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Effects of feeding different dietary net energy levels to growing-finishing pigs when dietary lysine is adequate

Abstract

A total of 543 pigs (PIC 1050 Ã— 327: PIC Hendersonville, TN) were used in 2 consecutive experiments with initial BW of 105 and 125 lb in Experiments 1 and 2, respectively. The objective was to validate the regression equations predicting growth rate and feed efficiency of growing-finishing pigs based on dietary NE content by comparing actual and predicted performance. Thus, the 5 treatments included diets with: (1) 30% dried distillers grains with solubles (DDGS), 20% wheat middlings, and 4 to 5% soybean hulls (low-energy); (2) 20% wheat middlings and 4 to 5% soybean hulls (low-energy); (3) a corn-soybean meal diet (medium-energy); (4) diet 2 supplemented with 3.7% choice white grease (CWG) to equalize NE level to diet 3 (medium-energy); and (5) a corn-soybean meal diet with 3.7% CWG (high-energy). In Experiments 1 and 2, increasing dietary NE increased (linear, P < 0.01) final weight, ADG, and improved feed efficiency but decreased (P < 0.11) ADFI. Only small differences were observed between the predicted and observed values of ADG and feed efficiency, except for the low-energy diet containing the highest fiber content (30% DDGS, wheat middlings and soy hulls; diet 1). Carcass weight and carcass yield increased (linear, P = 0.01) with increasing dietary NE. Also, backfat depth increased (linear, P = 0.01), loin depth decreased (quadratic, P = 0.05), and lean percentage decreased (linear, P = 0.01) with increasing dietary NE (linear, P = 0.01). Jowl iodine value (IV) also decreased with increasing dietary NE. No differences (P > 0.26) in net energy caloric efficiency (NEE) on a live weight basis were observed with increasing dietary NE. Nevertheless, feeding 30% DDGS (diet 1) resulted in a poorer (P = 0.05) NEE on a carcass basis compared with feeding the other diets. In conclusion, the prediction equations provided a good estimate of growth rate and feed efficiency of growing-finishing pigs fed different levels of dietary NE except for the pigs fed low-energy diet containing highest fiber content (diet 1). These predictions of growth performance can be used to model the economic value of different dietary energy strategies.; Swine Day, Manhattan, KS, November 20, 2014

Keywords

Swine Day, 2014; Kansas Agricultural Experiment Station contribution; no. 15-155-S; Report of progress (Kansas State University. Agricultural Experiment Station and Cooperative Extension Service); 1110; Growth; Growing-finishing pig; Net energy; Regression

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Effects of Feeding Different Dietary Net Energy Levels to Growing-Finishing Pigs When Dietary Lysine is Adequate

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Summary

A total of 543 pigs (PIC 1050 × 327: PIC Hendersonville, TN) were used in 2 consecutive experiments with initial BW of 105 and 125 lb in Experiments 1 and 2, respectively. The objective was to validate the regression equations predicting growth rate and feed efficiency of growing-finishing pigs based on dietary NE content by comparing actual and predicted performance. Thus, the 5 treatments included diets with: (1) 30% dried distillers grains with solubles (DDGS), 20% wheat middlings, and 4 to 5% soybean hulls (low-energy); (2) 20% wheat middlings and 4 to 5% soybean hulls (low-energy); (3) a corn-soybean meal diet (medium-energy); (4) diet 2 supplemented with 3.7% choice white grease (CWG) to equalize NE level to diet 3 (medium-energy); and (5) a corn-soybean meal diet with 3.7% CWG (high-energy). In Experiments 1 and 2, increasing dietary NE increased (linear, $P < 0.01$) final weight, ADG, and improved feed efficiency but decreased ($P < 0.11$) ADFI. Only small differences were observed between the predicted and observed values of ADG and feed efficiency, except for the low-energy diet containing the highest fiber content (30% DDGS, wheat middlings and soy hulls; diet 1). Carcass weight and carcass yield increased (linear, $P = 0.01$) with increasing dietary NE. Also, backfat depth increased (linear, $P = 0.01$), loin depth decreased (quadratic, $P = 0.05$), and lean percentage decreased (linear, $P = 0.01$) with increasing dietary NE (linear, $P = 0.01$). Jowl iodine value (IV) also decreased with increasing dietary NE. No differences ($P > 0.26$) in net energy caloric efficiency (NEE) on a live weight basis were observed with increasing dietary NE. Nevertheless, feeding 30% DDGS (diet 1) resulted in a poorer ($P = 0.05$) NEE on a carcass basis compared with feeding the other diets. In conclusion, the prediction equations provided a good estimate of growth rate and feed efficiency of growing-finishing pigs fed different levels of dietary NE except for the pigs fed low-energy diet containing highest fiber content (diet 1). These predictions of growth performance can be used to model the economic value of different dietary energy strategies.

Key words: growth, growing-finishing pig, net energy, regression

Introduction

A meta-analysis was recently conducted to predict growth rate and feed efficiency of growing-finishing pigs based on dietary NE content, and results revealed that improvements in growth rate and feed efficiency could be obtained by increasing dietary NE (Nitikanchana et al., 2013[2]). However, the magnitude of improvement in growth performance when increasing dietary NE will be minimized if dietary lysine is limit-

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[2] Nitikanchana et al., Swine Day 2013, Report of Progress 1092, pp. 236–245.

ing. Therefore, this study was conducted to validate these newly developed prediction equations by comparing actual and predicted performance of growing-finishing pigs fed different dietary NE where dietary lysine was provided above the requirement.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in these experiments. The experiments were conducted at the K-State Swine Teaching and Research Center in Manhattan, KS. The facility was a totally enclosed, environmentally regulated, mechanically ventilated barn containing 38 pens (7.9 × 10.2 ft). The pens had adjustable gates facing the alleyway that allowed for 8 ft^2/pig. Each pen was equipped with a cup waterer and a single-sided, dry self-feeder (Farmweld, Teutopolis, IL) with 2 eating spaces located in the fence line. The facility was also equipped with a computerized feeding system (FeedPro; Feedlogic Corp., Willmar, MN) that delivered and recorded diets as specified. Pigs had ad libitum access to feed and water.

