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Optimizing Dietary Net Energy for Maximum Profitability in Growing- Finishing Pigs

J. Soto
Kansas State University, Manhattan, josesoto@k-state.edu

M. D. Tokach
Department of Animal Science and Industry, Kansas State University, mtokach@ksu.edu

S. S. Dritz
Kansas State University, Manhattan, dritz@k-state.edu

M. A. Goncalves
Genus PIC-USA, Hendersonville, TN

See next page for additional authors

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Optimizing Dietary Net Energy for Maximum Profitability in Growing-Finishing Pigs

Abstract

Feed accounts for a significant portion of swine production cost, with dietary energy alone representing more than half of the total cost. Considering the financial implications of determining the energy content of the diet, the objective of this research project was to develop a tool to accurately estimate the dietary NE content that yields maximum profitability for growing-finishing pigs. A Microsoft Excel®-based model was developed to contrast dietary NE defined by the user with recommended concentrations that are intended to maximize profitability in user defined production and economic scenarios. To calculate pig performance, the model uses prediction equations for ADG and feed efficiency. In addition, the model also uses the NDF content of the diet because of its effect on dressing percentage. For profitability calculations, a non-linear mathematical programming model was designed to select the optimum dietary NE content that yields the greatest income over total cost per pig on a live or carcass basis. The model can be used to predict dietary NE content that yields the highest economic benefit considering dynamic productive and economic scenarios. The model can be downloaded at www.ksuswine.org.

Keywords

Net energy, neutral detergent fiber, linear programming

Cover Page Footnote

The authors thank Genus PIC-USA, (Hendersonville, TN) for technical and financial support.

Authors

J. Soto, M. D. Tokach, S. S. Dritz, M. A. Goncalves, J. C. Woodworth, J. M. DeRouchey, R. D. Goodband, and U. A. Orlando

Optimizing Dietary Net Energy for Maximum Profitability in Growing-Finishing Pigs[1]

J.A. Soto, M.D. Tokach, S.S. Dritz,[2] M.A.D. Goncalves,[3] J.C. Woodworth, J.M. DeRouchey, R.D. Goodband, and U.A.D. Orlando[3]

Summary

Feed accounts for a significant portion of swine production cost, with dietary energy alone representing more than half of the total cost. Considering the financial implications of determining the energy content of the diet, the objective of this research project was to develop a tool to accurately estimate the dietary NE content that yields maximum profitability for growing-finishing pigs. A Microsoft Excel®-based model was developed to contrast dietary NE defined by the user with recommended concentrations that are intended to maximize profitability in user defined production and economic scenarios. To calculate pig performance, the model uses prediction equations for ADG and feed efficiency. In addition, the model also uses the NDF content of the diet because of its effect on dressing percentage. For profitability calculations, a non-linear mathematical programming model was designed to select the optimum dietary NE content that yields the greatest income over total cost per pig on a live or carcass basis. The model can be used to predict dietary NE content that yields the highest economic benefit considering dynamic productive and economic scenarios. The model can be downloaded at www.ksuswine.org.

Introduction

Feed accounts for up to 75% of pork production cost, with energy alone representing 50% or more of the total cost.[4,5] The knowledge of energy metabolism is essential to predict, optimize, and formulate diets to achieve expected performance. Typically, the DE (digestible energy) and the ME (metabolizable energy) systems are the most common in the US.[5] However, the concentration of dietary NE provides the most accurate estimate of the amount of energy available to the pig.[6] Acknowledging the difficulties of

[1] The authors thank Genus PIC-USA. (Hendersonville, TN) for technical and financial support.

[2] Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.

[3] Genus PIC-USA. (Hendersonville, TN).

[4] Noblet, J., H. Fortune, C. Dupire, S. Dubois. 1993. Digestible, metabolizable and net energy values of 13 feedstuffs for growing pigs. Anim. Feed Sci. Tech 42:131-149.

[5] Patience, John F. 2009. Energy in swine nutrition. Animal industry report: AS 665, ASL R2457. Available at: http://lib.dr.iastate.edu/ans_air/vol655/iss1/80.

