Effects of Increasing Wheat Middlings and Net Energy Formulation on Nursery Pig Growth Performance

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Summary
A total of 210 pigs (PIC 327 × 1050, initially 15.15 lb) were used in a 29-d trial to evaluate the effects of dietary wheat middlings and NE formulation on nursery pig growth performance. Pens of pigs were balanced by initial BW and randomly allotted to 1 of 5 dietary treatments with 6 replications per treatment. The 5 corn-soybean meal–based diets were: (1) corn-soybean meal (positive control), (2) 10% added midds, (3) 20% added midds, (4) Treatment 2 with 1.4% added soybean oil, and (5) Treatment 3 with 2.8% added soybean oil. Treatments 4 and 5 were balanced on an NE basis equal to that of the positive control. Feed ingredients were assigned NE values for the growing pig by INRA (2004[2]). Treatment diets were fed in a 2-phase feeding program from d 0 to 12 and 12 to 29.

From d 0 to 12, a midds × fat interaction was observed ($P < 0.01$) for ADFI. This was the result of pigs fed increasing midds having increased feed intake with no added fat but decreased intake when increasing fat was combined with increasing midds. From d 12 to 29, no midds × fat interactions were observed. For the main effects of midds (regardless of NE), there was a tendency for decreased ($P < 0.09$) ADG and poorer ($P < 0.001$) F/G. Feed efficiency was similar among pigs fed either 0 or 10% wheat midds, but decreased (quadratic, $P < 0.03$) when midds increased to 20% of the diet; however, balancing on a NE basis tended to increase ($P < 0.09$) ADG compared with not balancing for NE when midds were added.

Overall (d 0 to 29), no midds × fat interactions were observed. Pigs fed increasing midds exhibited a tendency toward poorer (linear, $P < 0.06$) F/G and energetic efficiency when expressed on an ME basis (kcal ME/lb gain), but when balanced on NE, increasing midds had no effect on pig performance. Caloric efficiency and F/G were also poorer ($P < 0.01$) on an ME basis as midds were included in the diets regardless of formulated energy value, but no differences were observed for energetic efficiency on an NE basis (kcal NE/lb gain). This result suggests that the ME values slightly overestimated the energy value of the soybean oil or midds added to the diet and that the NE values provided by IRNA (2004) are a closer approximation of the true energetic value of the feed ingredients, because balancing diets on an NE basis had no effect ($P > 0.16$). For overall economics, feed cost/pig increased ($P < 0.01$) as expected with the NE formulation due to the added soy oil, and increasing midds and balanc-

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[2] INRA (Institut National de la Recherche Agronomique). 2004. Tables of composition and nutritional value of feed materials, Sauvant, D., J-M. Perez and G. Tran, Eds. Wageningen Academic Publishers, The Netherlands and INRA, Paris, France.

ing for NE increased feed cost/lb gain (linear, $P < 0.05$). The main effect of midds level decreased (linear, $P < 0.02$) income over feed cost (IOFC); however, the highest numerical IOFC occurred at both 10% inclusion levels with and without balancing for NE.

In summary, 10% midds can be added to nursery diets without influencing performance. Formulating on an equal NE basis did not improve growth over those pigs fed on a ME basis; however, energetic efficiency values indicate that NE may value the energy content in midds more appropriately.

Key words: ME, NE, nursery pig, wheat middlings

Introduction

Wheat middlings, a by-product of wheat milling, are a common high-fiber ingredient (crude fiber [CF] <9.5%) used in swine diets. Our past research has shown that approximately 10% midds can be fed to nursery pigs without negatively affecting performance. We also found that when calculating caloric efficiencies for diets containing wheat middlings, the NE values provided by INRA (2004) are more accurate in predicting the true energetic value of the diets.[3] This was shown by consistently similar caloric efficiencies regardless of inclusion rate of midds compared with caloric efficiencies derived from ME values, which regularly overestimated the value of midds.