A total of 543 pigs (PIC 1050 × 327: PIC Hendersonville, TN) were used in 2 consecutive experiments with initial BW of 105 and 125 lb in Experiments 1 and 2, respectively. There were 4 barrows and 4 gilts per pen and 13 to 14 pens per treatment. Pens of pigs were assigned to 1 of 5 dietary treatments in a completely randomized design while balancing for initial BW within study. The dietary treatments included 3 different levels of dietary NE by adding low-energy ingredients (wheat middlings or soybean hulls), 30% dried distillers grains with solubles (DDGS), or choice white grease (CWG) to a corn-soybean meal–based diet. Thus, the 5 treatments included diets with: (1) 30% DDGS, 20% wheat middlings, and 4 to 5% soybean hulls (low-energy); (2) 20% wheat middlings and 4 to 5% soybean hulls (low-energy); (3) a corn-soybean meal diet (medium-energy); (4) diet 2 supplemented with 3.7% CWG to equalize NE level to diet 3 (medium-energy); and (5) a corn-soybean meal diet with 3.7% CWG (high-energy). The difference in dietary NE content between high vs. medium and medium vs. low energy was 75 kcal/lb (166 kcal/kg) across all phases of feeding. The NRC ingredient library (chapter 17, NRC, 2012[3]) was used as a reference for nutrient values in diet formulation except for DDGS. Samples of DDGS were analyzed for oil content (Ward Laboratories, Inc., Kearney NE; Table 1) prior to feed manufacturing and used to determine the NE content from the equation: NE (kcal/kg) = 115.011×oil (%) + 1501.01 (Nitikanchana et al., 2013[4]). The equation adapted from Main et al. (2008[5]) [Gilts SID Lys:NE ratio : $-0.000000153 \times ((\text{Initial BW (kg)} + \text{Final BW (kg)}) \times 1.1)^3 + 0.000104928 \times ((\text{Initial BW (kg)} + \text{Final BW (kg)}) \times 1.1)^2 - 0.030414451 \times ((\text{Initial BW (kg)} + \text{Final BW (kg)}) \times 1.1) + 6.043540689$; Barrow SID Lys:NE ratio : $0.0000454 \times ((\text{Initial BW (kg)} + \text{Final BW (kg)}) \times 1.1)^2 - 0.0249885 \times ((\text{Initial BW (kg)} + \text{Final BW (kg)}) \times 1.1) + 5.8980083$] was used to calculate the standardized ileal digestible lysine (SID Lys) requirement at different dietary energy levels and BW. SID Lys was formulated at 105% requirement of the lightest BW pig fed the highest energy level in each feeding phase to ensure that the SID Lys intake was above the estimated

[3] NRC. 2012. Nutrient Requirements of Swine. 11th ed. Natl. Acad. Press, Washington, DC.

[4] Nitikanchana, S., A.B. Graham, R.D. Goodband, M.D. Tokach, S.S. Dritz, and J.M. DeRouchey. 2013. Predicting digestible energy (DE) and net energy (NE) of dried distillers grains with solubles from its oil content. J. Anim. Sci. 91(E-Suppl. 2):701 (Abstr.).

[5] Main, R.G., S.S. Dritz, M.D. Tokach, R.D. Goodband, and J.L. Nelssen. 2008. Determining an optimum lysine:calorie ratio for barrows and gilts in a commercial finishing facility. J. Anim. Sci. 86:2190–2207.

requirement. All diets were fed in meal form and fed in 3 phases from 105 to 125, 125 to 167, and 167 to 216 lb in Experiment 1, and 125 to 169, 169 to 216, and 216 to 273 lb in Experiment 2 (Tables 2 through 7). Thus, Experiment 1 was terminated prior to harvest at a lighter BW than in Experiment 2. Diet samples were collected from feeders during every phase and stored at -20°C, then the proximate analysis was conducted on composite samples (Ward Laboratories, Inc., Kearney NE).

Pens of pigs were weighed and feed disappearance was recorded at d 9, 29, and 53 in Experiment 1 and at d 21, 44, and 74 in Experiment 2 to determine ADG, ADFI, and G:F. At the end of Experiment 2, pigs were individually weighed and transported to a commercial packing plant (Triumph Foods LLC, St. Joseph, MO) for processing and carcass data collection. Before slaughter, pigs were tattooed to allow for carcass data collection. Hot carcass weights were measured immediately after evisceration, and carcass criteria of backfat depth and loin depth were collected using an optical probe. Carcass percentage yield was calculated by dividing carcass weight at the plant by live weight at the farm. A processor proprietary equation that depended on backfat and loin depth was used to calculate percentage lean. Net energy caloric efficiencies (NEE) were calculated on a pen basis by multiplying total feed intake by the dietary NE concentration and dividing by total live or carcass weight gain. The carcass weight gain was obtained from subtracting HCW from the initial carcass weight by assuming 75% carcass yield across all pigs.

The experimental data were analyzed using the MIXED procedure of SAS (SAS institute, Inc., Cary, NC) where treatment was a fixed effect. Pen was the experimental unit for all data analysis. Significance and tendencies were set at $P \leq 0.05$ and $P \leq 0.10$, respectively. Analysis of backfat depth, loin depth, and percentage lean were adjusted to a common HCW. Contrast coefficients were used to evaluate linear and quadratic responses to dietary NE level.

Calculations of predicted performance

Prediction equations used in the analysis were used to calculate predicted ADG and G:F by feeding phase [ADG (g/day) = 0.1135 × NE (kcal/kg) + 8.8142 × Average BW (kg) – 0.05068 × Average BW (kg) × Average BW (kg) + 275.99; G:F = 0.000096 × NE (kcal/kg) – 0.0025 × Average BW (kg) + 0.003071 × fat (%) + 0.3257]. The actual BW at the beginning and end of each phase was averaged and used to represent the average BW in the equation. The total gain in each phase was then calculated by multiplying the predicted ADG and days on feed for each phase. Next, the total gain for each phase was divided with the predicted G:F in that phase to calculate the total feed intake for each phase. Lastly, the overall G:F was obtained by dividing the summation of total gain with the summation of total feed intake, and the overall ADG was calculated by dividing the summation of total gain with the overall days on feed. To accommodate the variation between baseline predicted and actual performance, the difference between predicted and actual growth performance of pigs fed the corn-soybean meal diet was used to adjust the intercept of the prediction equations, thus adjusting the growth performance of the other pens fed the other diets.

Results

The proximate analysis of diet samples was in agreement with the calculated values in the diet formulation for both Experiment 1 and 2 (Tables 8 and 9).

Experiment 1

For the overall period (d 0 to 53), increasing dietary NE resulted in increased final BW, ADG, and G:F but decreased ADFI (linear, $P < 0.04$; Table 10). Pigs fed the diet with wheat middlings and soybean hulls had greater ($P < 0.01$) ADG and G:F than those fed the diet containing 30% DDGS, wheat middlings, and soybean hulls; however, there was no difference ($P = 0.83$) in ADFI. Pigs fed the corn-soybean meal diet had similar ADG and ADFI ($P > 0.34$) but poorer feed efficiency ($P = 0.05$) compared with pigs fed diets with wheat middlings, soybean hulls, and CWG.

Only small differences between predicted and actual ADG and G:F were observed when feeding the diets, with the exception of pigs fed the lowest-energy, highest-fiber diet. The prediction equations overestimated ADG and G:F of pigs fed the diet containing 30% DDGS, wheat middlings, and soybean hulls by 4.5 and 6.1%, respectively.

