/lb	3000	2500	2000	1500	2500	4000	4000
Vitamin D_3, IU/lb	300	250	200	150	250	300	300
Vitamin E, IU/lb	30	15	12	9	15	30	30
Vitamin K, mg/lb[g]	2	1	0.8	0.6	1	2	2
Riboflavin, mg/lb	4	4	3	2	4	4	4
Niacin, mg/lb	22	11	9	7	11	15	15
Pantothenic acid, mg/lb	12	7	6	5	7	10	10
Choline, mg/lb	0	0	0	0	0	250	250
Biotin, mg/lb	0	0	0	0	0	0.1	0.1
Vitamin B_{12}, mg/lb	0.02	0.01	0.008	0.006	0.01	0.01	0.01
Folic acid, mg/lb	0	0	0	0	0	0.75	0.75
Vitamin B_6,mg/lb	0	0	0	0	0	0	0

[a]Ractopamine hydrochloride (Paylean®).
[b]23, 18, 7.2 and 0% for phase 1 (9 to 11 lb), phase 2 (11 to 15 lb), phase 3 (15 to 25 lb) and phase 4 (25 to 45 lb), respectively.
[c]Salt is usually added at the rate of 5 to 7 lb/ton in nursery diets, 6 to 7 lb/ton in grower-finisher diets and 10 lb/ton in sow and breeding boar diets to help provide a significant portion of the *total* dietary sodium and chloride recommendations.
[d]Recommendations for sodium and chloride represent *total* dietary amounts, not additions; 0.25, 0.20, 0.20 and 0.15% for nursery phase 1 (9 to 11 lb), nursery phase 2 (11 to 15 lb), nursery phase 3 (15 to 25 lb) and nursery phase 4 (25 to 45 lb), respectively.
[e]Levels of 3,000 ppm Zn for Phases 1 and 2 (9 to 15 lb) and 2,000 ppm Zn for Phase 3 (15 to 25 lb) from zinc oxide should be added to growth promotion; or 125 to 250 ppm Cu from copper sulfate or tri-basic copper chloride in Phases 1, 2, and 3 (9 to 25 lb).
[f]Maximum legal addition is 0.3 ppm.
[g]Menadione activity.
See PIG factsheet #07-02-06 (Trace Minerals and Vitamins for Swine Diets) for more details, including a recommended minimum and maximum amount to add to diets.

Table 12. Trace mineral premix specifications[abc]		
Nutrient	**Units**	**Potency per lb of premix**
Copper	mg	4,850
Iodine	mg	90
Iron	mg	50,000
Manganese	mg	9,000
Selenium	mg	90
Zinc	mg	50,000

[a]Mineral sources are listed in Table 22.
[b]Premix usage rates:
Sows, breeding boars and nursery pigs, 3 lb/ton of complete feed.
Grower (45 to 135 lb pigs), 2.5 lb/ton of complete feed.
Finisher 1 (135 to 225 lb pigs), 2 lb/ton of complete feed.
Finisher 2 (225 to 315 lb pigs), 1.5 lb/ton of complete feed.
Finisher + RAC (225 to 315 lb pigs), 2.5 lb/ton of complete feed.
[c]The mineral additions shown in Table 11 are met or exceeded with a premix containing the potency indicated and used as directed.

Table 13. Vitamin premix specifications for nursery diets[abc]		
Nutrient	**Units**	**Potency per lb of premix**
Vitamin A	IU/lb	1,200,000
Vitamin D_3	IU/lb	120,000
Vitamin E	IU/lb	12,000
Vitamin K	mg	800
Riboflavin	mg	1,600
Niacin	mg	8,800
Pantothenic acid	mg	4,800
Choline	mg	0
Biotin	mg	0
Vitamin B_{12}	mg	8.28
Folic acid	mg	0
Vitamin B_6	mg	0

[a]Vitamin sources are listed Table 24.
[b]Premix usage rate: 5 lb/ton of complete feed.
[c]A premix containing the potency indicated and used as directed will fortify diets as shown in Table 11.

Table 14. Vitamin premix specifications for growing-finishing diets[abc]		
Nutrient	**Units**	**Potency per lb of premix**
Vitamin A	IU/lb	1,000,000
Vitamin D_3	IU/lb	100,000
Vitamin E	IU/lb	6,000
Vitamin K	mg	400
Riboflavin	mg	1,600
Niacin	mg	4,400
Pantothenic acid	mg	2,800
Choline	mg	0
Biotin	mg	0
Vitamin B_{12}	mg	4
Folic acid	mg	0
Vitamin B_6	mg	0

[a]Vitamin sources are listed Table 24.
[b]Premix usage rates:
Grower (45 to 135 lb pigs), 5 lb/ton of complete feed.
Finisher 1 (135 to 225 lb pigs), 4 lb/ton of complete feed.
Finisher 2 (225 to 315 lb pigs), 3 lb/ton of complete feed.
Finisher + RAC (225 to 315 lb pigs), 5 lb/ton of complete feed.
[c]A premix containing the potency indicated and used as directed will fortify diets as shown in Table 11.

Table 15. Vitamin premix specifications for sow and breeding boar diets[abc]		
Nutrient	**Units**	**Potency per lb of premix**
Vitamin A	IU/lb	1,600,000
Vitamin D_3	IU/lb	120,000
Vitamin E	IU/lb	12,000
Vitamin K	mg	800
Riboflavin	mg	1,600
Niacin	mg	6,000
Pantothenic acid	mg	4,000
Choline	mg	100,000
Biotin	mg	40
Vitamin B_{12}	mg	4
Folic acid	mg	300
Vitamin B_6	mg	0

[a]Vitamin sources are listed in Table 24.
[b]Premix usage rate: 5 lb/ton of complete feed.
[c]A premix containing the potency indicated and used as directed will fortify diets as shown in Table 11.

Ingredient composition and use rate

Individual ingredients can vary widely in composition because of the variation in species or variety, storage conditions, climate, soil moisture, agronomic differences and manufacturing practices. Variations in chemical analytical procedures can also affect the values obtained. Therefore, the values listed in this publication should be used as a guide in formulating diets. Otherwise, rely on ingredient analyses as necessary prior to diet formulation.

Most of the tabular information contained herein was obtained from the NRC (1998). Information published since the NRC (1998) was also included. An attempt was made to include analytical results of feed ingredients obtained from contemporary crop cultivars, newer processing techniques, and improved analytical procedures.

Net energy
The net energy value for approximately 40% of the ingredients in Table 16 was obtained from EvaPig (2008); for other ingredients, net energy was calculated from one of the following equations where ME = metabolizable energy, EE = ether extract, ST = starch, CP = crude protein, CF = crude fiber and ADF = acid detergent fiber. Equation NE1 was used when values for EE, ST, CP and ADF were known or could be reasonably estimated. When ADF was not available, equation NE2 was used to estimate NE.

NE_1 = 0.726 x ME + 1.33 x EE + 0.39 x ST – 0.62 x CP – 0.83 x ADF (R2 = 0.97; Noblet et al., 1994)

NE_2 = 0.730 x ME + 1.31 x EE + 0.37 x ST – 0.67 x CP – 0.97 x CF (R2 = 0.97; Noblet et al., 1994)

The net energy value for fats and oils (Table 24) was calculated by multiplying ME by 0.90, the estimated efficiency with which fat is converted from ME to NE (INRA, 2004).

Iodine value and iodine product
Due to carcass fat quality concerns when feeding high levels of dietary unsaturated fat, both iodine value (IV) and iodine value product (IVP) are listed for each ingredient. The iodine value for each ingredient reflects the fat saturation level of each ingredient. A lower iodine value indicates a higher degree of fat saturation in the ingredient. Iodine value product is the value assigned to each ingredient that accounts for its IV and percentage fat it contains. Once calculated, IVP can be used to help predict the carcass fat IV of pigs fed those diets. Iodine values for available ingredients were obtained from the NRC (1998). For ingredients not listed in the NRC (1998), fatty acid profiles were obtained from cited references from which iodine values were calculated using the following equation:

IV = [C16:1] × 0.95 + [C18:1] × 0.86 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C22:1] × 0.723, where the brackets indicate concentration (percentage) of the fatty acid (AOCS, 1998).

Iodine value product for each ingredient was calculated using the following equation:

IVP = IV of the ingredient oil × % oil in the ingredient × 0.10 (Christensen, 1962).

Ingredient use rate
The upper limits of usage presented in this factsheet (Table 25) represent conservative estimates of the extent ingredients can be included in swine diets balanced for energy, amino acids, minerals and vitamins and not negatively impact growth and reproductive performance and/or carcass composition. We acknowledge that establishing upper limits of usage is greatly dependent on individual risk tolerance. Also, situations exist were it is economically justified to increase the inclusion rate of an ingredient even if performance is negatively impacted.

In general, factors such as palatability, risk of gastrointestinal disturbance, unspecified loss of performance, appetite impairment and others that are involved in affecting growth and reproductive performance and/or carcass composition were considered in establishing the upper limits of usage indicated in this factsheet.

Table 16. Chemical composition of feed ingredients for swine (as-fed basis).[ab]													
Ingredient	**Dry matter (%)**	**Digestible energy (kcal/lb)**	**Metabolizable energy (kcal/lb)**	**Net Energy (kcal/lb)**	**Crude protein (%)**	**Acid detergent fiber (%)**	**Neutral detergent fiber (%)**	**Crude fiber (%)**	**Starch (%)**	**Crude fat (%)**	**Linoleic acid (%)**	**Iodine value**	**Iodine value product**
Alfalfa meal, dehydrated	92	830	750	398	17.0	30.2	41.2	24.0	0	2.6	0.35	100	26.0
Bakery waste, dehydrated	91	1787	1682	1349	10.8	1.3	2.0	1.2	53.7	11.3	5.70	125	141.3
Barley, two row	89	1383	1322	1034	11.3	6.2	18.0	5.0	52.2	1.9	0.88	125	23.8
Beet pulp	91	1300	1134	671	8.6	24.3	42.4	18.2	0	0.8	0.04	1	0.1
Blood													
Cells, spray-dried	92	1996	1900	1115	92.0	---	---	0.5	0	1.5	---	44	7.0
Meal, flash-dried	92	1043	886	386	87.6	---	---	1.0	0	1.6	---	44	7.0
Meal, spray-dried	93	1529	1338	710	88.8	---	---	1.0	0	1.3	0.17	44	6.0
Plasma protein, spray-dried	91	2066	1809	1094	78.0	---	---	0.2	0	2.0	---	44	8.0
Canola meal	90	1309	1200	687	35.6	17.2	21.2	11.1	0	3.5	0.42	118	41.3
Corn													
Distillers dried grains w/solubles (DDGS)	88	1649	1552	1076	27.4	12.2	30.5	7.7	7.3	9.9	2.15	125	123.8
Distillers dried grains -high protein	90	1997	1876	1252	41.8	8.7	16.4	7.2	11.2	3.4	---	125	42.5
Germ	91	1665	1618	1259	14.8	5.6	20.4	6.2	23.6	17.5	---	125	218.8
Gluten feed	90	1356	1184	740	21.5	10.7	33.3	6.8	18.0	3.0	1.43	125	37.5
Gluten meal, 60% CP	90	1920	1741	1122	60.2	4.6	8.7	1.1	17.2	2.9	1.17	125	36.3
Grain, yellow dent	89	1602	1555	1203	8.3	2.8	9.6	2.3	64.1	3.9	1.92	125	48.8
Grain, high nutrient	87	1580	1662	1273	9.2	2.3	6.3	2.3	58.0	4.5	---	125	56.3
Grain, high oil	87	1697	1629	1291	8.4	2.9	---	2.0	60.3	6.0	---	125	75.0
Grain, low-phytate	88	1697	1629	1286	9.2	2.8	---	2.2	64.1	4.4	---	125	55.0
Hominy feed	90	1522	1459	1104	10.3	8.1	28.5	5.0	36.0	6.7	2.97	125	83.8
Egg, spray-dried	---	2380	2285	1696	47.0	0	---	---	0	28	---	71	198.8
Fish meal, menhaden	92	1710	1527	994	62.3	---	---	0.9	0	9.4	0.12	110	103.4
Flax (linseed) meal, sol. extr.	90	1388	1229	793	33.6	15.0	23.9	9.8	0	1.8	0.36	169	30.4
Lactose	96	1602	1561	1447	0.3	---	---	---	---	---	---	---	---
Meat and bone meal (≥ 4.0% P)	96	1432	1249	798	52.8	5.6	32.5	2.4	0	10.1	0.72	70	76.3
Meat meal (< 4% P)	96	1507	1328	842	56.4	8.3	31.6	2.3	0	11.2	0.80	70	84.0
Millet, proso	90	1370	1340	1004	11.1	13.8	15.8	6.1	52.8	3.5	1.92	135	47.3
Molasses													
Beet	76	1093	1060	716	11.0	---	---	0	0	0.2	---	1	0
Cane	74	1044	1011	697	4.0	---	---	0	0	1.1	---	1	0.1