Although research has been conducted with wheat middlings and their effects on nursery pig growth performance when formulated on an ME basis, little is known how performance will be affected when formulated on an equal NE basis. The objective of this study was to determine the effects of increasing dietary midds and equalizing diet NE on growth performance, caloric efficiency, and economics of nursery pigs from 15 to 50 lb.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at the K-State Swine Teaching and Research Center in Manhattan, KS.

A total of 210 pigs (PIC 327 × 1050, initially 15.5 lb and 26 d of age) were used in a 29-d growth trial. Pigs were allotted to pens by initial BW, and pens were assigned to treatments in a completely randomized design with 7 pigs per pen and 6 replications per treatment. The 5 corn-soybean meal–based diets were: (1) corn-soybean meal diet (positive control); 2) 10% added midds; 3) 20% added midds; 4) Treatment 2 with 1.4% added soybean oil, and 5) Treatment 3 with 2.8% added soybean oil (Table 1). Treatments 4 and 5 were balanced on an NE basis equal to that of the positive control. Feed ingredients were assigned an NE value for the growing pig by INRA (2004). Pigs were fed in a 2-phase feeding program from d 0 to 12 and 12 to 29. All diets were fed in meal form and were prepared at the K-State Animal Science Feed Mill.

[3] De Jong, J. A., J. M. DeRouchey, M. D. Tokach, R. D. Goodband, S. S. Dritz, and J. L. Nelssen. 2012. Effects of increasing dietary wheat middlings and corn dried distillers grains with solubles in diets for 7- to 23-kg nursery pigs. J. Anim. Sci. 90(Suppl. 2):168 (Abstr.).

Each pen contained a 4-hole, dry self-feeder and a nipple waterer to provide ad libitum access to feed and water. Pens had wire-mesh floors and were allowed approximately 3 ft^2/pig. Pig weight and feed disappearance were measured on d 0, 7, 12, 19, 26, and 29 of the trial to determine ADG, ADFI, and F/G.

Wheat midds and complete diet samples were collected and submitted to Ward Laboratories, Inc. (Kearney, NE) for analysis of DM, CP, ADF, NDF, NFE, CF, fat, ash, Ca, and P (Tables 2 and 3). Bulk density of the midds and complete diets were also determined. Caloric efficiencies of pigs were determined on both an ME and NE (INRA, 2004[4]) basis. Efficiencies were calculated by multiplying total feed intake by energy in the diet (kcal/lb) and dividing by total gain. Lastly, feed cost/pig, feed cost/lb gain, revenue/pig, and IOFC were also calculated. Diet costs were determined with the following ingredient costs: corn = 0.14/lb; soybean meal = 0.24/lb; midds = 0.12; soybean oil = .61. Feed cost/pig was determined by total feed intake × cost/lb feed. Feed cost/lb gain was calculated using F/G × feed cost/lb. Revenue/pig was determined by total gain × \$0.65/lb live gain, and IOFC was calculated using revenue/pig – feed cost/pig.

Data were analyzed as a completely randomized design using the PROC MIXED procedure of SAS (SAS Institute, Inc., Cary, NC), with pen as the experimental unit. Contrasts were used to compare midds × fat interactions and linear and quadratic effects of increasing midds (with and without added fat). Contrasts used in analysis examined: (1) midds × balanced NE interaction; (2) midds linear combines Treatments 2 and 4 and 3 and 5 to create a 0, 10, 20 linear contrast; (3) midds quadratic combines Treatments 2 and 4 and 3 and 5 to create a 0, 10, 20 quadratic contrast; (4) midds level contrasts the main effect of midds in diets regardless of fat inclusion (compares Treatments 2 and 4 to 3 and 5; (5) balanced NE effect contrasts the main effect of balancing diets on NE (compares Treatments 2 and 3 to 4 and 5). Results were considered significant at $P \leq 0.05$ and a trend at $P \leq 0.10$.

Results and Discussion

The chemical analysis of the midds (Table 2) indicated that CP and fat levels were slightly below formulated values with CF, Ca, and P all slightly above the formulated values. The analysis of complete diets (Table 3) also showed the expected increases in fiber as midds increased. Bulk density was dramatically influenced by diet formulation, with low density as midds were increased but high density when soybean oil was added.