There was no difference in NEE on a live weight basis due to increasing dietary NE ($P > 0.26$). Nevertheless, feeding the diet containing wheat middlings and soybean hulls resulted in similar ($P = 0.22$) NEE for pigs fed diets with CWG but resulted in improved ($P < 0.01$) NEE compared with other diets. Pigs fed the wheat middlings and soybean hulls diet with CWG had NEE similar ($P > 0.06$) to those fed the corn-soybean meal diet with or without CWG but had improved ($P = 0.03$) NEE compared with those fed the diet containing 30% DDGS, wheat middlings, and soybean hulls. No differences in NEE were observed between pigs fed 30% DDGS diet, corn-soybean meal diet, and corn-soybean meal diet with addition of CWG.

Experiment 2

For the overall period (d 0 to 74), increasing dietary NE increased (linear, $P < 0.01$; Table 11) final weight, ADG, and G:F but tended ($P = 0.11$) to decrease ADFI. Pigs fed the diet containing wheat middlings and soybean hulls tended ($P = 0.08$) to have better feed efficiency than those fed the diet containing 30% DDGS, wheat middlings, and soybean hulls; however, there were no differences ($P > 0.41$) in ADG and ADFI. Pigs fed the diet with wheat middlings, soybean hulls, and CWG had similar ($P > 0.14$) ADG, ADFI, and feed efficiency to those fed the corn-soybean meal diet.

The prediction equations overestimated ADG and G:F of pigs fed the diet containing 30% DDGS, wheat middlings, and soybean hulls by 3.2 and 6.1%, respectively; however, the predicted ADG and G:F of pigs fed with other diets were within the 95% confidence interval of the actual performance.

For carcass characteristics, carcass weight and carcass yield linearly increased ($P = 0.01$) with increasing dietary NE. In addition, backfat depth increased (linear, $P = 0.01$) and loin depth decreased (quadratic, $P = 0.05$) with increasing dietary NE, resulting in a reduction of percentage lean (linear, $P = 0.01$). Decreased (linear, $P = 0.01$) jowl IV was also observed with increasing dietary NE. Pigs fed the diet containing 30% DDGS, wheat middlings, and soybean hulls tended to have lower carcass weight ($P = 0.11$), carcass yield ($P = 0.01$), and backfat depth ($P = 0.06$) but had greater lean percentage

($P = 0.01$) and jowl IV ($P = 0.01$) than pigs fed the diet containing wheat middlings and soybean hulls; however, there was no difference ($P = 0.19$) in loin depth. Pigs fed the wheat middling, soybean hulls, and CWG diet had lower ($P = 0.02$) carcass yield and greater ($P = 0.01$) jowl IV than those fed the corn-soybean meal diet, but there were no differences in carcass weight, backfat depth, loin depth, and percentage lean.

No differences ($P = 0.35$) in NEE on a live weight basis were observed with increasing dietary NE and across diets. Nevertheless, feeding the diet containing 30% DDGS, wheat middlings, and soybean hulls resulted in poorer ($P = 0.05$) NEE on a carcass basis compared with feeding other diets.

Discussion

An improvement in ADG and feed efficiency with increasing dietary NE in Experiments 1 and 2 generally agree with the prediction equations derived from the meta-analysis (Nitikanchana et al., 2013[6]). These equations indicate a linear improvement in ADG and feed efficiency when dietary NE increases. Low feed intake was also observed with increasing dietary NE, indicating an adjustment of feed intake according to energy density to achieve a suitable amount of energy intake on a daily basis.

From the prediction equations, feeding diets with the same NE should result in similar ADG as long as the dietary SID Lys is adequate. This is based on the equations in which as long as pigs were fed adequate Lys, dietary NE was the only significant dietary predictor for growth rate. As predicted in both experiments, pigs fed the corn-soybean meal diet with added CWG had the best growth rate. Adding CWG to a diet with wheat middlings and soybean hulls to restore the dietary NE to those fed the corn-soybean meal diet resulted in a similar growth rate to feeding corn-soybean meal diet as predicted. This result was similar in both Experiments 1 and 2. However, pigs fed the diet containing 30% DDGS, wheat middlings, and soybean hulls had lower ADG than those fed the diet with wheat middlings and soybean hulls that had the same dietary NE in both experiments. Average daily gain was 4.5 and 3.2% lower than predicted in Experiment 1 and Experiment 2, respectively, whereas ADG of pigs fed the diet with wheat middlings and soybean hulls was similar to the predicted value in both experiments.

Dried distillers grains with solubles, wheat middlings, and soybean hulls are fibrous ingredients that when combined together resulted in higher fiber than other diets in the experiments. The bulkiness property of dietary fiber would increase mastication time and stimulate the mechanoreceptors in the gastrointestinal tract, which will promote meal termination, thus limiting the meal size (Leeuw et al., 2008[7]). Thus, when the fiber content of the diet is high enough, the pig may not be able to compensate for the increased eating time needed to consume the same amount of calories as with a high–energy density diet, leading to a lower growth rate. Nevertheless, the feed intake of pigs fed the diet containing 30% DDGS, wheat middlings, and soybean hulls was not negatively affected compared with feeding the diet with only wheat middlings and soybean hulls even though the dietary fiber content was greater when DDGS was also

[6] Nitikanchana et al., Swine Day 2013, Report of Progress 1092, pp. 236–245.

[7] Leeuw, J.A.D., J.E. Bolhuis, G. Bosch, and W.J.J. Gerrits. 2008. Effects of dietary fibre on behaviour and satiety in pigs. Proc. Nutr. Soc. 67:334–342.

included. Another effect of fiber to be considered is the increase in size and weight of gastro-intestinal tract. The proliferation of intestinal cells will result in a higher demand for energy to support the increase in protein turnover in the epithelial lining of the gut. Thus, energy requirements for maintenance are increased and a lower amount of energy from the diet is used for growth. This would explain the poorer ADG in pigs fed the diet containing 30% DDGS, wheat middlings, and soybean hulls compared with those fed the diet with only wheat middlings and soybean hulls and may also explain the over-estimation of the prediction equation. Another consideration would be that the NE of DDGS was overestimated. In this study, NE of DDGS was estimated to be 91 to 95% of NE of corn in diet formulation.

Little difference (0.25 to 2.2%) between observed and predicted feed efficiency was noted for all treatments except for pigs fed the diet containing 30% DDGS, wheat middlings, and soybean hulls. For the pigs fed the diet containing 30% DDGS, wheat middlings, and soybean hulls, feed efficiency was 6.1% lower than predicted in Experiments 1 and 2. The good agreement between determined and predicted feed efficiency from the prediction equation that accounts for fat content suggests that the value of adding fat to the diet is underestimated by NE calculations.

In the prediction equation for feed efficiency, both dietary NE and fat content were significant dietary predictors. Therefore, the equation predicted better feed efficiency for the wheat middlings and soybean hulls diet with CWG compared with the corn-soybean meal diet even though they had the same dietary NE content. Similarly, for pigs fed the 2 low-energy treatments, a better feed efficiency was predicted for pigs fed the diet containing 30% DDGS, wheat middlings, and soybean hulls due to the high dietary fat content.