Table 16. Chemical composition of feed ingredients for swine (as-fed basis).[ab] *(continued)*													
Ingredient	**Dry matter (%)**	**Digestible energy (kcal/lb)**	**Metabolizable energy (kcal/lb)**	**Net Energy (kcal/lb)**	**Crude protein (%)**	**Acid detergent fiber (%)**	**Neutral detergent fiber (%)**	**Crude fiber (%)**	**Starch (%)**	**Crude fat (%)**	**Linoleic acid (%)**	**Iodine value**	**Iodine value product**
Oats													
Grain	89	1256	1232	861	11.5	13.5	27.0	10.7	36.2	4.7	1.62	106	49.8
Groat	90	1674	1575	1218	13.9	4.6	11.6	2.5	52.6	6.2	2.40	106	65.7
Peas	88	1580	1500	1082	22.0	8.2	13.7	5.5	44.6	1.2	0.47	135	16.2
Rye	88	1483	1390	1070	11.8	4.6	12.3	2.2	53.8	1.6	0.76	131	21.0
Skim milk, dried	96	1809	1689	1232	34.6	---	---	0.2	0	0.9	0.01	27	2.4
Sorghum, grain (milo)	89	1536	1518	1187	9.2	8.3	18.0	2.2	64.1	2.9	1.13	116	33.6
Soybean													
Hulls	89	908	848	453	12.0	40.4	56.4	34.2	0.9	2.2	0.16	130	28.6
Meal, dehulled, 47.5% CP	90	1672	1536	907	47.5	5.4	8.9	3.4	0.8	3.0	0.60	130	39.0
Meal, dehulled, 46.5% CP	90	1651	1517	894	46.5	6.4	10.2	4.4	0.8	3.0	0.59	130	39.0
Meal, 44% CP	89	1586	1445	881	44.0	9.4	13.3	7.3	0.8	1.5	0.69	130	19.5
Meal, enzymatically treated	92	---	---	---	54.4	---	---	3.8	0.8	1.1	---	130	14.3
Meal, fermented	91	1620	1520	938	53.7	---	---	3.3	0.8	0.8	---	130	10.4
Protein concentrate	90	1860	1591	969	64.0	---	---	3.5	0	3.0	---	130	39.0
Protein isolate	92	1882	1618	922	85.8	---	---	0.4	0	0.6	---	130	7.8
Seeds, heat processed	90	1878	1677	1162	35.2	8.0	13.9	5.2	0.4	18.0	9.13	130	234.0
Sunflower meal, 42% CP	93	1288	1243	732	42.2	18.4	27.8	15.8	0	2.9	1.07	120	34.8
Triticale	90	1506	1445	1122	12.5	3.2	12.7	4.0	59.9	1.8	0.71	87	15.7
Wheat													
Bran	89	1098	1034	679	15.7	11.9	42.1	10.0	19.8	4.0	1.80	83	33.2
Grain, hard red winter	88	1526	1459	1114	13.5	3.7	13.5	2.6	55.5	2.0	0.93	83	16.6
Middlings, <9.5% fiber	89	1395	1375	993	15.9	9.2	35.6	7.8	27.7	4.2	1.74	83	34.9
Whey													
Dried	96	1513	1450	1299	12.1	---	---	---	0	0.9	0.01	27	2.4
Permeate	96	1558	1500	1080	3.8	0	---	---	0	0.2	---	27	0.5
Protein concentrate, 78%CP	94	2250	1978	1290	78.2	0	---	---	0	12.8	---	27	35.0

[a]Dashes indicate no data were available.
[b]See PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) for more details.

Table 17. Amino acid composition of feed ingredients for swine (as-fed basis). Percent standardized ileal digestibility (SID) of amino acids for swine shown in parenthesis[ab]

Ingredient	Dry Matter (%)	Crude protein (%)	Lysine (%)	Threonine (%)	Methionine (%)	Cysteine (%)	Tryptophan (%)	Isoleucine (%)	Valine (%)	Arginine (%)	Histidine (%)	Leucine (%)	Phenylalanine (%)	Tyrosine (%)
Alfalfa meal, dehy	92	17.0	0.74 (56)	0.70 (63)	0.25 (71)	0.18 (37)	0.24 (46)	0.68 (68)	0.86 (64)	0.71 (74)	0.37 (59)	1.21 (71)	0.84 (70)	0.55 (66)
Bakery waste, dehy	91	10.8	0.27 (77)	0.33 (69)	0.18 (90)	0.23 (91)	0.10 (91)	0.38 (94)	0.46 (93)	0.46 (---)	0.24 (---)	0.80 (90)	0.50 (---)	0.36 (---)
Barley, two row	89	11.3	0.41 (79)	0.35 (81)	0.20 (86)	0.28 (86)	0.11 (80)	0.39 (84)	0.52 (82)	0.54 (86)	0.25 (86)	0.77 (86)	0.55 (88)	0.29 (87)
Beet pulp	91	8.6	0.52 (51)	0.38 (30)	0.07 (64)	0.06 (21)	0.10 (41)	0.31 (60)	0.45 (42)	0.32 (57)	0.23 (61)	0.53 (59)	0.30 (54)	0.40 (51)
Blood														
Cells, spray-dried	92	92.0	8.51 (98)	3.38 (96)	0.81 (94)	0.61 (89)	1.37 (97)	0.49 (53)	8.50 (98)	3.77 (99)	6.99 (98)	12.70 (98)	6.69 (98)	2.14 (88)
Meal, flash-dried	92	87.6	7.56 (77)	4.07 (80)	0.95 (80)	1.20 (64)	1.06 (77)	0.88 (65)	8.03 (77)	3.37 (79)	4.57 (79)	11.48 (80)	6.41 (81)	2.32 (54)
Meal, spray-dried	93	88.8	7.45 (94)	3.78 (94)	0.99 (96)	1.04 (91)	1.48 (94)	1.03 (92)	7.03 (91)	3.69 (92)	5.30 (92)	10.81 (92)	5.81 (93)	2.71 (93)
Plasma proteins, spray-dried	91	78.0	6.84 (91)	4.72 (87)	0.75 (92)	2.63 (85)	0.36 (92)	2.71 (92)	4.94 (89)	4.55 (95)	2.55 (91)	7.61 (92)	4.42 (92)	3.53 (92)
Canola meal	90	35.6	2.08 (78)	1.59 (76)	0.74 (86)	0.91 (83)	0.45 (75)	1.43 (78)	1.82 (77)	2.21 (85)	0.96 (85)	2.58 (81)	1.43 (82)	1.13 (79)
Corn														
Distillers dried grains w/sol (DDGS)	88	27.4	0.78 (62)	0.97 (71)	0.58 (82)	0.38 (74)	0.20 (70)	1.04 (75)	1.38 (75)	1.16 (81)	0.71 (77)	3.32 (83)	1.34 (81)	1.16 (81)
Distillers dried grains -high protein	90	41.8	1.17 (64)	0.54 (77)	0.86 (88)	0.80 (82)	0.24 (81)	1.73 (81)	2.11 (80)	1.52 (83)	1.10 (81)	o.96 (91)	2.38 (87)	1.97 (88)
Germ	91	14.8	0.79 (58)	0.52 (53)	0.26 (68)	0.31 (64)	0.11 (67)	0.45 (57)	0.73 (62)	1.10 (83)	0.42 (69)	1.09 (68)	0.58 (64)	0.42 (59)
Gluten feed	90	21.5	0.63 (66)	0.74 (71)	0.35 (83)	0.46 (59)	0.07 (64)	0.66 (80)	1.01 (77)	1.04 (87)	0.67 (78)	1.96 (85)	0.76 (87)	0.58 (84)
Gluten meal, 60% CP	90	60.2	1.02 (80)	2.08 (84)	1.43 (90)	1.09 (82)	0.31 (63)	2.48 (84)	2.79 (80)	1.93 (89)	1.28 (80)	10.19 (88)	3.84 (85)	3.25 (87)
Grain, yellow dent	89	8.3	0.26 (78)	0.29 (82)	0.17 (90)	0.19 (86)	0.06 (84)	0.28 (87)	0.39 (87)	0.37 (89)	0.23 (87)	0.99 (92)	0.39 (90)	0.25 (89)
Grain, high nutrient	87	9.2	0.27 (78)	0.31 (79)	0.22 (87)	0.22 (82)	o.07 (76)	0.33 (83)	0.44 (82)	0.43 (88)	0.26 (85)	1.17 (87)	0.41 (85)	0.20 (80)
Grain, high oil	87	8.4	0.28 (---)	0.31 (---)	0.20 (---)	0.19 (---)	0.07 (---)	0.31 (---)	0.42 (---)	0.43 (---)	0.27 (---)	1.06 (---)	0.42 (---)	--- (---)
Grain, low-phytate	88	9.2	0.29 (81)	0.30 (81)	0.20 (88)	0.19 (85)	0.07 (---)	0.33 (86)	0.46 (85)	0.41 (93)	0.25 (86)	1.10 (90)	0.37 (89)	0.32 (89)
Hominy feed	90	10.3	0.38 (65)	0.40 (65)	0.18 (86)	0.18 (67)	0.10 (60)	0.36 (75)	0.52 (73)	0.56 (86)	0.28 (74)	0.98 (83)	0.43 (84)	0.40 (88)
Egg, spray-dried	---	47.0	3.09 (81)	2.25 (84)	1.48 (90)	1.11 (90)	0.73 (90)	2.87 (89)	3.30 (86)	---	---	4.03 (89)	---	---
Fish meal, menhaden	92	62.9	4.81 (95)	2.64 (88)	1.77 (94)	0.57 (88)	0.66 (90)	2.57 (94)	3.03 (93)	3.66 (94)	1.78 (93)	4.54 (94)	2.51 (93)	2.04 (92)
Flax (linseed) meal, sol. extr.	90	33.6	1.24 (82)	1.26 (79)	0.59 (85)	0.59 (87)	0.52 (84)	1.56 (81)	1.74 (82)	2.97 (78)	0.68 (81)	2.06 (80)	1.57 (80)	1.03 (---)
Lactose	96	0.3	---	---	---	---	---	---	---	---	---	---	---	---
Meat and bone meal (≥ 4.0% P)	96	52.8	2.76 (80)	1.62 (80)	0.72 (83)	0.51 (63)	0.36 (78)	1.54 (82)	2.28 (79)	3.55 (83)	0.98 (83)	3.17 (81)	1.74 (81)	1.16 (78)
Meat meal (< 4% P)	96	56.4	3.29 (83)	1.89 (82)	0.87 (87)	0.52 (58)	0.43 (79)	1.92 (84)	2.60 (80)	3.58 (86)	1.29 (83)	3.71 (83)	2.00 (85)	1.37 (80)
Millet, proso	90	11.1	0.23 (90)	0.40 (94)	0.31 (93)	0.18 (92)	0.16 (98)	0.46 (96)	0.57 (94)	0.41 (93)	0.20 (88)	1.24 (94)	0.56 (98)	0.31 (---)

Table 17. Amino acid composition of feed ingredients for swine (as-fed basis). Percent standardized ileal digestibility (SID) of amino acids for swine shown in parenthesis[ab] *(continued)*