From d 0 to 12, a midds × fat interaction was observed ($P < 0.01$) for ADFI. This was the result of pigs fed increasing midds having increased feed intake with no added fat but decreased intake when increasing fat was combined with increasing midds. From d 12 to 29, no midds × fat interactions were observed. The main effects of midds (regardless of NE), showed a tendency for decreased ($P < 0.09$) ADG and poorer ($P < 0.001$) F/G. Feed efficiency was similar among pigs fed either 0 or 10% wheat midds but decreased (quadratic, $P < 0.03$) when midds increased to 20% of the diet; however, balancing on a NE basis tended to increase ($P < 0.09$) ADG compared with not balancing for NE when midds were added.

[4] INRA (Institut National de la Recherche Agronomique). 2004. Tables of composition and nutritional value of feed materials, Sauvant, D., J-M. Perez and G. Tran, eds. Wageningen Academic Publishers, The Netherlands and INRA, Paris, France.

Overall (d 0 to 29), no midds × fat interactions were observed. Pigs fed increasing midds had a tendency for poorer (linear, $P < 0.06$) F/G and energetic efficiency when expressed on an ME basis (kcal ME/lb gain), but when balanced on NE, increasing midds had no effect on pig performance. Poorer ($P < 0.01$) F/G and caloric efficiency on an ME basis were also found as midds were included in the diets regardless of formulated energy value, but no differences were observed for energetic efficiency on an NE basis (kcal NE/lb gain). This result suggests that the ME values slightly overestimated the energy value of the soybean oil or midds added to the diet, and the NE values provided by IRNA (2004) are a closer approximation of the true energetic value of the feed ingredients, because balancing diets on an NE basis had no effect ($P > 0.16$).

For overall economics, feed cost/pig increased ($P < 0.01$) as expected with the NE formulation due to the added soy oil. Increasing midds and balancing for NE also increased feed cost/lb gain (linear, $P < 0.05$). The main effect of midds decreased (linear, $P < 0.02$) IOFC; however, the highest numerical IOFC occurred at both 10% inclusion levels with and without balancing for NE.

In summary, adding 10% midds to diets for nursery pigs did not affect performance. Formulating on an equal NE basis did not significantly improve growth over those pigs fed on an ME basis. This result is supported by caloric efficiencies tending to worsen when calculated using ME, suggesting that ME values overestimate the value of midds. When calculated on an NE basis, caloric efficiency did not differ with the addition of midds. We should note that although the INRA (2004) NE values are a more accurate energetic value of midds, the actual NE value may change depending on the amount of midds added to the diet, and perhaps the energetic value of midds changes in correlation with its inclusion level in swine diets.

Although using dietary midds reduces performance as expected due to the reduction in diet energy, performance can be restored by formulating on an equal NE basis with the addition of added fat; however, this restored performance increased ($P < 0.01$) feed cost/pig. The economic analysis also showed a decrease (linear, $P < 0.04$) in IOFC as increasing midds were added to the diet, which was primarily due to reduced IOFC ($P < 0.01$) for pigs fed 20% vs.10% midds. The highest numerical IOFC was observed when 10% midds were included in the diet without balancing for NE and the lowest was at 20% midds inclusion; yet, the highest numerical revenue/pig was observed at 10% inclusion of midds with added fat to balance for NE. Notably, soybean oil was used to balance for NE in this experiment, but less expensive fat sources such as choice white grease are available and may influence the economics of balancing on an NE basis. Thus, production and economic goals will determine formulation strategies when using wheat midds in nursery pig diets.