The increased carcass yield, greater backfat depth, and decreased lean shown in this study are common observations when diets are increased in energy density (Stahly and Cromwell, 1979[8]). In the present study, the reduced dietary NE was associated with incorporating wheat middlings, soybean hulls, and DDGS in the diets. Addition of these high-fiber ingredients increases gut fill, thus reducing carcass yield, which has been observed in several studies (Asmus, 2012[9]), including the current results. The diet combination of DDGS, wheat middlings, and soybean hulls resulted in the lowest carcass yield compared with other diets, which also was the diet with the highest fiber content. Increasing dietary NE by adding CWG to the wheat middlings and soybean hulls diet or to the corn-soybean meal diet in this study did not improve carcass yield. Therefore, the increase in carcass yield with increasing dietary NE observed in the present study was driven mainly by the correlation with lower fiber content as dietary NE increased.

[8] Stahly, T.S., and G.L. Cromwell. 1979. Effect of environmental temperature and dietary fat supplementation on the performance and carcass characteristics of growing and finishing swine. J. Anim. Sci. 49:1478–1488.

[9] Asmus, M.D. 2012. Effects of dietary fiber on the growth performance, carcass characteristics, and carcass fat quality in growing-finishing pigs. M.S. Thesis. Kansas State Univ., Manhattan, KS.

The interaction between energy intake and protein deposition has been described as a linear-plateau (Campbell and Taverner, 1988[10]). The increase in energy intake results in greater protein deposition in a linear fashion until the maximum is reached, at which no further increase in protein deposition occurs. The addition of energy after the maximum point is then incorporated into body fat content. This relationship potentially describes the increase in backfat depth with increasing dietary NE, whereas no further improvements in loin depth were observed in our study.

In the current study, pigs fed the diet with wheat middlings and soybean hulls had jowl IV similar to those fed the corn-soybean meal diet. This finding disagreed with the results from Asmus (2012[7]) and Salyer et al. (2012[11]), who found an increase in jowl IV when 19 to 20% wheat middlings was added to the corn-soybean meal diet. Nevertheless, 4 to 5% soybean hulls were included in the diets with wheat middlings in our study, which may partly contribute to the difference in the responses. Adding CWG to the corn-soybean meal diet also resulted in a jowl IV similar to feeding a corn-soybean meal diet with or without wheat middlings and soybean hulls. However, when including CWG in the wheat middling and soybean hulls diet, jowl IV was significantly increased. A similar finding was also reported by Asmus (2012[9]), who found an increase in jowl IV when feeding wheat middlings and DDGS, where a greater response was observed when CWG was added in this diet. In addition, the increased jowl IV when including DDGS in diets in this study was consistent with other studies that documented higher unsaturated carcass fatty acids determined by IV value with increasing DDGS (Asmus, 2012[9]; Salyer et al., 2012[10]).

If the NE system truly valued the ingredient energy content correctly, the NEE should be constant among diets. In our study, NEE calculated on a live weight basis was not affected by dietary NE in either Experiment 1 or 2. The NEE on a live weight basis of the corn-soybean meal diet with wheat middlings and soybean hulls with and without CWG was slightly lower than the rest of diets in Experiment 1, but was similar in Experiment 2. This discrepancy might be due to the variation in the source of wheat middlings or soybean hulls between experiments that affected the energy content of these by-product ingredients. The NEE on a carcass basis was also similar across diets except for the diet containing 30% DDGS, wheat middlings, and soybean hulls that demonstrated a greater (poorer) value due to a lower carcass weight gain from a negative impact on carcass yield with feeding this diet. Thus, this result may suggest that NE value of DDGS used in this study was overestimated.

The similar NEE across experimental diets suggested that the assigned NE values of ingredients used in this study which were based on NRC (2012) values (except for DDGS) can be used to determine NE level in the diet. Nevertheless, a discrepancy remained when calculating NEE on carcass basis due to a negative impact of carcass yield in a high-fiber diet containing DDGS.

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[10] Campbell, R.G., and M.R. Taverner. 1986. The effects of dietary fiber, source of fat and dietary energy concentration on the voluntary food intake and performance of growing pigs. Anim. Prod. 43:327–333.
[11] Salyer, J.A., J.M. DeRouchey, M.D. Tokach, S.S. Dritz, R.D. Goodband, J.L. Nelssen, and D.B. Petry. 2012. Effects of dietary wheat middlings, distillers dried grains with solubles, and choice white grease on growth performance, carcass characteristics, and carcass fat quality of finishing pigs. J. Anim. Sci. 90:2620–2630.

In conclusion, the prediction equations provided a good estimation of growth rate and feed efficiency of growing-finishing pigs fed different levels of dietary NE except for the pigs fed the highest-fiber diet with DDGS, wheat middlings, and soy hulls. These predictions of growth performance can then be used to model economic value of different dietary energy strategies.

Table 1. Analyzed nutrient composition of dried distillers grains with solubles (as-fed basis)[1]

	Exp. 1		Exp. 2
Items	Phases 1 and 2	Phase 3	All phases
DM, %	90.3	90.0	90.1
CP, %	30.0	30.2	29.2
Crude fat, %	8.6	8.2	9.0
Calculated NE, kcal/kg[2]	2,490 (1,129)	2,444 (1,109)	2,536 (1,150)
Crude fiber, %	7.2	8.3	8.1
ADF, %	9.8	10.7	13.0
NDF, %	25.3	24.8	28.6
Ash, %	4.4	4.4	4.3

[1] Samples of dried distillers grains with solubles (DDGS) were analyzed for fat content prior to each feed manufacturing to determine the net energy content (NE) from the equation: NE (kcal/kg) = 115.011 × oil (%) + 1501.01 (Nitikanchana et al., 2013[3]).
[2] Values in parentheses are NE in kcal/lb.

Table 2. Composition of diets (Experiment 1, Phase 1; as-fed basis)[1]

NE level:	Low		Medium		High
Ingredient combinations:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG
Ingredient, %					
Corn	23.5	47.3	68.0	43.3	64.0
Soybean meal, (46.5% CP)	19.7	24.8	28.8	25.0	29.1
DDGS	30.0	---	---	---	---
Soybean hulls	4.3	5.0	---	5.0	---
Wheat middlings	20.0	20.0	---	20.0	---
CWG	---	---	---	3.7	3.7
Monocalcium P, (21% P)	---	0.55	0.88	0.55	0.88
Limestone	1.5	1.2	1.2	1.2	1.2
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.15	0.15	0.15	0.15	0.15
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
L-lysine HCl	0.38	0.36	0.33	0.36	0.33
DL-methionine	---	0.10	0.10	0.11	0.10
L-threonine	0.04	0.12	0.10	0.12	0.10
Total	100	100	100	100	100

continued

Table 2. Composition of diets (Experiment 1, Phase 1; as-fed basis)[1]