Ingredient	Dry Matter (%)	Crude protein (%)	Lysine (%)	Threonine (%)	Methionine (%)	Cysteine (%)	Tryptophan (%)	Isoleucine (%)	Valine (%)	Arginine (%)	Histidine (%)	Leucine (%)	Phenylalanine (%)	Tyrosine (%)
Molasses														
Beet	76	11.0	0.16 (---)	0.07 (---)	0.02 (---)	0.07 (---)	0.08 (---)	0.28 (---)	0.19 (---)	0.08 (---)	0.06 (---)	0.29 (---)	0.05 (---)	0.29 (---)
Cane	74	4.0	0.01 (---)	0.06 (---)	0.02 (---)	0.04 (---)	0.01 (---)	0.03 (---)	0.12 (---)	0.02 (---)	0.01 (---)	0.05 (---)	0.02 (---)	0.05 (---)
Oats														
Grain	89	11.5	0.40 (76)	0.44 (71)	0.22 (84)	0.36 (75)	0.14 (78)	0.48 (80)	0.66 (79)	0.87 (89)	0.31 (85)	0.92 (83)	0.65 (86)	0.41 (82)
Groat	90	13.9	0.48 (79)	0.44 (80)	0.20 (86)	0.22 (85)	0.18 (82)	0.55 (83)	0.72 (81)	0.85 (86)	0.24 (82)	0.98 (83)	0.66 (84)	0.51 (84)
Peas	88	22.0	1.60 (88)	0.90 (78)	0.24 (80)	0.26 (73)	0.19 (75)	0.95 (83)	1.05 (80)	1.85 (92)	0.55 (88)	1.65 (85)	1.05 (86)	0.75 (85)
Rye	88	11.8	0.38 (73)	0.32 (73)	0.17 (81)	0.19 (83)	0.12 (75)	0.37 (77)	0.51 (75)	0.50 (79)	0.24 (78)	0.64 (79)	0.50 (82)	0.26 (76)
Skim milk, dried	96	34.6	2.86 (93)	1.62 (92)	0.92 (96)	0.30 (89)	0.51 (97)	1.87 (88)	2.33 (91)	1.24 (92)	1.05 (96)	3.67 (97)	1.78 (98)	1.87 (97)
Sorghum, grain (milo)	88	9.2	0.22 (81)	0.31 (84)	0.17 (89)	0.17 (83)	0.10 (83)	0.37 (87)	0.46 (87)	0.38 (87)	0.23 (81)	1.21 (90)	0.49 (88)	0.35 (87)
Soybean														
Hulls	89	12.0	0.71 (59)	0.43 (58)	0.14 (68)	0.19 (63)	0.14 (63)	0.44 (60)	0.51 (58)	0.59 (77)	0.28 (58)	0.74 (61)	0.45 (68)	0.36 (64)
Meal, dehulled, 47.5% CP	90	47.5	3.02 (90)	1.85 (87)	0.67 (91)	0.74 (87)	0.65 (90)	2.16 (89)	2.27 (88)	3.48 (94)	1.28 (91)	3.66 (89)	2.39 (89)	1.82 (90)
Meal, dehulled, 46.5% CP	90	46.5	2.96 (89)	1.81 (86)	0.66 (90)	0.72 (86)	0.64 (89)	2.11 (88)	2.22 (87)	3.40 (94)	1.25 (90)	3.58 (88)	2.34 (88)	1.78 (89)
Meal, 44% CP	89	44.0	2.83 (89)	1.73 (85)	0.61 (91)	0.70 (84)	0.61 (87)	1.99 (88)	2.06 (86)	3.23 (93)	1.17 (90)	3.42 (88)	2.18 (88)	1.69 (90)
Meal, enzymatically treated	92	54.4	3.06 (88)	2.02 (86)	0.71 (92)	0.76 (85)	0.69 (88)	2.31 (90)	2.40 (90)	3.75 (98)	1.35 (89)	3.98 (89)	2.74 (92)	2.03 (92)
Meal, fermented	91	53.7	3.11 (77)	1.98 (79)	0.76 (88)	0.77 (70)	0.67 (84)	2.48 (86)	2.69 (84)	3.50 (94)	1.30 (84)	4.09 (85)	2.71 (87)	1.97 (88)
Protein concentrate	90	64.0	4.20 (95)	2.80 (94)	0.90 (94)	1.00 (94)	0.90 (93)	3.30 (94)	3.40 (93)	5.79 (99)	1.80 (97)	5.30 (95)	3.40 (97)	2.50 (96)
Protein isolate	92	85.8	5.26 (91)	3.17 (85)	1.01 (92)	1.19 (82)	1.08 (88)	4.25 (90)	4.21 (89)	6.87 (99)	2.25 (91)	6.64 (89)	4.34 (92)	3.10 (91)
Seeds, heat processed	90	35.2	2.22 (93)	1.41 (86)	0.53 (92)	0.55 (85)	0.48 (89)	1.61 (90)	1.68 (89)	2.60 (97)	0.96 (92)	2.75 (90)	1.83 (91)	1.32 (91)
Sunflower meal, 42% CP	93	42.2	1.20 (90)	1.33 (84)	0.82 (90)	0.66 (81)	0.44 (84)	1.44 (84)	1.74 (82)	2.93 (93)	0.92 (85)	2.31 (85)	1.66 (86)	1.03 (88)
Triticale	90	12.5	0.39 (81)	0.36 (76)	0.20 (89)	0.26 (87)	0.14 (88)	0.39 (84)	0.51 (84)	0.57 (88)	0.26 (84)	0.76 (86)	0.49 (85)	0.32 (83)
Wheat														
Bran	89	15.7	0.64 (71)	0.52 (70)	0.25 (79)	0.33 (77)	0.22 (74)	0.49 (76)	0.72 (75)	1.07 (87)	0.44 (82)	0.98 (78)	0.62 (81)	0.43 (80)
Grain, hard red winter	88	13.5	0.34 (81)	o.37 (83)	0.20 (89)	0.29 (91)	0.15 (88)	0.41 (89)	0.54 (86)	0.60 (88)	0.32 (90)	0.86 (90)	0.60 (91)	0.38 (90)
Middlings, <9.5% fiber	89	15.9	0.57 (89)	0.51 (88)	0.26 (93)	0.32 (91)	0.20 (91)	0.53 (92)	0.75 (90)	0.97 (95)	0.44 (94)	1.06 (93)	0.70 (95)	0.29 (92)
Whey														
Dried	96	12.1	0.90 (87)	0.72 (79)	0.17 (81)	0.25 (85)	0.18 (79)	0.62 (83)	0.60 (77)	0.26 (48)	0.23 (89)	1.08 (87)	0.36 (83)	0.25 (77)
Permeate	96	3.8	0.18 (---)	0.14 (---)	0.03 (---)	0.04 (---)	0.03 (---)	0.17 (---)	0.13 (---)	0.06 (---)	0.05 (---)	0.22 (---)	0.06 (---)	--- (---)
Protein concentrate, 78%CP	94	78.2	7.33 (96)	5.21 (88)	1.65 (94)	1.75 (85)	1.72 (102)	5.07 (94)	4.75 (93)	1.96 (95)	1.58 (91)	8.49 (95)	2.69 (90)	2.44 (86)

[a]Dashes indicate no data were available.
[b]See PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) for more details.

Table 18. Chemical composition of manufactured amino acids sources for swine (as-fed basis).[ab]												
Amino acid	**Source**	**Dry Matter (%)**	**Digestible energy (kcal/lb)**	**Metabolizable energy (kcal/lb)**	**Net energy (kcal/lb)**	**Crude protein (%)**	**Lysine (%)**	**Threonine (%)**	**Methionine (%)**	**Tryptophan (%)**	**Isoleucine (%)**	**Valine (%)**
Isoleucine	L-isoleucine	99	2926	2781	2146	65.4					98	
Lysine	L-lysine HCl	99.5	2175	1979	1533	95.4	78.8					
	Lysine, liquid	55.0	---	1333	---	59.9	50.0					
	Lysine, liquid	---	---	---	---	---	60.0					
	Lysine, sulfate	95.0	2023	1925	1435	75.0	50.7	0.4	0.2	0.14	0.4	0.7
Methionine	DL-methionine	99.5	2566	2436	1881	58.4			99.0			
	MHA	88.0	2273	2153	1664	---			88			
Threonine	L-threonine	99.5	1870	1718	1338	73.1		99.0				
Tryptophan	L-tryptophan	99.5	2990	2806	2175	85.3				98.5		
Valine	L-valine	98.5	2644	2486	---	72.1						96.5

[a]Dashes indicate no data were available.
[b]See PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) for more details.

Table 19. Chemical composition of fats, oils and crude glycerol for swine (as-fed basis).[ab]									
Ingredient	Dry Matter (%)	Digest-ible energy (kcal/lb)	Metabo-lizable energy (kcal/lb)	Net energy (kcal/lb)	Unsatu-rated: saturated fatty acid ratio	Iodine value	Iodine value product	Total Σ N-6	Total Σ N-3
Animal fats									
Beef tallow	99	3636	3491	3142	0.92	44	440	3.1	0.6
Choice white grease	99	3768	3616	3254	1.45	60	600	11.6	0.4
Poultry fat	99	3873	3718	3346	2.20	78	780	19.5	1.0
Glycerol, crude (86.96 % glyc-erol)	91	1520	1458	---	---	---	---	---	---
Fish oils									
Herring	99	3945	3786	3407	3.39	---	---	1.4	17.8
Menhaden	99	3852	3698	3328	2.00	---	---	1.5	25.1
Vegetable oils									
Canola	100	3982	3823	3441	12.46	118	1180	20.3	9.3
Corn	100	3980	3820	3438	6.53	125	1250	58.0	0.7
Restaurant grease	98	3886	3730	3357	2.34	75	750	17.5	1.9
Soybean	100	3977	3818	3436	5.64	130	1300	51.0	6.8

[a]Dashes indicate no data were available.
[b]See PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) for more details.

Table 20. Mineral composition of feed ingredients for swine (as-fed basis). Percent bio-availablity and apparent digestibility of phosphorus for swine shown in parenthesis, respectively [a*]