[6] Noblet, J. 2007. Recent developments in net energy research for swine. Adv. Pork Prod. 18:149-156.

measuring NE and limited availability of NE estimates in dietary ingredients, Nitikanchana et al. (2015)[7] developed and validated regression equations to predict growth rate and feed efficiency of growing-finishing pigs the NE system. These equations provide a useful estimate for growth performance of pigs fed different dietary NE concentrations. Taking into consideration the financial implications of the energy density of the diet, the objective of this study was to develop a tool to estimate the dietary NE concentration that yields maximum profitability for growing-finishing pigs.

Procedures: Building the Model

Model Description

The NE optimization tool is a Microsoft Excel®-based model. This tool is intended for use by swine nutritionists as a method to contrast current dietary NE concentrations to recommended values that yield maximum profitability. The model is divided into 3 sections: 1) model inputs, with economics, production, and dietary criteria; 2) model calculations and optimization, for growth performance and carcass yield predictions, and profitability indicators; and 3) model outputs with recommended dietary NE concentrations, predicted growth performance, carcass yield, and profitability indicators contrasting current with the estimated ideal dietary NE concentrations.

User Input Page

Economics and System Performance

For calculation of growth performance and profitability, the user is required to enter the following inputs: current ADG (lb), F/G, and carcass yield (%), pork carcass price ($/lb), feeder pig cost ($/pig), facility cost ($/pig/d), and other cost (e.g., veterinary supplies, insurance, etc.). For the growth curve, the user can utilize default values or input a custom growth curve. In addition, the profit determination criteria can be customized by selecting the economic evaluation based on a live- or carcass-basis and marketing pigs on either a fixed time or fixed weight basis.

Nutritional Program Specifics

In this section, the number of dietary phases is selected (currently the model allows the selection of 4 to 6 phases) along with the BW range per phase. In addition, current, minimum, and maximum NE (kcal/lb) concentrations are specified by the user in each dietary phase. Inputs for minimum and maximum NE will be obtained by diet formulation. With these three NE inputs, the model will calculate 5 equidistant NE values, maintaining the minimum, maximum as well as the current NE value used. Afterward, the user needs to input the feed cost ($/ton) for diets at each NE value in all phases and the percentage of neutral detergent fiber (NDF) associated to each concentration of dietary NE for diet phases 3 and greater.

Building the Calculations for Performance and Economics

Growth performance prediction equations and SID Lys adequacy

This model utilizes the ADG prediction equations developed by Nitikanchana[7] et al. Their publication provides two equations: 1) equation with adequate dietary SID Lys

[7] Nitikanchana, S., S. Dritz, M. Tokach, J. DeRouchey, R. Goodband, and B. White. 2015. Regression analysis to predict growth performance from dietary net energy in growing-finishing pigs. J. Anim. Sci. 93:2826-2839.

(this equation includes BW, dietary NE, and the quadratic term of BW as regressors) and 2) equation with dietary SID Lys at suboptimal values (this equation includes BW, dietary NE, and SID Lys). In the inputs section, the user is required to select if their diets are adequate in SID Lys or not. If diets are deficient, the user needs to input the SID Lys associated to each value of dietary NE in each dietary phase.

To calculate ADG, the user provides a current system overall ADG, which is partitioned to a current calculated ADG in each dietary phase with the use of a regression equation developed from a reference population (Table 1). Furthermore, ADG is calculated with the inputs provided by the user (BW and dietary NE in each dietary phase). The difference between both, current and calculated ADG, are added or subtracted to predict ADG, which represents an adjustment to the intercept for the calculated ADG results.

To calculate G:F, the model utilizes estimations performed by Beaulieu[8] et al., which suggested a 1:1 ratio between feed efficiency and dietary energy concentration. The model utilizes this ratio to calculate the influence of dietary NE on F/G. Comparable to the procedures to calculate predicted ADG, the user provides an overall F/G, and these values are partitioned to a current F/G (as G:F) in each dietary phase with the use of a growth curve from the reference population (Table 1).