NE level:	Low		Medium		High
Ingredient combinations:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG
Calculated analysis					
Standardized ileal digestible (SID) amino acids, %					
Lysine	1.14	1.14	1.14	1.14	1.14
Isoleucine:lysine	67	59	62	59	61
Leucine:lysine	160	121	130	118	128
Methionine:lysine	30	32	32	32	32
Methionine & Cys:lysine	56	56	56	56	56
Threonine:lysine	61	61	61	61	61
Trptophan:lysine	18	18	18	18	18
Valine:lysine	79	67	68	66	67
Total lysine, %	1.37	1.29	1.28	1.29	1.28
NE, kcal/kg[3]	2,262	2,269	2,434	2,434	2,599
NE, kcal/lb	1,026	1,029	1,104	1,104	1,179
CP, %	24.3	19.9	19.8	19.7	19.6
Crude fiber,%	5.9	4.7	2.5	4.6	2.4
ADF, %	7.6	5.9	3.5	5.8	3.4
NDF, %	20.9	16.3	8.6	16.0	8.2
Crude fat, %	4.4	2.7	2.8	6.2	6.3
Ca, %	0.68	0.66	0.67	0.66	0.67
P, %	0.58	0.62	0.57	0.61	0.56
Available P, %	0.26	0.26	0.26	0.26	0.26

[1] Phase 1 experimental diets were fed from d 0 to 9 (106- to 126-lb BW).

[2] Dried distillers grains with solubles.

[3] All energy levels used to calculate dietary net energy (NE) were based on NRC (2012) values except DDGS, where the energy value was calculated from its oil content: NE (kcal/kg) = 115.011 × oil (%) + 1501.01 (Nitikanchana et al., 2013[3]).

Table 3. Composition of diets (Experiment 1, phase 2; as-fed basis)[1]

NE level:	Low		Medium		High
Ingredient combinations:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG
Ingredient, %					
Corn	29.7	53.5	74.3	49.3	70.3
Soybean meal, (46.5% CP)	13.8	18.8	22.8	19.3	23.1
DDGS	30.0	---	---	---	---
Soybean hulls	4.3	5.0	---	5.0	---
Wheat middlings	20.0	20.0	---	20.0	---
CWG	---	---	---	3.8	3.8
Monocalcium P (21%P)	---	0.48	0.78	0.48	0.78
Limestone	1.4	1.1	1.1	1.1	1.1
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.13	0.13	0.13	0.13	0.13
Trace mineral premix	0.13	0.13	0.13	0.13	0.13
L-lysine HCl	0.33	0.31	0.28	0.31	0.28
DL-methionine	---	0.06	0.05	0.07	0.06
L-threonine	0.02	0.09	0.07	0.09	0.08
Total	100	100	100	100	100

continued

Table 3. Composition of diets (Experiment 1, phase 2; as-fed basis)[1]

NE level:	Low		Medium		High
Ingredient combinations:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG
Calculated analysis					
Standardized ileal digestible (SID) amino acids, %					
Lysine	0.96	0.96	0.96	0.96	0.96
Isoleucine:lysine	69	60	63	60	63
Leucine:lysine	176	129	140	127	138
Methionine:lysine	32	31	31	31	31
Methionine & Cys:lysine	62	57	57	57	57
Threonine:lysine	62	62	62	61	62
Trptophan:lysine	18	18	18	18	18
Valine:lysine	84	69	70	69	70
Total lysine, %	1.17	1.10	1.08	1.10	1.08
NE, kcal/kg[3]	2,301	2,309	2,474	2,475	2,641
NE, kcal/lb	1,044	1,047	1,122	1,123	1,198
CP, %	21.9	17.5	17.4	17.3	17.2
Crude fiber,%	5.8	4.6	2.4	4.5	2.3
ADF, %	7.5	5.8	3.3	5.7	3.2
NDF, %	20.9	16.4	8.6	16.0	8.3
Crude fat, %	4.5	2.8	2.9	6.4	6.5
Ca, %	0.61	0.60	0.60	0.60	0.60
P, %	0.56	0.58	0.52	0.57	0.51
Available P, %	0.25	0.23	0.23	0.23	0.23

[1] Phase 2 experimental diets were fed from d 9 to 29 (126- to 168-lb BW).
[2] Dried distillers grains with solubles.
[3]All energy levels used to calculate dietary net energy (NE) were based on NRC (2012) values except DDGS, where the energy value was calculated from its oil content: NE (kcal/kg) = 115.011 × oil (%) + 1501.01 (Nitikanchana et al., 2013[3]).

Table 4. Composition of diets (Experiment 1, phase 3; as-fed basis)[1]

NE level:	Low		Medium		High
Ingredient combinations:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG
Ingredient, %					
Corn	33.1	57.0	77.8	52.8	73.8
Soybean meal, (46.5% CP)	10.6	15.7	19.7	16.1	20.0
DDGS	30.0	---	---	---	---
Soybean hulls	4.3	5.0	---	5.0	---
Wheat middlings	20.0	20.0	---	20.0	---
CWG	---	---	---	3.8	3.7
Monocalcium P, (21% P)	---	0.45	0.75	0.45	0.75
Limestone	1.2	1.0	0.9	1.0	0.9
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.10	0.10	0.10	0.10	0.10
Trace mineral premix	0.10	0.10	0.10	0.10	0.10
L-lysine HCl	0.28	0.26	0.23	0.25	0.23
DL-methionine	---	0.03	0.02	0.04	0.03
L-threonine	---	0.08	0.06	0.08	0.07
Total	100	100	100	100	100

continued

Table 4. Composition of diets (Experiment 1, phase 3; as-fed basis)[1]

NE level:	Low		Medium		High
Ingredient combinations:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG
Calculated analysis					
Standardized ileal digestible (SID) amino acids, %					
Lysine	0.84	0.84	0.84	0.84	0.84
Isoleucine:lysine	73	62	66	62	65
Leucine:lysine	193	139	152	136	149
Methionine:lysine	35	30	30	31	31
Methionine & Cys:lysine	67	59	58	59	58
Threonine:lysine	64	64	64	64	64
Trptophan:lysine	18.5	18.5	18.5	18.5	18.5
Valine:lysine	89	73	74	73	73
Total lysine, %	1.04	0.97	0.95	0.97	0.95
NE, kcal/kg[3]	2,312	2,333	2,498	2,498	2,664
NE, kcal/lb	1,049	1,058	1,133	1,133	1,208
CP, %	20.7	16.2	16.1	16.0	15.9
Crude fiber,%	6.1	4.6	2.3	4.5	2.2
ADF,%	7.7	5.7	3.3	5.6	3.2
NDF,%	20.8	16.4	8.7	16.1	8.4
Crude fat, %	4.5	2.9	3.0	6.4	6.5
Ca, %	0.53	0.53	0.53	0.53	0.53
P, %	0.54	0.56	0.50	0.55	0.49
Available P, %	0.25	0.22	0.22	0.22	0.22

[1] Phase 3 experimental diets were fed from d 29 to 53 (76- to 125-lb BW).
[2] Dried distillers grains with solubles.
[3] All energy levels used to calculate dietary net energy (NE) were based on NRC (2012) values except DDGS, where the energy value was calculated from its oil content: NE (kcal/kg) = 115.011 × oil (%) + 1501.01 (Nitikanchana et al., 2013[3]).