Ingredient	Dry matter (%)	Calcium (%)	Phosphorus (%)	Sodium (%)	Chlorine (%)	Copper (ppm)	Iodine (ppm)	Iron (ppm)	Manganese (ppm)	Selenium (ppm)	Zinc (ppm)	Magnesium (%)	Potassium (%)	Sulfur (%)
Alfalfa meal, dehy	92	1.53	0.26 (100, 20)	0.09	0.47	10	0.15	333	32	0.34	24	0.23	2.30	0.29
Bakery waste, dehy	91	0.13	0.25 (36, ---)	1.14	1.48	5	---	28	65	---	15	0.24	0.39	0.02
Barley, two row	89	0.06	0.35 (30, 41[b])	0.04	0.12	7	0.04	78	18	0.19	25	0.14	0.45	0.15
Beet pulp	91	0.70	0.10 (20, 20)	0.20	0.10	11	2	411	46	0.09	12	0.22	0.61	0.31
Blood														
Cells, spray-dried	92	0.02	0.34 (92, 80)	0.55	0.61	3	---	2618	0.4	1.0	16	0.02	0.80	0.49
Meal, flash-dried	92	0.21	0.21 (92, 80)	0.29	0.38	6	0.34	2341	10	0.58	16	0.21	0.14	0.45
Meal, spray-dried	93	0.41	0.30 (92, 80)	0.44	0.25	8	0.34	2919	6	0.58	30	0.11	0.15	0.47
Plasma proteins, spray-dried	91	0.15	1.48 (92, 80)	2.76	1.19	18	---	77	2.5	1.6	13	0.03	0.02	1.02
Canola meal	90	0.63	1.01 (16, 32)	0.07	0.11	6	0.09	142	49	1.10	69	0.51	1.22	0.85
Corn														
Distillers dried grains w/sol (DDGS)	88	0.06	0.69 (76, 59)	0.21	0.20	5	0.03	105	14	0.39	85	0.29	0.82	0.41
Distillers dried grains-high protein	90	0.02	0.38 (76, 60)	---	---	---	---	---	---	---	---	---	---	---
Germ	91	0.02	1.20 (33, 29)	---	---	---	---	---	---	---	---	---	---	---
Gluten feed	90	0.22	0.83 (59, 22)	0.15	0.22	48	0.07	460	24	0.27	70	0.33	0.98	0.22
Gluten meal, 60% CP	90	0.05	0.44 (15, 19)	0.02	0.06	26	---	282	4	1.0	33	0.08	0.18	0.43
Grain, yellow dent	89	0.03	0.28 (14, 28)	0.02	0.05	3	0.09	29	7	0.07	18	0.12	0.33	0.13
Grain, high nutrient	87	0.04	0.26 (35, 40)	---	---	---	---	---	---	---	---	0.11	0.32	---
Grain, high oil	87	0.01	0.26 (32, 40)	---	---	---	---	---	---	---	---	---	---	---
Grain, low-phytate	88	0.03	0.28 (66, 55)	---	---	---	---	---	---	---	---	0.10	0.28	---
Hominy feed	90	0.05	0.43 (14, 21)	0.08	0.07	13	---	67	15	0.10	30	0.24	0.61	0.03
Egg, spray-dried	---	0.21	0.67 (50, ---)	---	---	---	---	---	---	---	---	---	---	---
Fish meal, menhaden	92	5.21	3.04 (93, 77)	0.40	0.55	11	1.09	440	37	2.10	147	0.16	0.70	0.45
Flax (linseed) meal, sol. extr.	90	0.39	0.83 (---, 32)	0.13	0.06	22	0.90	270	41	0.63	66	0.54	1.26	0.39
Lactose	96	---	---	---	---	---	---	---	---	---	---	---	---	---
Meat and bone meal (≥ 4.0% P)	96	9.87	4.63 (90, 75)	0.69	0.65	11	1.31	606	17	0.31	0.38	0.41	0.65	0.38
Meat meal (< 4% P)	96	6.60	3.17 (90, 75)	0.80	0.97	10	---	440	10	0.37	94	0.35	0.57	0.45
Millet, proso	90	0.03	0.31 (32, ---)	0.04	0.03	26	---	71	30	0.70	18	0.16	0.43	0.14

Table 20. Mineral composition of feed ingredients for swine (as-fed basis). Percent bio-availablity and apparent digestibility of phosphorus for swine shown in parenthesis, respectively [a*] *(continued)*

Ingredient	Dry matter (%)	Calcium (%)	Phosphorus (%)	Sodium (%)	Chlorine (%)	Copper (ppm)	Iodine (ppm)	Iron (ppm)	Manganese (ppm)	Selenium (ppm)	Zinc (ppm)	Magnesium (%)	Potassium (%)	Sulfur (%)
Molasses														
Beet	76	0.10	0.02 (33, 20)	0.68	0.45	13	1.1	117	29	---	17	0.05	3.92	---
Cane	74	0.74	0.06 (33, 20)	0.24	1.59	29	---	188	59	---	13	0.33	3.74	---
Oats														
Grain	89	0.07	0.31 (22, 32)	0.08	0.10	6	0.09	85	43	0.30	38	0.16	0.42	0.21
Groat	90	0.08	0.41 (14, 32)	0.05	0.09	6	---	49	32	0.09	26	0.11	0.38	0.20
Peas	88	0.10	0.44 (30, 55)	0.04	0.05	9	0.26	65	23	0.38	23	0.12	1.02	0.20
Rye	88	0.06	0.33 (---, 50[b])	0.02	0.03	7	0.08	60	58	0.38	31	0.12	0.48	0.15
Skim milk, dried	96	1.31	1.00 (91, 90)	0.48	1.00	5	0.82	8	2	0.12	42	0.12	1.60	0.32
Sorghum, grain (milo)	89	0.03	0.29 (20, 25)	0.01	0.09	5	0.02	45	15	0.20	15	0.15	0.35	0.08
Soybean														
Hulls	89	0.49	0.14 (78, 20)	0.01	0.02	8	---	580	22	0.21	40	0.22	1.20	0.13
Meal, dehulled, 47.5% CP	90	0.34	0.69 (23, 32)	0.02	0.05	20	0.15	176	36	0.27	55	0.30	2.14	0.44
Meal, dehulled, 46.5% CP	90	0.34	0.67 (23, 32)	0.02	0.05	20	0.15	187	36	0.27	55	0.30	2.14	0.44
Meal, 44% CP	89	0.32	0.65 (31, 20)	0.01	0.05	20	---	202	29	0.32	50	0.27	1.96	0.43
Meal, enzymatically treated	92	0.35	0.74 (---, 59)	---	---	---	---	---	---	---	---	---	---	---
Meal, fermented	91	0.29	0.82 (---, 59)	0.12	---	7	---	142	21	---	39	0.18	1.20	0.36
Protein concentrate	90	0.35	0.81 (33, ---)	0.05	---	13	---	110	47	---	30	0.32	2.20	0.54
Protein isolate	92	0.15	0.65 (---, ---)	0.07	0.02	14	---	137	5	0.14	34	0.08	0.27	0.71
Seeds, heat processed	90	0.25	0.59 (33, 32)	0.03	0.03	16	0.09	80	30	0.11	39	0.28	1.70	0.30
Sunflower meal, 42% CP	93	0.37	1.01 (3, 19)	0.04	0.13	25	0.09	200	35	0.32	98	0.75	1.27	0.38
Triticale	90	0.05	0.33 (46, 48b)	0.03	0.03	8	0.09	31	43	---	32	0.10	0.46	0.15
Wheat														
Bran	89	0.16	1.20 (29, 50[b])	0.04	0.07	14	0.06	170	113	0.51	100	0.52	1.26	0.22
Grain, hard red winter	88	0.06	0.37 (50, 45[b])	0.01	0.06	6	0.09	39	34	0.33	40	0.13	0.49	0.15
Middlings, <9.5% fiber	89	0.12	0.93 (41, 50[b])	0.05	0.04	10	0.11	84	100	0.72	92	0.41	1.06	0.17
Whey														
Dried	96	0.75	0.72 (97, 90)	0.94	1.40	13	---	130	3	0.12	10	0.13	1.96	0.72
Permeate	96	0.86	0.66 (97, 86)	1.00	2.23	0.3	---	36	0.26	---	1.1	0.15	2.10	0.27
Protein concentrate, 78%CP	94	0.63	0.38 (---, ---)	---	---	---	---	---	---	---	---	---	---	---

[a]Dashes indicate no data were available.
[b]Assumes the ingredient is not heated or cooked; if the ingredient is heat-treated, the digestibility coefficient shown will be reduced by the following percentage units due to the inactivation of endogenous phytase (barley, 9; rye, 20; triticale, 18; wheat bran, 25; wheat, 15; wheat midds, 25).
*See PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) for more details.

Photo courtesy of National Pork Board.

Photo courtesy of National Pork Board.

Table 21. Mineral concentrations in macro mineral sources for swine (as-fed basis)a. Percent bio-availablity and apparent total tract digestibility of phosphorus for swine shown in parenthesis, respectively[a*]

Mineral element	Source	Dry Matter (%)	Calcium (%)[b]	Phosphorus (%)[c]	Sodium (%)	Chloride (%)	Iron (ppm)	Manganese (ppm)	Zinc (ppm)	Magnesium (%)	Potassium (%)	Sulfur (%)
Calcium	Calcium chloride, dihydrate	---	27	---	---	---	---	---	---	---	---	---
	Limestone (minimum 95% calcium carbonate)	99	38.0	0.02 (---,---)	0.08	0.02	600	200	18	1.61	0.08	0.08
	Oyster shell	99	37.6	---	0.21	0.01	2840	133	---	0.30	0.10	---
Calcium and phosphorus	Bone meal, steamed	97	29.8	12.5 (82,---)	0.04	---	850	300	126	0.30	0.20	2.40
	Dicalcium phosphate	96	20 to 24	18.50 (100,81)	0.18	0.47	7900	1400	92	0.80	0.15	0.80
	Monocalcium phosphate	100	17.00	21.10 (100,81)	0.20	---	7500	100	220	0.90	0.16	0.80
	Calcium sulfate, dehydrate	85	21.85	---	---	---	---	---	---	0.48	---	16.19
	Defluorinated rock phosphate	100	32.00	18.00 (87, ---)	3.27	---	8400[c]	500	43	0.29	0.10	0.13
	Monoammonium phosphate	97	0.35	24.20 (100,---)	0.20	---	4100	100	300	0.75	0.16	1.50
	Curaco phosphate	100	35.09	14.23 (50, ---)	0.20	---	3500	---	---	0.80	---	---
	Soft rock phosphate	100	16.09	9.05 (40, ---)	0.10	---	19200	1000	---	0.38	---	---
Magnesium	Magnesium carbonate	81	0.02	---	---	---	---	100	---	30.20	---	---
	Magnesium oxide	100	1.69	---	---	---	10600	---	---	55.00	0.02	0.10
	Magnesium sulfate, heptahydrate	49	0.02	---	---	0.01	---	---	---	9.60	---	13.04
Potassium	***Potassium chloride***	100	0.05	---	1.00	46.93	600	10	---	0.23	51.37	0.32
	Potassium sulfate	---	0.15	---	0.09	1.50	700	10	---	0.60	43.04	17.64
Sodium	Sodium carbonate	---	---	---	43.30	---	---	---	---	---	---	---
	Sodium bicarbonate	---	0.01	---	27.00	---	---	---	---	---	0.01	---
Sodium and chloride	Sodium chloride	---	0.30	---	39.50	59.00	100	---	---	0.005	---	0.20
Sodium and phosphorus	Disodium phosphate	100	---	21.15 (100,---)	31.04	---	---	`---	---	---	---	---
	Monosodium phosphate	87	0.09	24.94 (100,92)	18.65	0.02	10	---	---	0.01	0.01	---
Sodium and sulfur	Sodium sulfate, decahydrate	---	---	---	13.80	---	---	---	---	---	---	9.70

[a]These mineral supplements are not chemically pure compounds, and the composition may vary substantially among sources. The supplier's analysis should be used if it is available. For example, feed-grade dicalcium phosphate contains some monocalcium phosphate and feed-grade monocalcium phosphate contains some dicalcium phosphate. Dashes indicate that no data were available. Most common sources are in bold-italic.
[b]Estimates indicate 90 to 100% relative bioavailability of calcium in most sources of monocalcium phosphate, dicalcium phosphate, tricalcium phosphate, defluorinated phosphate, calcium carbonate, calcium sulfate, and calcitic limestone. The calcium in high-magnesium limestone or dolomtic limestone is less bioavailable (50 to 80%).
[c]Bioavailability estimates are generally expressed as a percentage of monosodium phosphate or monocalcium phosphate.
dIron in defluorinated phosphate is about 65% as available as the iron in ferrous sulfate.
*See PIG factsheets #07-02-07 (Macro-Minerals for Swine Diets) and #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) for more details.