Table 1. Composition of experimental diets (as-fed basis)[1]

	Phase 1					Phase 2				
Wheat middlings, %:	0	10	20	10	20	0	10	20	10	20
Item Fat, %:	0	0	0	1.40	2.80	0	0	0	1.40	2.80
Ingredient, %										
Corn	54.77	47.25	39.73	45.75	36.72	63.74	56.22	48.71	54.72	45.69
Soybean meal (46.5% CP)	29.32	26.86	24.40	26.97	24.62	32.79	30.33	27.87	30.44	28.09
Wheat middlings	---	10.00	20.00	10.00	20.00	---	10.00	20.00	10.00	20.00
Select menhaden fish meal	3.00	3.00	3.00	3.00	3.00	---	---	---	---	---
Spray-dried whey	10.00	10.00	10.00	10.00	10.00	---	---	---	---	---
Soybean oil	---	---	---	1.40	2.80	---	---	---	1.40	2.80
Monocalcium phosphate (21% P)	0.65	0.50	0.35	0.50	0.35	1.05	0.90	0.75	0.90	0.75
Limestone	0.88	0.95	1.03	0.95	1.03	0.95	1.03	1.10	1.03	1.10
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
L-lysine HCl	0.25	0.29	0.33	0.29	0.33	0.33	0.37	0.41	0.37	0.41
DL-methionine	0.130	0.130	0.130	0.130	0.130	0.135	0.135	0.135	0.135	0.135
L-threonine	0.125	0.140	0.155	0.140	0.155	0.125	0.140	0.155	0.140	0.155
Phytase[2]	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Total	100	100	100	100	100	100	100	100	100	100

continued

Table 1. Composition of experimental diets (as-fed basis)[1]

	Phase 1					Phase 2				
Wheat middlings, %:	0	10	20	10	20	0	10	20	10	20
Item Fat, %:	0	0	0	1.40	2.80	0	0	0	1.40	2.80
Standard ileal digestible (SID) amino acids, %										
Lysine	1.32	1.32	1.32	1.32	1.32	1.28	1.28	1.28	1.28	1.28
Isoleucine:lysine	62	61	60	61	59	61	60	59	60	59
Methionine:lysine	34	34	34	34	34	34	33	33	33	33
Met & Cys:lysine	58	58	58	58	58	58	58	58	58	58
Threonine:lysine	65	65	65	65	65	63	63	63	63	63
Tryptophan:lysine	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Valine:lysine	68	68	67	68	67	68	67	67	67	66
Total lysine, %	1.46	1.45	1.45	1.45	1.45	1.42	1.41	1.40	1.41	1.40
ME, kcal/lb[1]	1,500	1,484	1,468	1,515	1,531	1,504	1,487	1,471	1,519	1,534
NE, kcal/lb[2]	1,091	1,063	1,035	1,091	1,091	1,073	1,045	1,017	1,073	1,073
SID lysine:ME, g/Mcal	3.99	4.04	4.08	3.95	3.91	3.86	3.90	3.95	3.82	3.78
CP, %	21.8	21.6	21.5	21.6	21.4	21.2	21.0	20.9	20.9	20.7
Ca, %	0.80	0.80	0.80	0.80	0.80	0.69	0.69	0.69	0.69	0.69
P, %	0.66	0.68	0.70	0.68	0.70	0.63	0.65	0.67	0.65	0.67
Available P, %	0.36	0.36	0.36	0.36	0.36	0.30	0.30	0.30	0.30	0.30

[1]Phase 1 diets fed from d 0 to 12 and Phase 2 was fed from d 13 to 29 of the experimental period.

[2] Phyzyme 600 (Danisco Animal Nutrition, St. Louis, MO) provided 340.5 phytase units (FTU)/lb, with a release of 0.12% available P.

Table 2. Chemical analysis of wheat middlings (as-fed basis)[1]

Item	Analyzed[2]
DM, %	89.38
CP, %	15.30 (15.90)
ADF, %	12.30
NDF, %	35.30
NFE, %[3]	56.10
Crude fiber, %	8.20 (7.00)
Ca, %	0.33 (0.12)
P, %	1.15 (0.93)
Fat, %	3.70 (4.20)
Ash, %	6.08
Particle size, µ	574
Bulk density, lb/bu	23.66

[1] Wheat middlings were from the same batch for both phases of the trial.
[2] Values in parentheses indicate those used in diet formulation.
[3] NFE: nitrogen-free extract.