Table 5. Composition of diets (Experiment 2, phase 1; as-fed basis)[1]

NE level:	Low		Medium		High
Ingredient combinations:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG
Ingredient, %					
Corn	27.1	51.3	72.2	47.2	68.0
Soybean meal, (46.5% CP)	16.0	21.1	25.0	21.4	25.4
DDGS	30.0	---	---	---	---
Soybean hulls	4.7	5.0	---	5.0	---
Wheat middlings	20.0	20.0	---	20.0	---
CWG	---	---	---	3.7	3.8
Monocalcium	---	0.45	0.85	0.45	0.85
Limestone	1.4	1.2	1.1	1.2	1.1
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.13	0.13	0.13	0.13	0.13
Trace mineral premix	0.13	0.13	0.13	0.13	0.13
L-lysine HCl	0.31	0.29	0.27	0.29	0.26
DL-methionine	---	0.06	0.05	0.07	0.06
L-threonine	---	0.08	0.07	0.08	0.07
Total	100	100	100	100	100

continued

Table 5. Composition of diets (Experiment 2, phase 1; as-fed basis)[1]

NE level:	Low		Medium		High
Ingredient combinations:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG
Calculated analysis					
Standardized ileal digestible (SID) amino acids, %					
Lysine	1.00	1.00	1.00	1.00	1.00
Isoleucine:lysine	70	61	64	61	64
Leucine:lysine	174	129	140	127	138
Methionine:lysine	32	30	31	31	31
Methionine & Cys:lysine	61	56	56	56	56
Threonine:lysine	61	61	61	61	61
Trptophan:lysine	18.5	18.5	18.5	18.5	18.5
Valine:lysine	84	70	71	69	70
Total lysine, %	1.22	1.14	1.13	1.14	1.13
NE, kcal/kg[3]	2,295	2,295	2,460	2,460	2,625
NE, kcal/lb	1,041	1,041	1,116	1,116	1,191
CP, %	22.6	18.3	18.2	18.1	18.1
Crude fiber,%	6.3	4.7	2.4	4.6	2.3
ADF,%	8.7	5.9	3.4	5.8	3.3
NDF,%	22.1	16.4	8.6	16.0	8.3
Crude fat, %	4.6	2.8	2.9	6.3	6.4
Ca, %	0.62	0.62	0.62	0.62	0.62
P, %	0.57	0.58	0.55	0.57	0.54
Available P, %	0.26	0.23	0.25	0.23	0.25

[1] Phase 1 experimental diets were fed from d 0 to 21 (125- to 170-lb BW).
[2] Dried distillers grains with solubles.
[3] All energy levels used to calculate dietary net energy (NE) were based on NRC (2012) values except DDGS, where the energy value was calculated from its oil content: NE (kcal/kg) = 115.011 × oil (%) + 1501.01 (Nitikanchana et al., 2013[3]).

Table 6. Composition of diets (Experiment 2, phase 2; as-fed basis)[1]

NE level:	Low		Medium		High
Ingredient combinations:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG
Ingredient, %					
Corn	32.7	57.0	77.7	52.8	73.7
Soybean meal, (46.5% CP)	10.6	15.7	19.7	16.1	20.0
DDGS	30.0	---	---	---	---
Soybean hulls	4.7	5.0	---	5.0	---
Wheat middlings	20.0	20.0	---	20.0	---
CWG	---	---	---	3.7	3.7
Monocalcium P, (21% P)	---	0.40	0.80	0.40	0.80
Limestone	1.2	1.0	0.9	1.0	0.9
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.10	0.10	0.10	0.10	0.10
Trace mineral premix	0.10	0.10	0.10	0.10	0.10
L-lysine HCl	0.28	0.26	0.23	0.25	0.23
DL-methionine	---	0.03	0.02	0.04	0.03
L-threonine	---	0.08	0.06	0.08	0.07
Total	100	100	100	100	100

continued

Table 6. Composition of diets (Experiment 2, phase 2; as-fed basis)[1]

NE level:	Low		Medium		High
Ingredient combinations:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG
Calculated analysis					
Standardized ileal digestible (SID) amino acids, %					
Lysine	0.84	0.84	0.84	0.84	0.84
Isoleucine:lysine	73	62	66	62	65
Leucine:lysine	193	139	152	136	149
Methionine:lysine	35	30	30	30	31
Methionine & Cystine:lysine	67	58	58	58	58
Threonine:lysine	64	64	64	64	64
Trptophan:lysine	18.5	18.5	18.5	18.5	18.5
Valine:lysine	89	73	74	73	73
Total Lysine, %	1.04	0.97	0.95	0.97	0.95
NE, kcal/kg[3]	2,332	2,332	2,496	2,496	2,661
NE, kcal/lb	1,058	1,058	1,132	1,132	1,207
CP, %	20.4	16.2	16.1	16.0	15.9
Crude fiber, %	6.2	4.6	2.3	4.5	2.2
ADF, %	8.5	5.7	3.3	5.6	3.2
NDF, %	22.2	16.4	8.7	16.1	8.4
Crude fat, %	4.7	2.9	3.0	6.4	6.5
Ca, %	0.55	0.55	0.55	0.55	0.55
P, %	0.54	0.55	0.51	0.54	0.51
Available P, %	0.25	0.21	0.23	0.21	0.23

[1] Phase 2 experimental diets were fed from d 21 to 44 (170- to 216-lb BW).
[2] Dried distillers grains with solubles.
[3] All energy levels used to calculate dietary net energy (NE) were based on NRC (2012) values except DDGS, where the energy value was calculated from its oil content: NE (kcal/kg) = 115.011 × oil (%) + 1501.01 (Nitikanchana et al., 2013[3]).