Table 22. Mineral concentrations in micro or trace mineral sources for swine[a*]			
Mineral element	**Source**	**Concentration of element, %**	**Relative bioavailability, %[b]**
Chromium	***Tripicolinate***	Variable	100
	Propionate	Variable	13
	Methionine	Variable	51
	Yeast	Variable	23
Copper	***Sulfate (pentahydrate)***	25.2	100
	Amino acid chelate	Variable	122
	Amino acid complex	Variable	---
	Acetate	32.1	---
	Carbonate	50 to 55	60 to 100
	Chloride, tribasic	58	100
	Lysine	Variable	94 to 124
	Oxide	75.0	0 to 10
	Polysaccharide complex	Variable	---
	Proteinate	Variable	105 to 111
Iodine	***Ethylenediamine dihydroiodiode (EDDI)***	79.5	100
	Calcium iodate	63.5	100
	Potassium iodide	68.8	100
	Potassium iodate	59.3	---
	Copper iodide	66.6	100
Iron	***Sulfate (monohydrate)***	30	100
	Amino acid chelate	Variable	---
	Amino acid complex	Variable	---
	Chloride	20.7	40 to 100
	Carbonate	38	15 to 80
	Methionine	Variable	---
	Polysaccharide complex	Variable	---
	Proteinate	Variable	---
	Sulfate (heptahydrate)	20	100
Manganese	***Sulfate (monohydrate)***	29.5	100
	Amino acid chelate	Variable	---
	Amino acid complex	Variable	---
	Carbonate	46.4	30 to 100
	Chloride	27.5	100
	Dioxide	63.1	35 to 95
	Methionine	Variable	120 to 125
	Oxide	60	70
	Polysaccharide complex	Variable	---
	Proteinate	Variable	110

Table 22. Mineral concentrations in micro or trace mineral sources for swine[a*] *(continued)*			
Mineral element	**Source**	**Concentration of element, %**	**Relative bioavailability, %[b]**
Selenium	***Sodium selenite***	45	100
	Proteinate (methionine)	Variable	102
	Sodium selenate	21.4	100
	Yeast	Variable	108
Zinc	***Sulfate (monohydrate)***	35.5	100
	Amino acid chelate	Variable	---
	Amino acid complex	Variable	---
	Carbonate	56	100
	Chloride	48	100
	Methionine	Variable	95 to 100
	Polysaccharide complex	Variable	---
	Oxide	72	50 to 80
	Proteinate	Variable	100
	Sulfate (heptahydrate)	22.3	100
	Tetrabasic chloride	58	---

[a]Most common sources are in bold-italic; dashes indicate no data were available
[b]In research a frequently used mineral source is often assumed to be 100% bioavailable and other forms are compared based on amount that accumulates in body tissues. The mineral source listed first within each category was generally the standard with which the other sources were compared to determine relative bioavailability.
*See PIG factsheets #07-02-06 (Trace Minerals and Vitamins for Swine Diets) and #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) for more details.

Table 23. Vitamin composition of feed ingredients for swine (as-fed basis).[ab]														
Ingredient	**Dry matter (%)**	**Vitamin A (IU/lb)**	**Vitamin D (IU/lb)**	**Vitamin E (IU/lb)**	**Vitamin K (IU/lb)**	**Riboflavin (mg/lb)**	**Niacin (mg/lb)**	**Pantothenic acid (mg/lb)**	**Choline (mg/lb)**	**Biotin (mg/lb)**	**Vitamin B_{12} (mg/lb)**	**Folic acid (mg/lb)**	**Pyridoxine (mg/lb)**	**Thiamin (mg/lb)**
Alfalfa meal, dehy	92	11457		33.7		6.2	17	13.2	635	0.24	0	1.98	2.9	1.5
Bakery waste, dehy	91	509		---		0.6	12	3.8	419	0.03	0	0.09	2.0	1.3
Barley, two row	89	497		5.0		0.8	25	3.6	0	0.06	0	0.14	2.3	2.0
Beet pulp	91	1284		8.9		0.3	8	0.6	371	---	0	---	0.9	0.2
Blood														
Cells, spray-dried	92	---		---		---	---	---	---	---	---	---	---	---
Meal, flash-dried	92	---		0.7		0.6	10	0.5	354	0.04	0.02	0.05	2.0	0.5
Meal, spray-dried	93	---		0.7		1.5	10	1.7	220	0.13	---	0.18	2.0	0.1
Plasma proteins, spray-dried	91	---		---		---	---	---	---	---	---	---	---	---
Canola meal	90	---		9.1		2.6	73	4.3	3039	0.44	0	0.38	3.3	2.4
Corn														
Distillers dried grains w/sol (DDGS)	89	423		---		3.9	34	6.4	1196	0.35	0	0.41	3.6	1.3
Distillers dried grains -high protein	92	---		---		---	---	---	---	---	---	---	---	---
Germ	92	---		---		---	---	---	---	---	---	---	---	---
Gluten feed	90	121		5.7		1.1	30	7.7	689	0.06	0	0.13	5.9	0.9
Gluten meal, 60% CP	90	---		4.5		1.0	25	1.6	150	0.07		0.06	3.1	0.1
Grain, yellow dent	89	97		5.6		0.5	11	2.7	281	0.03	---	0.07	2.3	1.6
Grain, high nutrient	87	---		---		---	---	---	---	---	---	---	---	---
Grain, high oil	87	---		----		---	---	---	---	---	---	---	---	---
Grain, low-phytate	88	---		---		---	---	---	---	---	---	---	---	---
Hominy feed	90	1090		4.4		1.0	2.1	3.7	524	0.06	0	0.10	5.0	3.7
Egg, spray-dried	---	---		---		---	---	---	---	---	---	---	---	---
Fish meal, menhaden	92	---		3.4		2.2	25	4.1	1386	0.06	0.06	0.17	1.8	0.2
Flax (linseed) meal, sol. extr.	90	24		1.4		1.3	15	6.7	686	0.19	0	0.59	2.7	3.4
Lactose	96	---		---		---	---	---	---	---	---	---	---	---
Meat and bone meal (≥ 4.0% P)	93	---		1.1		2.1	22	1.9	905	0.04	0.04	0.19	2.1	0.2
Meat meal (< 4% P)	94	---		0.8		2.1	26	2.3	942	0.04	0.04	0.23	1.1	0.3
Millet, proso	90	---		---		1.7	10	5.0	200	0.07	0	0.10	2.6	3.3
Molasses														
Beet	76	---		---		---	---	---	---	---	---	---	---	---
Cane	74	---		---		0.91	13	13	---	0.24	---	0.04	1.4	0.32
Oats														
Grain	89	448		5.3		0.8	9	5.9	429	0.11	0	0.14	0.9	2.7
Groat	90	---		---		0.7	6	6.1	517	0.09	0	0.23	0.5	2.9

Table 23. Vitamin composition of feed ingredients for swine (as-fed basis).[ab] *(continued)*														
Ingredient	**Dry matter (%)**	**Vitamin A (IU/lb)**	**Vitamin D (IU/lb)**	**Vitamin E (IU/lb)**	**Vitamin K (IU/lb)**	**Riboflavin (mg/lb)**	**Niacin (mg/lb)**	**Pantothenic acid (mg/lb)**	**Choline (mg/lb)**	**Biotin (mg/lb)**	**Vitamin B_{12} (mg/lb)**	**Folic acid (mg/lb)**	**Pyridoxine (mg/lb)**	**Thiamin (mg/lb)**
Peas	88	121		0.1		0.8	14	8.5	248	0.07	0	0.09	0.5	2.1
Rye	88	---		6.1		0.7	9	3.6	190	0.04	0	0.27	1.2	1.6
Skim milk, dried	96	---		2.8		8.7	5	16.5	632	0.11	0.02	0.21	1.9	1.7
Sorghum, grain (milo)	89	0.05		3.4		0.6	19	5.6	303	0.12	0	0.08	2.4	1.4
Soybean														
Hulls	89	---		---		---	---	---	---	---	---	---	---	---
Meal, dehulled, 47.5% CP	90	24		1.6		1.4	10	6.8	1239	0.12	0	0.62	2.9	1.5
Meal, dehulled, 46.5% CP	90	24		1.6		1.4	10	6.8	1239	0.12	0	0.62	2.9	1.5
Meal, 44% CP	89	24		1.6		1.3	15	7.3	1267	0.12	0	0.62	2.7	2.0
Meal, enzymatically treated		---		---		---	---	---	---	---	---	---	---	---
Meal, fermented														
Protein concentrate	90	---		---		---	---	---	---	---	---	---	---	---
Protein isolate	92	---		---		0.8	3	1.9	1	0.14	---	1.13	2.4	0.1
Seeds, heat processed	90	230		12.2		1.2	10	6.8	1046	0.11	0	1.63	4.9	5.0
Sunflower meal, 42% CP	90	---		6.2		1.6	100	10.9	1429	0.66	0	0.52	6.2	1.6
Triticale	90	---		1.1		0.2	8	3	210	---	---	0.07	---	1.4
Wheat														
Bran	89	121		11.2		2.1	84	14.1	559	0.16	0	0.29	5.4	3.6
Grain, hard red winter	88	48		7.8		0.6	22	4.5	353	0.05	0	0.10	1.5	2.0
Middlings, <9.5% fiber	89	---		---		1.0	19	6.0	696	0.05	0	0.36	2.1	10.3
Whey														
Dried	96	---		0.2		12.3	5	21.3	826	0.12	0.01	0.39	1.8	1.9
Permeate	96	---		---		---	---	---	---	---	---	---	---	---
Protein concentrate, 78%CP	94	---		---		---	---	---	---	---	---	---	---	---

[a]Dashes indicate no data were available.
[b]See PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) for more details.

Photo courtesy of National Pork Board.

Photo courtesy of National Pork Board.

Table 24. Vitamin concentration in manufactured vitamin sources for swine[ab]		
Vitamin	**Concentration/method of expression**	**Source**
Vitamin A	1 IU = 0.3 µg retinol or 0.344 µg vitamin A acetate or 1 USP unit	***Vitamin A acetate (all-trans retinyl acetate)***
	1 IU = 0.55 µg vitamin A palmitate	Vitamin A palmitate
	1 IU = 0.36 µg vitamin A propionate	Vitamin A propionate
Vitamin D	1 IU = 0.025 µg cholecalciferol or 1 USP unit or 1 ICU	Vitamin D3 (cholecalciferol)
Vitamin E	1 mg = IU dl-α-tocopheryl acetate	***dl-α-tocopheryl acetate (all rac)***
	1 mg = 1.36 IU *d*-α-tocopheryl acetate	***d-α-tocopheryl acetate (RRR)***
	1 mg = 1.11 IU *dl*-α-tocopherol	*dl*-α-tocopherol (all rac)
	1 mg = 1.49 IU *d*-α-tocopherol	*d*-α-tocopherol (RRR)
Vitamin K	1 Ansbacher unit = 20 Dam units = 0.0008 mg menadione	Menadione sodium bisulfite (MSB)
		Menadione nicotinamide bisulfite (MNB)
		Menadione dimethylpyrimidinol bisulfite (MPB)
Riboflavin	Commonly expressed as µg or mg	Crystalline riboflavin
Niacin	Commonly expressed as µg or mg	***Niacinamide***
		Nicotinic acid
Pantothenic acid	Commonly expressed as µg or mg	***d-calcium pantothenate***
		dl-calcium pantothenate
		dl-calcium pantothenate - calcium chloride complex
Choline	Commonly expressed as µg or mg	Choline chloride
Biotin	Commonly expressed as µg or mg	*d*-biotin
Vitamin B_{12}	1µg cyanocobalamin or 1 USP unit or 11,000 LLD (L. lactis Dorner) units	Cyanocobalamin
Folic acid	Commonly expressed as µg or mg	Folic acid
Pyridoxine	Commonly expressed as µg or mg	Pyridoxine hydrochloride
Thiamin	Commonly expressed as µg or mg	***Thiamin mononitrate***
		Thiamin hydrochloride
Vitamin C	Commonly expressed as µg or mg	L-ascorbic acid
		L-ascorbic acid phosphate
		L-ascorbic acid coated with ethyl cellulose

[a]Most common sources are in bold-italic.
[b]See PIG factsheet #07-02-06 (Trace Minerals and Vitamins for Swine Diets) for more details.