Table 3. Chemical analysis of diets containing wheat middlings (as-fed basis)[1]

	Phase 1					Phase 2				
Wheat middlings, %	0	10	20	10	20	0	10	20	10	20
Item Fat, %	0	0	0	1.4	2.8	0	0	0	1.4	2.8
DM, %	90.31	89.52	90.07	90.14	90.56	89.91	89.68	89.55	89.69	90.63
CP, %	21.8	22.0	21.2	22.0	21.8	21.5	22.3	21.7	21.6	20.8
ADF, %	4.1	4.1	4.2	3.7	3.3	2.8	4.4	5.1	4.1	4.9
NDF, %	8.0	8.9	10.0	8.5	9.6	9.0	13.2	13.5	10.0	13.0
Crude fiber, %	2.4	2.5	2.9	2.4	2.8	2.2	2.9	3.4	2.8	3.4
NFE, %[2]	55.9	55.4	54.7	55.4	55.2	58.4	55.8	55.8	55.6	55.5
Ca, %	1.74	1.27	1.89	1.45	1.23	1.03	1.11	1.36	1.13	0.99
P, %	0.69	0.70	0.82	0.67	0.71	0.63	0.72	0.74	0.71	0.68
Fat, %	2.5	2.7	2.7	3.5	4.1	2.4	2.6	2.6	3.6	5.3
Ash, %	7.83	6.99	8.47	6.77	6.67	5.19	6.11	6.14	6.09	5.60
Bulk density, lb/bu[3]	54.72	51.31	48.26	50.27	46.48	52.70	47.02	43.54	44.86	41.39

[1] A composite sample consisting of 6 subsamples was used for analysis.
[2] NFE: nitrogen-free extract.
[3] Bulk density of a material represents the mass per unit volume.

Table 4. The effects of increasing wheat middlings and NE formulation on nursery pig performance[1]

	Treatment							Midds			
	1	2	3	4	5						
Wheat middlings, %	0	10	20	10	20		Midds × balanced			Midds	Balanced
Item Fat, %	0	0	0	1.4	2.8	SEM	NE interaction[2]	Linear[3]	Quadratic[4]	level[5]	NE effect[6]
d 0 to 12											
ADG, lb	0.56	0.57	0.58	0.61	0.57	0.022	0.33	0.56	0.27	0.49	0.49
ADFI, lb	0.94	0.94	1.03	1.03	0.93	0.031	0.01	0.25	0.36	0.88	0.84
F/G	1.68	1.67	1.80	1.70	1.65	0.085	0.14	0.58	0.72	0.50	0.36
d 12 to 29											
ADG, lb	1.27	1.25	1.19	1.28	1.25	0.025	0.46	0.15	0.37	0.09	0.09
ADFI, lb	1.94	1.90	1.90	1.93	1.98	0.037	0.44	0.91	0.52	0.50	0.16
F/G	1.52	1.52	1.59	1.51	1.58	0.023	0.99	0.03	0.03	0.001	0.54
d 0 to 29											
ADG, lb	0.97	0.97	0.94	1.00	0.97	0.021	0.95	0.41	0.25	0.12	0.13
ADFI, lb	1.52	1.51	1.54	1.55	1.55	0.032	0.54	0.60	0.96	0.71	0.39
F/G	1.56	1.55	1.64	1.55	1.60	0.025	0.34	0.06	0.11	0.01	0.35
Caloric efficiency[7]											
ME	2,346	2,308	2,417	2,358	2,449	36.5	0.82	0.06	0.11	0.01	0.26
NE	1,696	1,643	1,697	1,691	1,728	27.9	0.76	0.64	0.17	0.11	0.16
BW, lb											
d 0	15.15	15.15	15.15	15.15	15.14	0.163	0.98	0.98	0.96	0.95	0.97
d 12	21.82	21.97	22.05	22.41	21.96	0.357	0.46	0.68	0.41	0.60	0.63
d 29	43.40	43.30	42.30	44.19	43.49	0.69	0.83	0.56	0.36	0.23	0.14