Table 7. Composition of diets (Experiment 2, phase 3; as-fed basis)[1]

NE level:	Low		Medium		High
Ingredient combinations:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG
Ingredient, %					
Corn	36.2	60.5	81.3	56.5	77.3
Soybean meal, (46.5% CP)	7.3	12.4	16.2	12.7	16.5
DDGS	30.0	---	---	---	---
Soybean hulls	4.7	5.0	---	5.0	---
Wheat middlings	20.0	20.0	---	20.0	---
CWG	---	---	---	3.7	3.7
Monocalcium P, (21% P)	---	0.43	0.85	0.43	0.85
Limestone	1.1	0.9	0.8	0.9	0.8
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.08	0.08	0.08	0.08	0.08
Trace mineral premix	0.08	0.08	0.08	0.08	0.08
L-lysine HCl	0.25	0.23	0.21	0.23	0.21
DL-methionine	---	0.02	0.02	0.02	0.02
L-threonine	---	0.09	0.07	0.09	0.07
Total	100	100	100	100	100

continued

Table 7. Composition of diets (Experiment 2, phase 3; as-fed basis)[1]

NE level:	Low		Medium		High
Ingredient combinations:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG
Calculated analysis					
Standardized ileal digestible (SID) amino acids, %					
Lysine	0.74	0.74	0.74	0.74	0.74
Isoleucine:lysine	75	63	67	63	67
Leucine:lysine	208	147	162	144	158
Methionine:lysine	38	31	31	30	31
Methionine & Cys:lysine	73	61	61	60	60
Threonine:lysine	67	68	67	67	67
Tryptophan:lysine	18.5	18.5	18.5	18.5	18.4
Valine:lysine	94	76	77	75	76
Total lysine, %	0.93	0.86	0.85	0.86	0.84
NE, kcal/kg[3]	2,355	2,355	2,519	2,519	2,684
NE, kcal/lb	1,068	1,068	1,143	1,143	1,217
CP, %	19.1	14.9	14.7	14.7	14.5
Crude fiber, %	6.1	4.5	2.2	4.4	2.2
ADF, %	8.5	5.7	3.2	5.6	3.1
NDF, %	22.2	16.5	8.7	16.1	8.4
Crude fat, %	4.8	3.0	3.1	6.4	6.6
Ca, %	0.50	0.50	0.50	0.50	0.50
P, %	0.53	0.54	0.51	0.53	0.50
Available P, %	0.24	0.21	0.24	0.21	0.24

[1] Phase 3 experimental diets were fed from d 44 to 74 (216- to 273-lb BW).
[2] Dried distillers grains with solubles.
[3] All energy levels used to calculate dietary net energy (NE) were based on NRC (2012) values except DDGS, where the energy value was calculated from its oil content: NE (kcal/kg) = 115.011 × oil (%) + 1501.01 (Nitikanchana et al., 2013[3]).

Table 8. Analyzed nutrient composition of experimental 1 diets (as-fed basis)[1]

NE level:	Low		Medium		High
Ingredient combinations:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG
Phase 1					
DM	89.8	89.8	89.7	90.1	89.9
CP	23.7	23.0	19.9	20.2	19.1
Crude fat	4.4	3.8	2.9	5.6	5.8
Crude fiber	5.6	3.8	1.5	4.4	1.9
ADF	9.1	6.2	4.5	6.4	4.1
NDF	20.5	13.1	9.2	14.0	7.3
Ash	6.0	5.4	5.2	5.3	5.0
Phase 2					
DM	90.4	89.6	89.2	90.0	89.7
CP	23.5	18.1	17.4	18.1	17.0
Crude fat	4.7	2.8	3.0	5.0	5.4
Crude fiber	5.3	3.9	1.6	4.3	1.9
ADF	10.1	6.1	1.8	7.4	2.1
NDF	19.2	13.1	6.7	13.5	6.5
Ash	5.7	5.3	4.9	5.2	4.6
Phase 3					
DM	90.5	89.7	89.7	90.1	90.0
CP	21.1	16.5	17.3	17.4	17.4
Crude fat	4.9	3.0	2.7	5.2	4.5
Crude fiber	5.7	4.4	2.3	4.5	2.2
ADF	7.4	5.3	3.0	5.3	2.5
NDF	19.5	14.9	8.6	14.1	8.3
Ash	5.3	5.0	4.4	5.2	4.5

[1] Diet samples were collected from feeders during phase and stored at -20°C, then the proximate analysis was conducted on composite samples (Ward Laboratories, Inc., Kearney NE). Diets were fed in 3 phases from 106 to 126, 126 to 168, and 168 to 216 lb.
[2] Dried distillers grains with solubles.

Table 9. Analyzed nutrient composition of experimental 2 diets (as-fed basis)[1]

NE level:	Low		Medium		High
Ingredient combinations:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG
Phase 1					
DM	89.6	88.6	88.7	89.5	89.1
CP	22.8	18.4	17.6	18.6	18.4
Crude fat	3.6	2.2	2.3	5.5	5.4
Crude fiber	5.2	4.2	1.7	4.6	2.1
ADF	7.0	5.3	2.1	5.2	2.4
NDF	17.3	13.4	6.3	13.3	5.5
Ash	5.9	5.1	4.7	5.2	4.8
Phase 2					
DM	89.8	89.2	88.9	89.5	88.9
CP	20.5	16.8	16.5	16.3	16.1
Crude fat	4.3	2.8	2.6	5.8	5.7
Crude fiber	5.7	3.9	2.0	4.7	2.3
ADF	7.1	5.0	2.3	5.5	2.2
NDF	17.6	12.8	6.7	14.4	6.5
Ash	5.3	4.9	4.1	4.4	4.1
Phase 3					
DM	90.2	89.5	89.3	89.9	87.7
CP	19.7	15.4	15.7	15.6	16.4
Crude fat	4.4	3.4	2.7	6.2	5.5
Crude fiber	5.9	4.4	2.1	5.5	2.4
ADF	7.7	5.2	1.9	6.5	2.7
NDF	17.7	15.4	7.0	16.1	7.0
Ash	5.1	4.6	2.7	4.4	3.7

[1] Diet samples were collected from feeders during phase and stored at -20°C, then the proximate analysis was conducted on composite samples (Ward Laboratories, Inc., Kearney NE). Diets were fed in 3 phases from 125 to 170, 170 to 216, and 216 to 273 lb.
[2] Dried distillers grains with solubles.

Table 10. Effects of feeding different dietary net energy (NE) levels to growing-finishing pigs when dietary lysine is adequate (Experiment 1)[1]

NE level:	Low		Medium		High		Probability, $P <$		
								NE level	
Ingredient combinations[2]:	DDGS,[2] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG	SEM	TRT	Linear	Quad
Initial BW, lb	106.0	106.0	106.0	105.8	106.0	1.81	1.00	0.99	0.99
Final BW, lb	210.5^{a}	216.3^{ab}	217.4^{b}	218.9^{b}	220.7^{b}	2.67	0.11	0.04	0.65
Overall period									
ADG, lb	1.97^{a}	2.08^{b}	2.10^{cb}	2.13^{cb}	2.16^{c}	0.025	0.01	0.01	0.34
95% CI[4] of ADG	1.92–2.02	2.03–2.13	2.05–2.16	2.08–2.18	2.11–2.22	---	---	---	---
ADFI, lb	5.51^{b}	5.49^{b}	5.44^{b}	5.34^{ab}	5.20^{a}	0.067	0.02	0.01	0.53
F/G (G:F)[5]	2.79 (0.358^{a})	2.63 (0.380^{bf})	2.58 (0.387^{df})	2.51 (0.399^{c})	2.40 (0.416^{e})	0.004	0.01	0.01	0.91
95% CI of F/G	2.73–2.86	2.58–2.70	2.53–2.65	2.46–2.56	2.36–2.45	---	---	---	---
Predicted performance[6]									
ADG, lb	2.06	2.06	2.10	2.10	2.15	---	---	---	---
F/G	2.63	2.69	2.58	2.51	2.43	---	---	---	---
Live wt NEE[7], Mcal/lb	2.92^{a}	2.77^{b}	2.91^{ac}	2.82^{bc}	2.84^{ac}	0.03	0.01	0.26	0.97

[1] A total of 273 pigs (PIC 1050 × 327; initially 106.0 lb BW) were used in a 53-d growing-finishing trial with 8 pigs per pen and 6 to 7 pens per treatment.