Table 25. Recommended upper limits of usage (% of the diet) for feed ingredients in swine diets. An * denotes no nutritional limitations in a balanced diet[ab]						
Type of diet	**Nursery**	**Nursery**	**Grower**	**Finisher**	**Gestation**	**Lactation**
Body weight, lb	**< 25**	**25 to 45**	**45 to 130**	**130 to 315**		
Alfalfa meal, dehydrated	0	5	10	15	25	0
Bakery waste, dehydrated	15	25	*	*	*	*
Barley, two row (48 lb/bushel)	*	*	*	*	*	*
Beet pulp	0	5	10	15	50	10
Blood						
Cells, spray-dried	3	3	5	5	5	5
Meal, flash-dried	3	3	5	5	5	5
Meal, spray-dried	3	3	5	5	5	5
Plasma protein, spray dried	*	*	*	*	*	*
Canola meal	0	5	15	20	15	15
Corn						
Distillers dried grains w/solubles (DDGS)	10	20	30	20	40	20
Distillers dried grains-high protein	10	20	20	20	30	15
Germ	10	20	20	10	30	20
Gluten feed	5	5	10	15	40	10
Gluten meal, 60% CP	5	10	20	20	30	10
Grain, yellow dent (>40 lb/bushel)	*	*	*	*	*	*
Grain, high nutrient	*	*	*	*	*	*
Grain, high oil	*	*	*	30	*	*
Grain, low-phytate	*	*	*	*	*	*
Hominy feed	0	20	60	30	60	60
Egg, spray-dried	10	*	*	*	*	*
Fish meal, menhaden	15	20	6	0	6	6
Flax (linseed) meal, sol. extr.	3	15	15	15	20	10
Lactose	*	*	20	20	20	20
Meat and bone meal, 50% CP	5	10	*	*	*	*
Meat meal, 55% CP	5	10	*	*	*	*
Millet, proso	40	40	*	*	*	40
Molasses						
Beet	5	5	5	5	5	5
Cane	5	5	5	5	5	5
Oats						
Grain (38 lb/bushel)	15	30	35	40	*	10
Groat	*	*	*	*	*	*

Table 25. Recommended upper limits of usage (% of the diet) for feed ingredients in swine diets. An * denotes no nutritional limitations in a balanced diet [ab] *(continued)*						
Type of diet	**Nursery**	**Nursery**	**Grower**	**Finisher**	**Gestation**	**Lactation**
Body weight, lb	**< 25**	**25 to 45**	**45 to 130**	**130 to 315**		
Peas	15	30	40	50	15	25
Rye (ergot free)	0	10	25	35	20	10
Skim milk, dried	*	*	*	*	*	*
Sorghum, grain (milo) (> 48 lb/bushel)	*	*	*	*	*	*
Soybean						
Hulls	5	5	10	10	25	5
Meal, dehulled, 47.5% CP	15	*	*	*	*	*
Meal, dehulled, 46.5% CP	15	*	*	*	*	*
Meal, 44% CP	15	*	*	*	*	*
Meal, enzymatically treated	15	*	*	*	*	*
Meal, fermented	15	*	*	*	*	*
Protein concentrate	20	*	*	*	*	*
Protein isolate	*	*	*	*	*	*
Seeds, heat processed	5	*	*	15	*	*
Sunflower meal, 42% CP	0	5	*	*	*	*
Triticale (ergot free)	20	30	*	*	*	40
Wheat						
Bran	0	5	10	20	30	10
Grain, hard red winter (> 55 lb/bushel)	*	*	*	*	*	*
Middlings, <9.5% fiber	5	10	25	35	*	10
Whey						
Dried	40	30	20	15	5	5
Permeate	30	25	20	15	5	5
Protein concentrate 78%CP	*	*	*	*	*	*

[a]Assumes diets are balanced for energy, essential amino acids, minerals and vitamins.
[b]Higher levels may be fed although growth and reproductive performance and carcass composition and quality may be negatively impacted. Economic considerations should influence actual inclusion rates.

U.S. Pork Center of Excellence

Communities of National Cooperation

U.S. Pork Center of Excellence
1202 NSRIC
Iowa State University
Ames, IA 50011

Ph: 515-294-2490
Fax: 515-294-5995
uspce@iastate.edu

www.usporkcenter.org
www.porkgateway.org

Temperament and Housing:

The University of Manitoba Glenlea research station has two identical barns (totally identical in layout, sow genetic lines and management) on the same site. This allows a very good comparison between the two barns. One barn is bedding free, with all sows housed on part-slatted flooring (Conventional system). The other barn has a solid floor, with straw bedding (Alternative system).

Fig 1 Part slatted dry sow barn University of Manitoba

The gestation area in both barns has four pens. In the part-slatted system each of these pens is 606 sqft, to house 26 sow (23.3sqft/sow). The solid part of the floor is 8'x 24'6", and runs along one side of the pen, with partial walls dividing up the pen into separate areas.
The each gestation pen in the straw bedded system has a slightly larger pen area of 752sq ft, for housing 26 sows (28.9sqft/sow).

For each system, breeding is performed in free access stalls, which are bedded or part slatted depending on the barn.

Fig 2 Part slatted dry sow ESF feeders, University of Manitoba

Fig 3 Straw bedded dry sow ESF barn, University of Manitoba

Results related to housing system interaction:
The temperament and sow longevity work was conducted in this system, along with a parallel study in the PSC free-access stalls.

Over the course of the first breeding gestation, a significantly greater number of sows became lame in the part-slatted, then the straw-based ESF, (X^2 = 5.70, d.f.= 1, P<0.05). This result repeated itself for the second gestation.

Table 1 The incidence of lame and non lame sows in straw-bedded and part-slatted ESF housing systems, throughout the first breeding gestation

Straw-bedded ESF (n=140)	**Not lame**	**Lame**
Frequency	99	41
Percentage (%)*	70.7	29.3
Partial-slatted ESF (n=139)	**Not lame**	**Lame**
Frequency	78	59
Percentage (%)	56.9	43.1

*Percentage given is within system

Conclusions:

- When scored at two intervals in gestation (8 and 16 weeks) sows housed in straw bedded systems had a higher total average body injury score.
- Temperament types differed between the bedded and unbedded ESF systems.
- Sows in the bedded system showed more extremes of active passive traits, whilst those in the unbedded system showed more of confident/fearful traits. The results found there were more extremeness of temperament, as signified by more variation in these temperament dimensions in these systems.
- Sows in an unbedded free-access system also showed more confident/fearful traits, as those in an unbedded ESF system had. This provides further evidence that the housing environment influences temperament.

Temperament tests and how to conduct them:

Previous research has determined that temperaments exist in pigs. These have been defined as distinct characteristics that fall within active/passive and confident/fearful dimensions. Simple behavioural tests have been developed and validated to effectively assess pig temperament. These are:

- The open door test (ODT)
- The human approach test (HAP)
- The pig approaching human test (PAH)
- The novel object test (NOT).

The ODT and NOT are considered good measures of active/passive temperaments, both testing a pig's willingness to explore unknown territory. The HAP and PAH both test behavioural responses to humans, and are considered a better evaluation of confident/fearful temperaments. These temperament characteristics should not be viewed as separate entities, but rather that an individual's temperament is made up of overlapping characteristics. The temperament types defined by these tests are illustrated in Figure 1.

Figure 1 Temperament categories defined by active/passive and confident fearful characteristics

The temperament tests are simple to perform and can be conducted on farm as follows:

- Prior to performing all tests, animals should be individually marked for identification. A clear spray mark on their back works well.
- Have a clipboard, pen, stopwatch and designated recording sheet ready to start recording the behaviour of the pigs.*
- Perform the test with two people for ease of management and accurate assessment.

The open door test ODT:

Animals can be tested in their home pen. This home pen is assumed to exist when gilts are raised in a group situation prior to puberty and first service. For test accuracy and ease of management, testing groups should be no larger than 20 animals. For groups larger than 20 animals, split the group into several smaller trial groups. If placing animals in a new pen specifically for the test, give the animals 10 minutes to acclimatise before starting.
The test begins with the observer opening the pen door fully, stands back behind the door so as not to obstruct the pigs or deter them from exiting, and starts a stopwatch. The observer records the latency for each pig to exit the pen, up to a maximum of three minutes. Pigs that fail to exit the pen following three minutes are assigned a latency of 180 seconds.
Pigs that rapidly exit the pen can be described as 'active', while those that are reluctant to exit are 'passive'

The HAP, PAH and NOT test should be performed in designated test pens. A series of circular lines is drawn on the floor to show clear visible distances within the pen.

The human approach test HAP:

Place one pig in a test pen. A human enters the pen and approaches the pig slowly (Fig. 2). A second observer scores the response of the pig as follows:
1- Pig appears fearful, and leaves area before human is within 0.5 m,
2- Pig is either active, does not appear fearful, leaves area before human is within 0.5 m, or 'freezes' (appears unaware of human/introverted),
3- Pig is neutral to human approach, not fearful or active, allows approach within 0.25 m, leaves calmly,
4- Pig allows approach and then interacts with human (sniffing or chewing coveralls or boots)
Pigs with a high HAP score (e.g. 4) can be described as 'confident', while those with a low score (e.g.1) are 'fearful'.

Figure 2 The HAP test being conducted, Prairie Swine Centre

Pig approaching human test PAH:

One pig is placed in a test pen. A human enters the test pen and stands in a set location, away from the pig and a stopwatch is immediately started.
Record:

- The time taken for the pig to make contact with the human
- The number of contacts made with their snout
- Duration of time the pig spent within one meter of the human.

Observation time runs for a maximum of three minutes.
Pigs with a shorter latency to contact the human are described as 'confident', while those with a longer latency, or no contact at all are described as 'fearful.'

Novel Object Test (NOT):

One pig is placed into the test pen with three objects. Objects should be novel to the pig, and spaced out so the objects are not touching and the pig must make a clear direction to the object (Figure 3).
One observer stands outside of the pen and records:

- The latency for the pig to make contact with the first object
- The number and duration of contacts with each object
- The number of times the pig switched between objects.

Total observation time will run up to a maximum of three minutes.
Pigs that are quick to make contact and then switched objects frequently are described as 'active', while pigs that were slower to contact the objects, but spend more time exploring each object are described as 'passive.'

Figure 3 Novel objects laid in position ready for testing to begin

The relationships between the behaviour seen by the pigs in the test and their temperament are shown in table 1.

Table 1 The relationship between behaviour and temperament

Test behaviour	Response	
	Active	**Passive**
ODT	fast exit	slow exit
NOT	fast to contact	slow to contact
	Calm	**Fearful**
PAH	fast approach	slow approach
HAP	high score	low score

*Recording sheets are available from the Prairie Swine Centre. Please contact Helen.Thoday@usask.ca for more information.

Whilst four tests are available, results have shown that temperament tests often relate well to one another. Therefore, it is plausible that sufficient information on pig temperament can be retrieved from performing just two tests, one aimed to explore the active/passive dimension, the other the calm/fearful dimension.

What can temperaments tell us about sow productivity?

Understanding temperament types provide information about how well an individual can cope with stress, and in turn can have important consequences for productivity. Figure 4 summarises the links found between temperament types, sow stress responses, aggression and productivity.

Figure 4a: The links found between temperament types, sow stress responses, aggression and productivity.