Feed Cost, SID Lys, and NDF Prediction Equations

For the calculated NE values not provided by the user, feed cost, SID Lys, and NDF for energy, are predicted using a set of regression equations that were developed using the least squares estimates method from the Linest function of Microsoft Excel. According to Briand and Carter,[9] the Linest function is an alternative to the use of least squares estimator formulas to obtain the best fit under a predefined criterion, and allows combinations with multiple functions to calculate statistics for other linear models.

For the feed cost prediction, Linest calculates the slope and intercept from the feed cost associated to each NE value provided by the user. In each dietary phase, a set of five linear regression equations are calculated by combining pairs of consecutive feed cost and associated NE values. The rationale supporting these calculations is to provide exact estimates of feed cost, and consequently more accurate economic estimates.

For the NDF prediction, Linest calculates a set of three linear regression equations (linear, quadratic, and cubic) and the equation with the best fit is selected to estimate NDF. The regression equations are calculated by selecting the NDF and associated NE values in each dietary phase from the inputs provided by the user. The equation fit is determined by the adjusted coefficient of determination, intended to account for the number of predictors in the model (Table 2).

[8] Beaulieu A., Williams N., and Patience J. 2009. Response to dietary digestible energy concentration in growing pigs fed cereal-grain based diets. J. Anim. Sci 87:965–976.

[9] Briand, G. and Carter, H. 2011. Using excel for principles of econometrics: 4th edition. John Wiley & Sons Inc. New York, NY.

Comparable to the procedures to calculate predicted NDF, Linest calculates a set of three linear regression equations, and the model with the best fit is selected for estimation of SID Lys.

Regression Equations to Predict Carcass Yield

This model uses carcass yield prediction equations developed by Soto[10] et al., which provides an estimate of the effects of dietary NDF on carcass yield.

Building the Linear Programming Model for Optimization in Excel

A non-linear mathematical programming (NLP) model was designed to select the optimum values of dietary NE that yields the maximum profitability for growing-finishing pigs. In Microsoft Excel Solver, NLP problems are solved with the generalized reduced gradient (GRG) algorithm. In this model, the objective function is income over total cost (IOTC) on a live- or carcass-basis and is maximized by the optimal value of NE in each dietary phase.

In the model, once economic, system performance, weight ranges, and dietary inputs are entered, the GRG algorithm begins the routine at any feasible solution (starting point). Then through multiple iterations across the feasible region, it searches for a solution that provides the value of NE that satisfies the greatest profitability (IOTC) defined in the objective function. When no further possibility for profitability improvement exists, the current solution becomes local optima in relation to nearby points. However, a global optimal solution represents the best possible solution for the objective function.[11] To land in the global optima, the model has the GRG in the Solver set up with the Multistart option, which selects several starting points throughout the feasible region, which produces multiple local optima solutions; therefore, increasing the chance of arriving to the global optima solution. The mathematical structure and economic calculations of the model are described in Tables 3 and 4.

Application of the Model

Scenario Building

An example using this model is presented in Tables 5, 6, 7, and 8. In this example, a six-phase feeding program based on corn-soybean meal and dried distillers grains with solubles (DDGS) was used. To generate the NE range, a series of 5 diets per phase were formulated to include 0, 10, 20, 30, and 40% DDGS. In our simulation, the base feeding program used for comparisons had 20% DDGS added throughout all dietary phases. The resulting NE values from the 20% DDGS diets in this simulation were: 1,104, 1,122, 1,130, 1,145, 1,150, and 1,140 Kcal/lb for phases 1, 2, 3, 4, 5, and 6, respectively (Table 5). From phases 3 to 6, resulting NDF values had an average of 13% for diets with a 20% DDGS inclusion. The results of calculations for 5 equidistant NE values and respective NDF values are presented in Table 5.