[2] The dietary treatments included 3 different levels of dietary NE by adding low-energy ingredients (wheat middlings or soybean hulls), 30% dried distillers grains with solubles, or choice white grease to a corn-soybean meal–based diet. The difference of dietary NE content between high vs. medium and medium vs. low energy was 75 kcal/lb (166 kcal/kg) across all phases of feeding.

[3] Dried distillers grains with solubles.

[4] 95% confidence interval.

[5] Values in parentheses are gain:feed. Statistics were done on a gain:feed basis.

[6] The prediction equations used were [ADG (g/day) = 0.1135 × NE (kcal/kg) + 8.8142 × Average BW (kg) – 0.05068 × Average BW (kg) × Average BW (kg) + 275.99; G:F = 0.000096 × NE (kcal/kg) – 0.0025 × Average BW (kg) + 0.003071 × fat (%) + 0.3257] were used to calculate predicted ADG and G:F. The difference between predicted and actual growth performance of pigs fed corn-soybean meal diet was used to adjust the intercept of the prediction equations thus adjusting the growth performance of the other pens fed the other diets.

[7] Net energy caloric efficiencies (NEE) were calculated on a pen basis by multiplying total feed intake by the dietary NE concentration and dividing by total live or carcass weight gain. The carcass weight gain was obtained from subtracting HCW with the initial carcass weight by assuming 75% carcass yield across diet.

[abcdef] Within a row, means without a common superscript differ ($P \leq 0.05$).

Table 11. Effects of feeding different dietary net energy (NE) levels to growing-finishing pigs when dietary lysine is adequate (Experiment 2)[1]

NE level:	Low		Medium		High		Probability, $P <$		
								NE level	
Ingredient combinations[2]:	DDGS,[3] wheat middlings, soybean hull	Wheat middlings, soybean hull	Corn-soybean meal	Wheat middlings, soybean hull, choice white grease (CWG)	Corn-soybean meal, CWG	SEM	TRT	Linear	Quad
Initial BW, lb	125.2	125.2	125.2	125.2	125.2	2.16	1.00	0.99	1.00
Final BW, lb	268.5[a]	271.6[a]	275.8[ab]	273.1[a]	282.9[b]	2.82	0.02	0.01	0.46
Overall period									
ADG, lb	1.94[a]	1.96[ab]	2.03[b]	2.00[ab]	2.12[c]	0.027	0.01	0.01	0.43
95% CI[4] of ADG	1.88–1.99	1.90–2.02	1.97–2.09	1.94–2.05	2.0 –2.18	---	---	---	---
ADFI, lb	5.88[a]	5.78[ab]	5.74[ab]	5.54[b]	5.65[ab]	0.090	0.11	0.11	0.25
F/G (G:F)[5]	3.03 (0.330[a])	2.95 (0.339[a])	2.82 (0.355[b])	2.78 (0.360[b])	2.66 (0.376[c])	0.004	0.01	0.01	0.58
95% CI of F/G	2.96–3.12	2.87–3.02	2.75–2.90	2.7 –2.84	2.60–2.72	---	---	---	---
Predicted performance[6]									
ADG, lb	2.00	1.99	2.03	2.04	2.07	---	---	---	---
F/G	2.86	2.94	2.82	2.72	2.66	---	---	---	---
Carcass wt, lb	192.9[a]	197.8[ab]	202.2[bc]	198.9[b]	207.7[c]	2.05	0.01	0.01	0.62
Yield, %	72.4[a]	73.4[bd]	74.0[dc]	73.2[b]	74.3[c]	0.22	0.01	0.01	0.90
Backfat[7], in.	0.60[a]	0.65[b]	0.70[c]	0.67[bc]	0.76[d]	0.017	0.01	0.01	0.73
Loin depth, in.	2.45[ab]	2.41[ab]	2.46[a]	2.43[ab]	2.39[b]	0.02	0.13	0.18	0.05
Lean, %	55.0[a]	54.2[b]	54.0[b]	54.1[b]	53.1[c]	0.18	0.01	0.01	0.20
Jowl IV	74.3[c]	70.1[a]	69.6[a]	71.6[b]	70.4[a]	0.42	0.01	0.01	0.08
Live wt NEE[8], Mcal/lb	3.22	3.12	3.19	3.15	3.21	0.04	0.35	0.36	0.60
Carcass NEE, Mcal/lb	4.66[a]	4.36[b]	4.44[b]	4.43[b]	4.44[b]	0.07	0.05	0.43	0.52

[abcd]Within a row, means without a common superscript differ ($P \leq 0.05$).

[1] A total of 271 pigs (PIC 1050 × 327; initially 125.2 lb BW) were used in a 74-d growing-finishing trial with 7 to 8 pigs per pen and 6 to 7 pens per treatment.

[2] The dietary treatments included 3 different levels of dietary NE by adding low-energy ingredients (wheat middlings or soybean hulls), 30% dried distillers grains with solubles, or choice white grease to a corn-soybean meal base diet. The difference of dietary NE content between high vs. medium and medium vs. low energy was 75 kcal/lb (166 kcal/kg) across all phases of feeding.

[3] Dried distillers grains with solubles.

[4] 95% confidence interval.

[5] Values in parentheses are gain:feed. Statistics were done on a gain:feed basis.

[6] The prediction equations from the meta-analysis [ADG (g/day) = 0.1135 × NE (kcal/kg) + 8.8142 × Average BW (kg) – 0.05068 × Average BW (kg) × Average BW (kg) + 275.99; G:F = 0.000096 × NE (kcal/kg) – 0.0025 × Average BW (kg) + 0.003071 × fat (%) + 0.3257] were used to calculate predicted ADG and G:F. The difference between predicted and actual growth performance of pigs fed corn-soybean meal diet was used to adjust the intercept of the prediction equations thus adjusting the growth performance of the other pens fed the other diets.

[7] Backfat, loin depth, and lean percentage were adjusted to a common HCW.

[8] Net energy caloric efficiencies (NEE) were calculated on a pen basis by multiplying total feed intake by the dietary NE concentration and dividing by total live or carcass weight gain. The carcass weight gain was obtained from subtracting HCW with the initial carcass weight by assuming 75% carcass yield across diet.