[1] A total of 210 pigs (PIC 327 × 1050, initially 15.15 lb and 26 d of age) were used in a 29-d growth trial with 7 pigs per pen and 6 pens per treatment.
[2] Interactive effects of midds level and balanced on an NE basis.
[3] Combines Treatments 2 and 4 and 3 and 5 to create a 0, 10, 20% added midds linear contrast.
[4] Combines Treatments 2 and 4 and 3 and 5 to create a 0, 10, 20% added midds quadratic contrast.
[5] Compares Treatments 2 and 4 vs. 3 and 5.
[6] Compares Treatments 2 and 3 vs. 4 and 5.
[7] Caloric efficiency is expressed as kcal/lb gain.

Table 5. Economics of increasing wheat middlings and NE formulation in nursery pigs[1]

Wheat middlings, %	0	10	20	10	20		Midds × balanced	Midds		Midds	Balanced
Item — Fat, %	0	0	0	1.4	2.8	SEM	NE Interaction[2]	Linear[3]	Quadratic[4]	level[5]	NE effect[6]
d 0 to 12											
Feed cost/pig, $	2.93	2.92	3.13	3.25	2.99	0.098	0.02	0.29	0.34	0.81	0.33
Feed cost/lb gain, $[7]	0.44	0.43	0.45	0.45	0.43	0.015	0.21	0.76	0.92	0.78	0.77
Total revenue/pig, $[8,9]	4.34	4.43	4.49	4.72	4.43	0.170	0.33	0.56	0.27	0.49	0.49
IOFC[10]	1.40	1.51	1.35	1.47	1.44	0.143	0.65	0.96	0.51	0.51	0.89
d 12 to 29											
Feed cost/pig, $	6.24	6.02	5.89	6.32	6.60	0.118	0.09	0.98	0.50	0.52	0.0003
Feed cost/lb gain, $	0.29	0.28	0.29	0.29	0.31	0.005	0.43	0.18	0.09	0.02	0.02
Total revenue/pig, $	14.02	13.86	13.16	14.15	13.87	0.278	0.46	0.15	0.37	0.09	0.09
IOFC	7.78	7.84	7.27	7.83	7.27	0.204	0.99	0.05	0.11	0.010	0.98
d 0 to 29											
Feed cost/pig, $	9.18	8.94	9.03	9.57	9.60	0.200	0.88	0.59	0.94	0.79	0.01
Feed cost/lb gain, $	0.32	0.32	0.33	0.33	0.34	0.005	0.79	0.05	0.15	0.01	0.05
Total revenue/pig, $	18.36	18.30	17.65	18.87	18.30	0.388	0.92	0.42	0.26	0.13	0.13
IOFC	9.19	9.35	8.62	9.30	8.70	0.270	0.81	0.13	0.12	0.02	0.96

[1] A total of 210 pigs (PIC 327 × 1050, initially 15.15 lb BW and 26 d of age) were used in a 29-d growth trial with 7 pigs per pen and 6 pens per treatment.
[2] Feed cost/lb gain = feed cost/lb × F/G, assumed grinding = $5/ton; mixing = $3/ton; delivery and handling = $7/ton.
[3] One pound of body gain = $0.65/lb.
[4] Total revenue/pig = total gain/pig ×× $0.65.
[5] Income over feed cost = total revenue/pig – feed cost/pig.
[6] Interactive effects of midds level and balanced on an NE basis.
[7] Combines Treatments 2 and 4 and 3 and 5 to create a 0, 10, 20% added midds linear contrast.
[8] Combines Treatments 2 and 4 and 3 and 5 to create a 0, 10, 20% added midds quadratic contrast.
[9] Compares Treatments 2 and 4 vs. 3 and 5.
[10] Compares Treatments 2 and 3 vs. 4 and 5.