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[10] Soto, J.A., M.D. Tokach, S.S. Dritz, M. A. Goncalves, J.C. Woodworth, J.M. DeRouchey, and R.D. Goodband. 2017. Regression Analysis to Predict the Impact of High Insoluble Fiber Ingredient on Carcass Yield. *Kansas Agricultural Experiment Station Research Reports*: Vol. 3: Iss. 7.

[11] Ragsdale, C. 2008. Spreadsheet modeling and decision analysis. 5th edition. Thomson Higher Education. Mason, OH.

For scenario building, the following inputs were used: 1) current overall ADG of 2.15 lb; 2) current overall F/G of 2.90; 3) current carcass yield of 73.4%; 4) feeder pig cost of $55.00/pig; 5) facility cost of $0.11/pig/d; and 6) other cost (veterinary supplies, field service personnel, trucking, etc.) of $8.00/pig.

Dynamic Scenario Variables Definition

To further evaluate the model performance, dried distillers grains with solubles (DDGS) pricing was modified from low-cost ($90.00/ton) to high-priced ($150.00/ton). Similarly, carcass pricing was also modified from moderate-priced ($0.65/lb) to high-priced ($0.85/lb). For calculation of feed cost the pricing of main ingredients used was: corn $3.48/bu, soybean meal $290.60/ton, and L-Lys $0.69/lb. Resulting feed costs are presented in Table 5.

Results and Discussion

Scenario Results

Considering a scenario with low-priced DDGS and moderate carcass, the model solution suggested that NE should be decreased, thus forcing in 40% DDGS. This decrease is only observed from phases 1 to 5. In phase 6, the model yielded no modification from the current energy value. The recommended NE values worsened ADG, feed efficiency, and carcass yield, nonetheless, the recommend NE values under the conditions of this scenario improved IOTC by $3.75/pig. Interestingly, by only changing the scenario to a high carcass price, the model solution suggested a similar NE decrease in phases 1 to 5 to the previously explained scenario. However, in phase 6 the model suggested the highest energy value, thus switching to a corn-soybean meal-based diet, and improving carcass yield. With the use of the recommend NE values under the conditions of this scenario, IOTC improved by $3.76/pig over the current system performance.

Considering a scenario with high-priced DDGS and moderated carcass price, the model solution still suggested that NE should be decreased; however, the extent of this decrease is lower compared to the scenarios described above, particularly for phases 1 and 3. For phases 2 and 4, the recommend NE values remain the lowest, forcing the 40% DDGS diet. For phases 5 and 6, the recommended NE values are increased, particularly for phase 6. The recommended NE values slightly worsened feed efficiency, yet carcass yield was improved. With the use of the recommend NE values under the conditions of this scenario, IOTC improved by $1.26/pig. With a more favorable scenario for carcass price, NE is moderately reduced for phases 1 and 3. For phase 2 the recommended NE value remained the lowest. For phase 4, the model yielded no modification. Like the previous scenario, the recommended NE values are increased for phases 5 and 6, particularly for phase 6. With the use of the recommend NE values under the conditions of this scenario, IOTC improved by $1.56/pig.

The model described in this paper can be used to predict the value of dietary NE that yields the greatest economic return to the production system. To evaluate the performance of the model, an example is presented considering different economic scenarios created by modifying DDGS and carcass pricing.

Table 1. Regression equation to partition ADG and G:F by dietary phase from overall growth performance inputs[1]

Growth performance	Model
ADG, g	$= ((0.0000000903 \times \text{Average BW}^3\text{ (lb)} - 0.0000794732 \times \text{Average BW}^2\text{ (lb)} + 0.0196290876 \times \text{BW (lb)} + 0.8587771286)/2.2046) \times 1000$
G:F	$= ((0.0000001334 \times \text{Average BW}^3\text{ (lb)} - 0.0000746844 \times \text{Average BW}^2\text{ (lb)} + 0.0206218569 \times \text{BW (lb)} + 0.9095818867)/2.2046) \times 1000$

[1] Growth curve reference taken from PIC 337 growing-finishing pigs (PIC internal data).