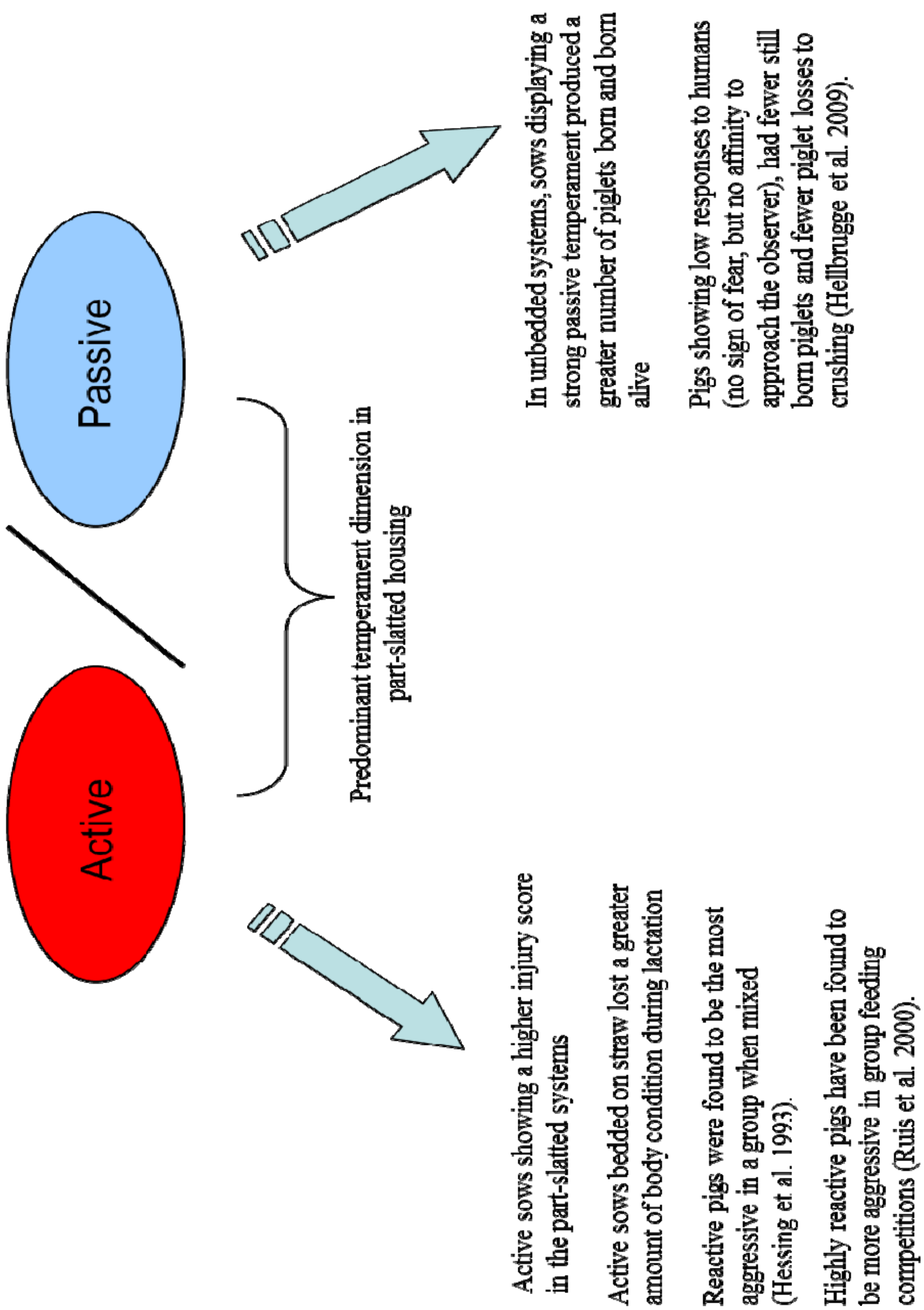
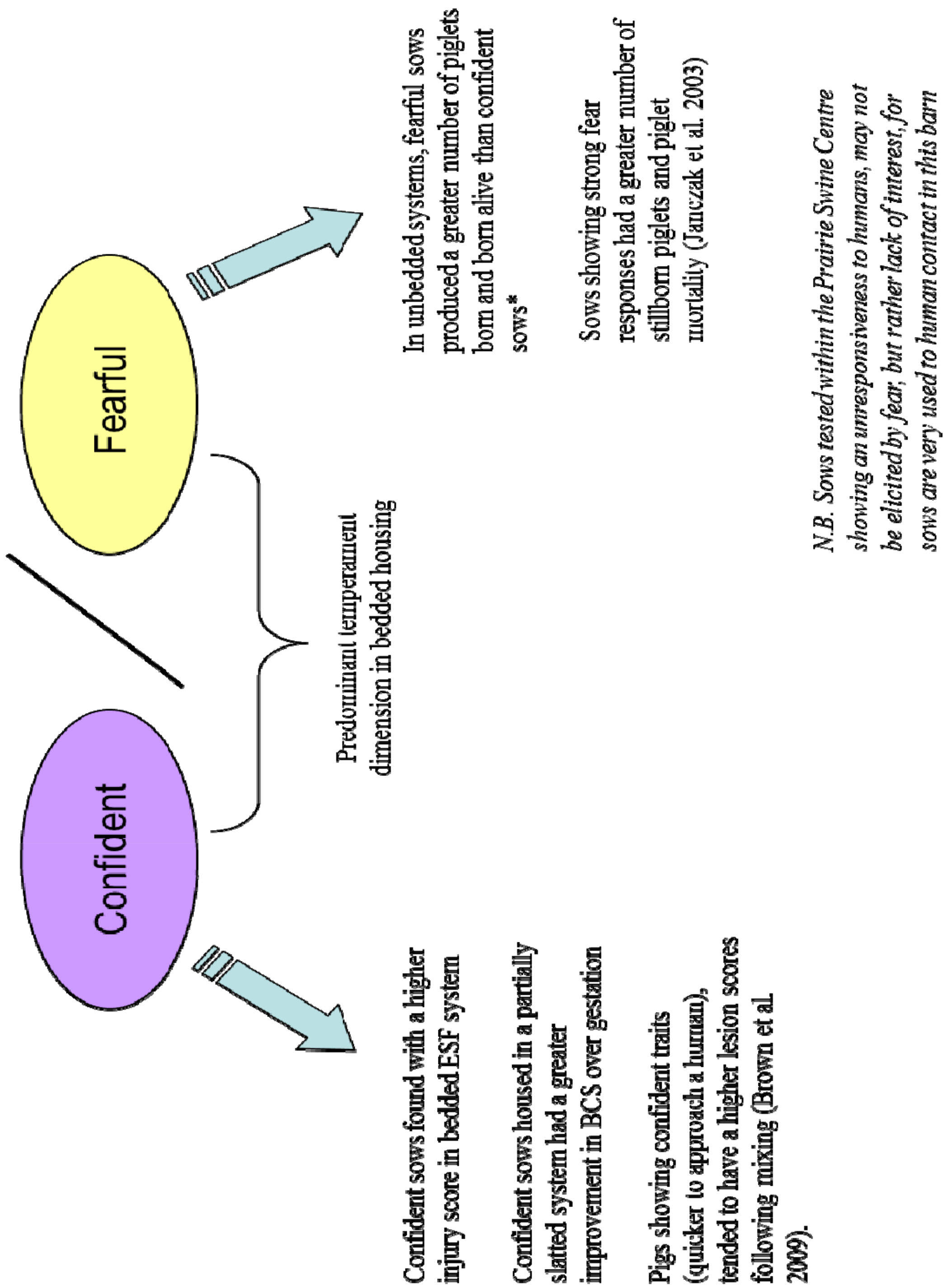


Figure 4b: The links found between temperament types, sow stress responses, aggression and productivity.



Infra-red thermography (IRT) technology

The IRT technique appeared to be effective in identifying lame sows in that there was a correlation between visual assessment and areas of increased temperature in the affected limb, particularly in the phalanges and metatarsi. Cameras for IRT work are compact, portable and the procedure was safe and easy to perform. However, at present the cameras are expensive, making this approach impractical for veterinary practices or large farming operations, but costs have decreased dramatically in the last few years and are expected to continue to drop.

IRT has been applied successfully in equine veterinary medicine, to the point where lameness may be detected before it becomes manifested as a clinical condition. However, the application of IRT on pig farms may face unique sow anatomical and behavioral challenges. Sows have shorter legs and leg conformation varies between animals far more than in the equine field. Sows also spend the vast majority of their time lying down within their gestation stall. The underside limb will be hotter.
In addition their legs are often contaminated with urine and feces, which will interfere with thermal imaging. Sows housed in loose pens are also problematic in that it is difficult to restrict the animal's movement, making it harder to standardize the images.

Figures 1: The camera in use in the sow barn.

Figure 2: Showing temperatures of various points on the leg.

The infra-red thermography (IRT) technology is currently cost prohibitive for routine on-farm diagnostics. Limb conformation, weight and parity effected the IRT temperatures. However, IRT was effective when compared to visual scores and may be a useful method of detecting early signs of inflammation and injury in the lower limbs and hooves of sows in the future.
Equipment available from FLIR www.flir.com

Lameness Assessment options.

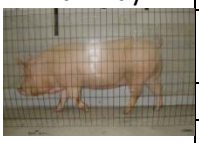
Lameness assessment using Global Visual Scoring (GVS):

Sows were evaluated for lameness using a Global Visual Scoring system. Sows were walked at a regular pace in a straight direction in a corridor, globally observed and a score from 0 to 4 was given:

0: normal gait, even strides
1: abnormal gait, stiffness but no easy identification of lameness
2: lameness detected, shortened strides, sow puts less weight on one leg
3: avoid putting weight on one leg
4: non ambulatory

Lameness assessment with Detailed Visual Scoring (DVS):

Detailed Visual Scoring was carried out in the same conditions than the GVS but forelegs and rear legs were observed separately, and the front, the side and the back of the animal was specifically observed to score different criteria for presence or absence according to the Table below.

Observer position	**Criteria=** *Does the sow…?:*	**Description**
Along the walkway 	Avoid putting weight on one leg	Sow lifts her leg to avoid putting weight on it.
	Head bob	The head gives jolt when walking
	Arched back	The back is arched and the length of the body is shortened
	Asymmetrical stride	Stride's length differs between right and left legs.
	Asymmetrical foot placement on the ground	The way to place the foot on the ground (flat, on one side of the toe…) differs between right and left legs
End of the walkway  	Less weight-bearing on one leg	Weight distribution differs between right and left. Sow has a slight limp in one leg.
	Asymmetrical Stiffness	Joints look stiff, one leg bends less than the opposite one.
	Asymmetrical circular movement of one leg	Asymmetrical movement of the legs: one leg does outwards or inwards movement while the other doesn't
	Asymmetrical swagger of caudal	Caudal body sways more on one side than the other.

Lameness assessment using accelerometers:

Accelerometers (Hobo® data logger, safely protected inside a Velcro®-pocket and a Vet-Rap® covering) which record the acceleration on the vertical axis were used to measure different parameters related to posture.

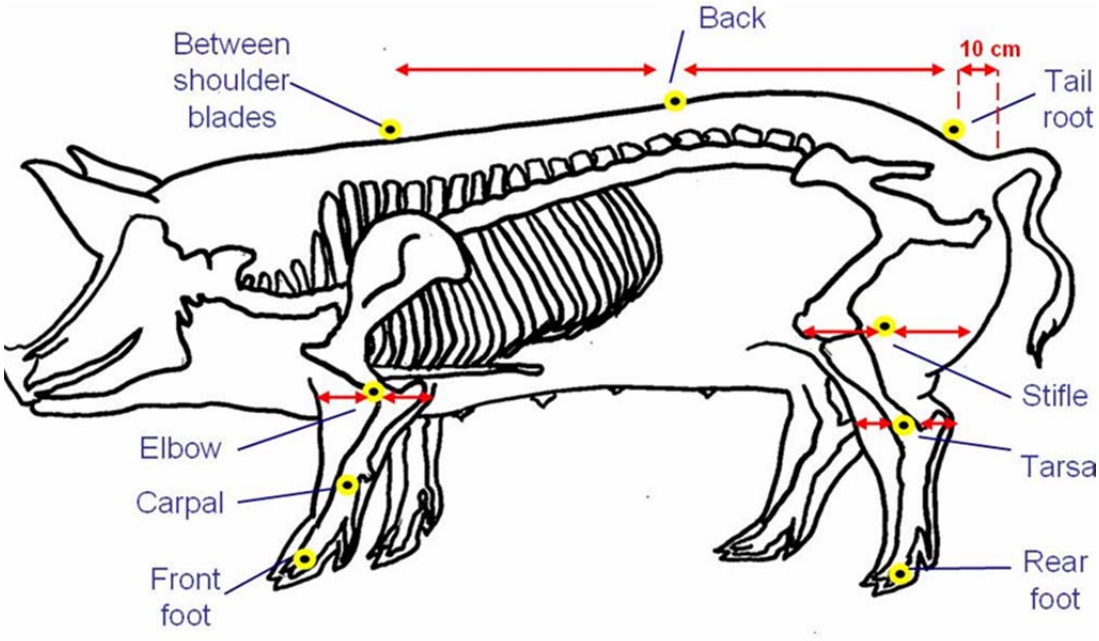
- One accelerometer was placed on one of the rear legs of each sow for recording of standing posture at 5-sec intervals for 24 hours;
- Evaluation of stepping for the two rear limbs was recorded for 15 min during feeding in the morning, using one accelerometer on each rear limb and recording vertical acceleration at 10 Hz;
- Latency to lie down after feeding was also calculated from data recorded during the hour following feeding.