Table 2. Sample set of regression equations for SID Lys and NDF by dietary phase for data provided by the user[1]

Variable	Equation	Model	Adjusted R^2
NDF, %	Linear	$= -0.0625131422 \times \text{NE (Kcal/lb)} + 82.7625557731$	0.9423
	Quadratic	$= 0.0001079914 \times \text{NE}^2\text{ (Kcal/lb)} - 0.2993946653 \times \text{NE (Kcal/lb)} + 211.99803997658$	0.9892
	Cubic	$= 0.0000004840 \times \text{NE}^3\text{ (Kcal/lb)} - 0.0014830859 \times \text{NE}^2\text{ (Kcal/lb)} + 1.4389476360 \times \text{NE (Kcal/lb)} - 419.1488833100$	0.9954
SID Lys, %	Linear	$= 0.0010985469 \times \text{NE (Kcal/lb)} - 0.0040594197$	0.9802
	Quadratic	$= -0.0000009635 \times \text{NE}^2\text{ (Kcal/lb)} + 0.0032120880 \times \text{NE (Kcal/lb)} - 1.1571443056$	0.9904
	Cubic	$= -0.0000000087 \times \text{NE}^3\text{ (Kcal/lb)} + 0.0000276581 \times \text{NE}^2\text{ (Kcal/lb)} - 0.0280586775 \times \text{NE (Kcal/lb)} + 10.1964581316$	0.9979

[1] The equation selected for the prediction is the one with the highest adjusted coefficient of determination.

Table 3. General linear programming model

Objective function	Calculation
Income over total cost, live basis	
MAX (IOTC Live, $/pig):	*f(x)*= ((Total gain Ph1-6, lb + Feeder pig BW, lb) × Live price, $/lb) – (Feed cost, $/pig + Facility cost, $/pig) – Feeder pig cost, $/pig
Subject to:	Phase 1 Predicted NE ≥ Minimum user NE, Phase 1 Predicted NE ≤ Maximum user NE
	Phase 2 Predicted NE ≥ Minimum user NE, Phase 2 Predicted NE ≤ Maximum user NE
	Phase 3 Predicted NE ≥ Minimum user NE, Phase 3 Predicted NE ≤ Maximum user NE
	Phase 4 Predicted NE ≥ Minimum user NE, Phase 1 Predicted NE ≤ Maximum user NE
	Phase n Predicted NE ≥ Minimum user NE, Phase n Predicted NE ≤ Maximum user NE
	Ph1 NE ≥ 0, Ph2 NE ≥ 0, Ph3 NE ≥ 0, Ph4 NE ≥ 0, Phn NE ≥ 0
Income over total cost, carcass basis	
MAX (IOTC Carcass, $/pig):	*f(x)*= (((Total gain Ph1-6, lb + Feeder pig BW, lb) × Predicted carcass yield, $/lb × Carcass price, $/lb) – (Feed cost, $/pig + Facility cost, $/pig)) – Feeder pig cost, $/pig
Subject to:	Phase 1 Predicted NE ≥ Minimum user NE, Phase 1 Predicted NE ≤ Maximum user NE
	Phase 2 Predicted NE ≥ Minimum user NE, Phase 2 Predicted NE ≤ Maximum user NE
	Phase 3 Predicted NE ≥ Minimum user NE, Phase 3 Predicted NE ≤ Maximum user NE
	Phase 4 Predicted NE ≥ Minimum user NE, Phase 4 Predicted NE ≤ Maximum user NE
	Phase n Predicted NE ≥ Minimum user NE, Phase n Predicted NE ≤ Maximum user NE
	Ph1 NE ≥ 0, Ph2 NE ≥ 0, Ph3 NE ≥ 0, Ph4 NE ≥ 0, Phn NE ≥ 0

Table 4. Input equations used in model development

Indicator	Calculation
Predicted daily feed intake, g	= Calculated ADG, g/Calculated G:F
Phase duration, d	= (Targeted BW, lb – Initial BW, lb/2.2046)/ (Calculated ADG, g/1000)
Total feed cost per phase, $/pig	= (Phase duration, d × (Predicted daily intake, g/d/1000) × (Diet cost, $/ton /2000) × 2.2046)
Gain per phase, lb	= Calculated ADG, g/1000 × Phase duration, d × 2.2046
Feed cost per lb of gain, $/pig	= ((Total feed cost by phase, $/pig/ (Targeted BW, lb – Initial BW, lb)))
Total phase intake, lb/pig	= (Predicted daily intake, g/d/1000) × 2.2046 × Phase duration, d
Feed and facility cost, $/pig	= Total feed cost, $/pig + (Phase duration, d × Facility cost, $/pig/d)
Income per pig, $/pig	= Gain per phase, lb × Live price, $/lb
Income over feed cost per phase, $/pig	= Income per pig, $/pig – Total feed cost per phase, $/pig
Income over feed and facility cost per phase, $/pig	= Income per pig, $/pig – Feed and facility cost, $/pig

Table 5. Resulting NE levels and respective feed cost and NDF

		Feed cost,[2,3] $/Ton		
Dietary phase	NE,[1] Kcal/lb	Low-priced DDGS	High-priced DDGS	NDF,[5] %
1	1,083	159.71	183.71	---
	1,093	168.08	186.08	---
	1,104[4]	177.77	189.77	---
	1,112	187.83	193.83	---
	1,122	204.55	204.55	---
2	1,097	150.01	174.01	---
	1,107	158.97	176.97	---
	1,117	168.43	180.43	---
	1,122[4]	177.97	183.97	---
	1,137	195.49	195.49	---
3	1,110	140.85	164.85	17.4
	1,121	148.75	166.75	15.2
	1,130[4]	157.45	169.45	13.1
	1,142	168.10	174.10	10.9
	1,153	183.68	183.68	8.7
4	1,119	135.70	159.70	17.4
	1,130	144.11	162.11	15.3
	1,145[4]	152.68	164.68	13.1
	1,153	161.71	167.71	11.0
	1,164	177.98	177.98	8.8
5	1,126	131.78	155.78	17.4
	1,137	139.74	157.74	15.3
	1,150[4]	148.16	160.16	13.1
	1,159	157.08	163.08	11.0
	1,170	173.69	173.69	8.8
6	1,117	132.17	156.17	17.4
	1,128	138.92	156.92	15.3
	1,140[4]	146.11	158.11	13.1
	1,149	154.40	160.40	11.0
	1,159	163.80	163.80	8.8

[1] Model calculated 5 equidistant NE levels by phase, keeping minimum, maximum, and currently used NE levels as defined by the user.

[2] The feeding program had an inclusion of 20% dried distillers grains with solubles (DDGS) in all dietary phases.

[3] Main ingredients pricing: corn $3.48/bu, soybean meal $290.60/ton, L-Lys $0.69/lb.

[4] Current levels of NE defined by user.

[5] Neutral detergent fiber defined by user for dietary phase 3 and greater.

Table 6. Recommended net energy levels (kcal/lb) compared with user defined levels in a six-phase feeding program with varying scenarios for distillers dried grains with solubles and carcass pricing on a fixed time marketing basis[1,2,3]

	DDGS, $/ton:	90						150					
	Carcass, $/lb:	0.65			0.85			0.65			0.85		
Phase	BW, lb	Current[4]	Recom.[5]	Diff[6]., %	Current	Recom.	Diff., %	Current	Recom.	Diff., %	Current	Recom.	Diff., %
1	50 to 75	1,104	1,083	(1.9)	1,104	1,083	(1.9)	1,104	1,093	(1.0)	1,104	1,093	(1.0)
2	75 to 125	1,122	1,097	(2.3)	1,122	1,097	(2.3)	1,122	1,097	(2.3)	1,122	1,097	(2.3)
3	125 to 175	1,130	1,110	(1.8)	1,130	1,110	(1.8)	1,130	1,121	(0.8)	1,130	1,121	(0.8)
4	170 to 210	1,145	1,119	(2.3)	1,145	1,119	(2.3)	1,145	1,119	(2.3)	1,145	1,145	0.0
5	210 to 250	1,150	1,126	(2.1)	1,150	1,126	(2.1)	1,150	1,159	0.8	1,150	1,159	0.8
6	250 to 285	1,140	1,140	0.0	1,140	1,159	1.6	1,140	1,159	1.6	1,140	1,159	1.6