Lameness assessment using kinematics:

Each sow was video recorded as she walks along a corridor. Fifteen reflective markers were placed in standardised spots on the sow's body (as shown in the diagram below). Each side of the sow was recorded separately for 3 full steps (2 strides) with no pause

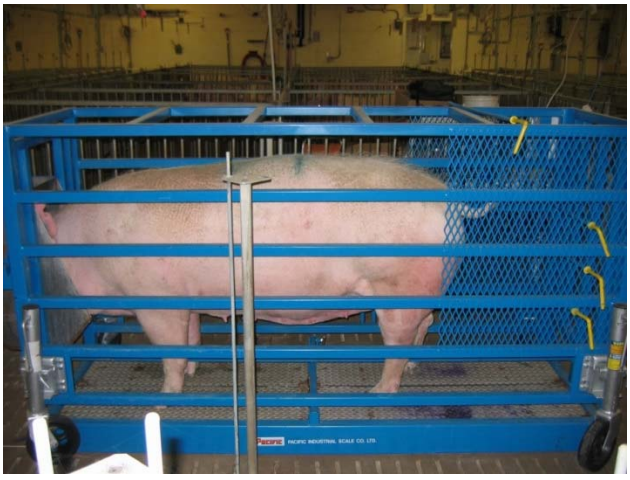
Video recordings were analyzed thereafter for gait characteristics including:

- stride length;
- stance time (when the foot is on the ground);
- swing time (when the foot is off the ground);
- walking speed;
- mean and amplitude of the angle of the tarsal and carpal joints during the swing and the stance phases of the stride;
- mean and amplitude of the angle of the back.



Force Plate Assessment:

Sows will be placed in the force plate scale for 15 minutes. A maximum of 1 kg of food will be given to the sow in order to keep her in place and quiet for this period of time. Each second (13-16 datapoints per second), the total weight and the weight placed in each platform are recorded. For the analysis, the data are cleaned from erroneous data with specific macros. Weights that are 5% above or below the sow's mean weight are automatically removed. Within this large dataset for each sow, the only period where the variation in weight within 51 data is less than 5% is considered for further calculations. The percentage of weight placed on each platform, the percentage of weight placed on the front/back/right/left sides, the average SD, and the leg weight ratio between legs of the front pair and of the back pair are calculated.



Sow inside the force plate scale.

Lameness: what to record?

John Deen
University of Minnesota

Recording lameness can take a number of different approaches. In most farming systems the initial questions surround the incidence, prevalence and the relationship between the presence of lameness and productivity of the sow or pig or boar. Much of the knowledge that we have gained can be identified through the work done on dairy cows. They have the opportunity of viewing and recording lameness on a regular basis as cows entered the milking facility. Moreover they have used a number of different technologies to instrumentalize the measuring process. Technology such as pressure plates, infrared cameras and accelerometers have all been used to create a consistent method of measuring between farms and thus allow better research to be done.

I would argue for the sake of the farm level analysis at this stage of our understanding that the measurement can be quite a bit simpler. The definition of lameness can vary from farm to farm, and it is also a function of the type of flooring under which the animal is observed as well as the level of fear response within the pigs. By fear response I mean that pigs, when they feel threatened, are less likely to show signs of lameness. We have estimated that the level can be as high as 40% when we compare video camera footage of sows in the pen with signs seen during movement of the sows from the gestation facility to farrowing.

We have tested various scoring systems to assess whether or not there are changes in the prevalence or incidence of lameness in target herds. For our analyses we have come up with five simple rules for gait analysis:

1. Record regularly (ie sows moved to farrowing crates)
2. Record both lame non-lame sows (zeros count)
3. Lameness involves a painful condition (conformation does not count)
4. If it is lame score as a one (no further scoring needed)
5. If you are not sure it is lame, score it as zero

Such a scoring system can be augmented by some training through video or mentorship. However, we have found that most people who work regularly with pigs can readily identify those sows whose behavior is affected by a painful condition. We also need to readily see that we are going to underestimate the prevalence as there will be hiding behavior and underestimation through missed diagnoses.

However, it does help us initially focus on the more affected and thus the animals with the strongest relationship between productivity and lameness. In most herds we are still seeing at least 20% of sows affected, and it has allowed us to core group to measure efficacy of interventions as well as create a management focus for stockmanship.

The influence of hoof trimming on lameness in sows

- Hoof lesions are common, likely underestimated and largely unnoticed, yet can contribute to lameness
- Use of a trimming chute now provides one way to help to reduce sow lameness associated with hoof lesions

Hoof lesions and lameness could be more prevalent than we realise:

- A recent survey on of 3,451 sows from one stall housed 6,000 sow herd found 94% of the herd had hoof lesions.
- Most common problems included: Heel overgrowth (85% of sows, Fig. 1), white line cracks (57%, Fig. 2), long dew claws (46%, Fig. 3) and hoof wall cracks (33% Fig. 4).
- Long toes, heel overgrowth and white line cracks were more common in the hind feet.
- Gait scored on a scale of 0-3, 54% of surveyed sows had an abnormal gait, a score of ≥1, indicating some discomfort in walking.
- 6% of sows showed more clear lameness in at least one leg, a <1% of sows were severely lame.
- Of sows that were observed with a gait score of ≥1, 23% were young parity sows, or parities 0-3.
- 86% of sows in parities 0-3 had hoof lesions present. Broken down by parity this showed: 39% of gilts (parity 0), 74% of parity 1, 93% of parity 2 and 97% of parity 3 sows had hoof lesions.

Figure 1 Heel overgrowth in sows

Figure 2 White line cracks

Figure 3 Long dew claws

Figure 4 Hoof wall cracks

The high prevalence of hoof lesions lends to the need for establishing a routine hoof trimming practice as an obvious strategy to help correct structural abnormalities and improve sow comfort. This could likely also help reduce hoof infections which could lead to more severe lameness and compromise sow welfare and longevity.

The high number of low parity sows (0-3) with lesions shows is a concern as to why lesions are developing so early in a sow's productive life.

This leads to questions on the robustness or sows, the housing environment and the management programme of the barn. With hoof health being influenced by nutrition, genetics and flooring quality, the requirement for hoof trimming, and whether it is an appropriate management strategy for a unit is likely to differ between barns.

Hoof Trimming

Figure 5 A sow lying in the FeetFirst® Chute

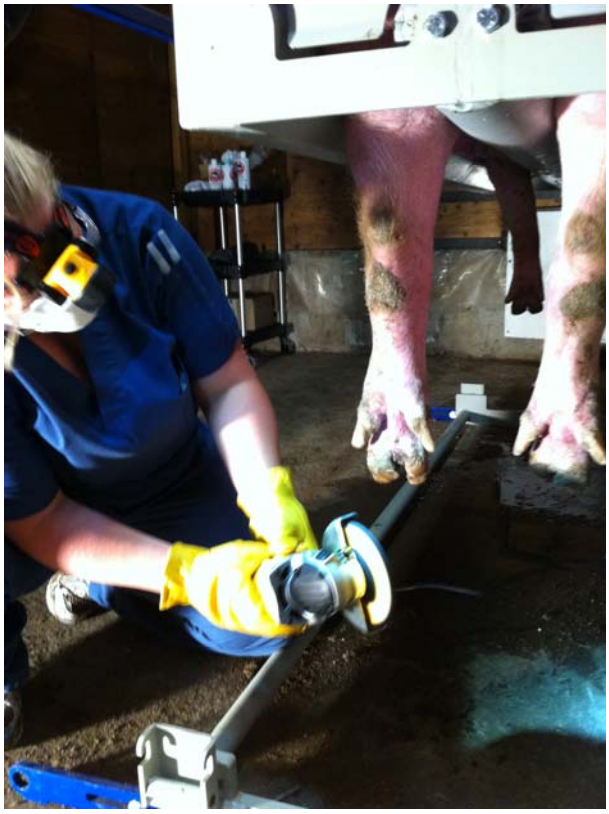


Figure 6 A sow receiving a trim in the Zinpro FeetFirst® chute

From a 200 sow study it was found that sows that were non-lame still had hoof lesions, and it is important to maintain awareness that this could be responsible for poor sow comfort and a deterioration to lameness later in the sow's life.

It was possible to drastically improve the confirmation of some hoof conditions, in one trim.

In other situations the trim actually revealed the true extent of the lesion, and a series of further trims would be required to fully correct the issue.

Studying the sows in the chute allows a full and detailed assessment of hoof lesions to be made, without which conditions that form on the underside of the hoof, such as white line cracks and heel erosion would likely be under-reported.

Older parity sows also had a greater hoof lesion score, indicating that unattended hoof lesions worsen as the sow ages, and will likely put the sow at increased risk of infection and culling.

This work does provides a demonstration that restraining gestating sows in the chute at eight weeks gestation and performing a hoof trim was not detrimental on sow productivity.

Effect of a comprehensive treatment program on sow lameness

The treatment program:

- A rubber stall mat throughout gestation,
- anti-inflammatory drugs at four and eight weeks
- Corrective hoof trim at eight weeks.

The effects of lameness of production:

- This result shows that, on average, lame sows weaned 6% fewer pigs than non-lame sows
- A cost evaluation based on the 6% reduction in performance indicates a $5 loss per market hog sold from lame sows. This loss is based on the cost overheads spread over fewer piglets produced

Applying a comprehensive intervention strategy was able to significantly reduce both the severity and prevalence of lameness in lame sows over the course of one gestation.
Lameness alone causes performance losses in sows. Furthermore, the majority (70%) of lame sows compared in this study had only mild lameness (lameness score of 1), and therefore even very mild lameness appears to be having an influence. Preventative action to prevent lameness in the first place is of great worth, and even very mild lameness should be receiving attention to halt its progression.

The significant reduction in gait score and lameness occurring in the observation period following corrective hoof trimming may indicate that trimming was the key factor in the treatment of the sows. However, there may also be an additive effect of the combined treatment regime, with rubber matting providing a cushioned floor to aid healing and the analgesic reducing any inflammation and initiate the heeling process. With evidence that this full treatment regime has a positive effect on healing, the next step is to refine the treatment, and identify the key parts that contribute to healing. In addition, following the progress of lame sows receiving treatment for a longer period of time will help identify how successful the treatment is in the longer term to help sow longevity within the herd, and the cost implications of the treatment.

What are the interventions and how should your business prioritize?

John Deen
University of Minnesota

Interventions can come from a number of different levels of management. The first one should always be to measure lameness on a prospective basis. In other words, lameness should be assessed on a regular basis and outcomes should be followed based on initial lameness diagnosis. Unfortunately, many of our lameness diagnoses show up at the time of culling and only in animals that are culled. We have found this to be a relatively worthless data set.

Measurement is an intervention because it often results in effect. It creates a focus for stockpersons and for production measures that often does not exist without a measurable in place. The first reaction in many cases is to create more care for sows in the farrowing crate, when appetites are particularly important. The use of analgesia should be almost mandatory, due to its significant effect upon a painful condition that results in lowered feed intake and lowered survivability. In many cases there is also an inflammatory process in play and the same analgesia products are also anti-inflammatories. Antibiotics are often used as well, with variable outcomes. Frankly, they work more often than expected and we need to understand more of the mechanisms of lameness.

Culling priority should then be reevaluated. In many herds the priorities of culling have performance such as multiple returns out ranking lameness as a culling concern. In our studies we find that lameness is rarely recoverable on its own and much more predictive of future poor performance than prior poor performance. Saying that, we often find that it is lameness that is behind poor performance of the sow.

If retained, environmental modification may be needed for lame sows. Tools such as rubber mats in farrowing crates and breeding stalls can improve the likelihood of recovery and concomitantly improve productivity. More ornate recovery depends using flooring such as dirt or sand have often been found to increase recovery likelihood.

Prevention still needs more study, and it often requires a better understanding of the genesis of lameness within the herd. Flooring is often the first step. Farrowing crate flooring with a high void to solid ratio shows more lameness, either amplifying lameness behavior or interacting with claw lesions such as white line lesions. In gestation, particularly pens, we see that agonistic behavior in combination with slatted floors can result in an increased amount of lameness. This can occur at mixing or at competition for entry into feeding stations and for other high activity behaviors. Feed intake and formulation are also indicated in interventions, also in gilt development.