[1] A corn-soybean meal-dried distillers grains with solubles-based feeding program with six dietary phases were used for comparisons.
[2] The feeding program had an inclusion of 20% dried distillers grains with solubles in all dietary phases.
[3] Main ingredients pricing: corn $3.48/bu, soybean meal $290.60/ton, L-Lys $0.69/lb.
[4] Current: user defined net energy levels by dietary phase.
[5] Recommended: optimized net energy levels by dietary phase.
[6] Difference between current and recommended energy levels expressed in percentage.

Table 7. Overall performance with recommended net energy levels compared with user defined levels in a six-phase feeding program with varying scenarios for distillers dried grains with solubles and carcass pricing on a fixed time marketing basis[1,2,3,4]

DDGS, $/ton:	90				150			
Carcass, $/lb:	0.65		0.85		0.65		0.85	
Item	Current[4]	Recom.[5]	Current	Recom.	Current	Recom.	Current	Recom.
ADG, lb	2.15	2.14	2.15	2.14	2.15	2.15	2.15	2.15
F/G	2.90	2.95	2.90	2.94	2.90	2.92	2.90	2.91
ADFI, lb	6.24	6.31	6.24	6.30	6.24	6.26	6.24	6.24
Carcass yield, %	73.4	73.2	73.4	73.7	73.4	74.0	73.4	74.0

[1] A corn-soybean meal-dried distillers grains with solubles-based feeding program with six dietary phases were used for comparisons.
[2] The feeding program had an inclusion of 20% dried distillers grains with solubles in all dietary phases.
[3] Current: user defined net energy levels by dietary phase.
[4] Recommended: optimized net energy levels by dietary phase.

Table 8. Economics of user defined net energy levels with recommended levels in a six-phase feeding program with varying scenarios for distillers dried grains with solubles and carcass pricing on a fixed time marketing basis[1,2,3]

DDGS, $/ton:	90				150			
Carcass, $/lb:	0.65		0.85		0.65		0.85	
Item	Current[4]	Recom.[5]	Current	Recom.	Current	Recom.	Current	Recom.
Phases duration, d	108.0	108.0	108.0	108.0	108.0	108.0	108.0	108.0
Total feed, lb/pig	672.4	681.0	672.4	679.5	672.4	675.5	672.4	673.5
Total feed cost, $/pig	53.01	48.37	53.01	49.38	56.69	56.36	56.69	56.50
Total feed cost and facility cost, $/pig	64.89	60.25	64.89	61.25	68.57	68.24	68.57	68.38
Gross Income, $/pig	135.97	135.46	177.81	177.24	135.97	135.78	177.81	177.71
Total IOFC,[6] $/pig	82.97	87.08	124.80	127.87	79.29	79.42	121.12	121.22
Total, IOFFC Carcass, $/pig	71.09	74.84	112.93	116.68	67.41	68.67	109.25	110.81
IOTC Carcass, $/pig	8.09	11.84	49.93	53.68	4.41	5.67	46.25	47.81

[1] A corn-soybean meal-dried distillers grains with solubles-based feeding program with six dietary phases were used for comparisons.
[2] The feeding program had an inclusion of 20% dried distillers grains with solubles (DDGS) in all dietary phases.
[3] Main ingredients pricing: corn $3.48/bu, soybean meal $290.60/ton, L-Lys $0.69/lb.
[4] Current: output using user-defined net energy levels by dietary phase.
[5] Recommended: output using optimized net energy levels by dietary phase.
[6] Income over feed cost.
[7] Income over feed and facility cost.