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Non-ruminants

Dietary net energy plans for barrows from 25 to 100 kg body weight

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ABSTRACT - This experiment was conducted to evaluate growth performance and carcass characteristics of barrows from 25 to 100 kg fed diets with different dietary net energy (NE) levels. Seventy-two barrows with initial body weight (BW) of 25.19±2.13 kg were allotted using a completely randomized block design to one of six dietary NE treatments (2300, 2380, 2460, 2540, 2620, and 2700 kcal kg^{-1}), which had two pigs per replicate and six replicates per treatment. Diets were formulated to be fed in three phases (25 to 60, 60 to 70, and 70 to 100 kg BW). The six different dietary NE densities were met by adding soybean oil in place of the inert ingredient (kaolin) to a corn-soybean meal-based diet. Increasing dietary NE decreased average daily feed intake and average daily standardized ileal digestible (SID) lysine intake in all of the three phases evaluated and improved the feed:gain ratio and SID lysine:gain ratio in the first and third phases. In the first and second phases, average daily NE intake and NE:gain ratio were similar among treatments, but NE increased and NE:gain worsened during the last phase as dietary NE increased. Average daily gain was not affected by dietary NE in the first and second phases; however, it improved in the last phase. Backfat was thicker, and lean percentage was reduced by increasing the dietary NE in all three phases of this study. Thus, barrows consume less feed, but carcass fat increases if dietary NE is increased from 2300 to 2700 kcal kg^{-1}.

Key Words: carcass quality, fat, feed intake, swine, vegetable oil

Introduction

Energy supply constitutes the largest portion of feed cost in swine diets because of the larger quantities of energy sources that need to be added to diets to meet energy demands. Moreover, pigs adjust their voluntary feed intake based on the energy density of the diet (Nyachoti et al., 2004; Quiniou and Noblet, 2012). Increasing dietary net energy (NE) often improves the feed:gain ratio (F:G) (Nitikanchana et al., 2015). This improvement in F:G results from either decreased average daily feed intake (ADFI) as dietary energy density increases, or from an increase in the average daily gain (ADG) in response to the higher energy concentration (Beaulieu et al., 2009; Quiniou and Noblet, 2012; Gonçalves et al., 2015).

The NE system is more accurate than the digestible energy (DE) and metabolizable energy (ME) systems, because the NE system corrects for energy lost as heat during digestion and nutrient metabolism (Kil et al., 2013). Using NE values for diet formulation ensures that the nutritional needs of pigs are achieved with greater accuracy, because in the NE system, diet energy values and energy requirements are similarly expressed (Noblet, 2007).

However, no experiments have been conducted to evaluate the effects on pigs fed fixed dietary NE concentrations for long periods, for example, from 25 to 100 kg BW. Because dietary energy supply is critical to swine nutrition, the objective of this study was to evaluate growth performance and carcass characteristics of barrows, from 25 to 100 kg BW, fed different dietary NE levels.

Material and Methods

Research on animals was conducted according to the guidelines of the institutional committee on animal use (UFMS 552/2013). The study was conducted in Terenos, Mato Grosso do Sul, Brazil (20°26'49" S and 54°50'37" W).

Pigs were housed in a curtain-sided barn with a solid concrete floor and ceramic roof. Each pen (1.15 × 2.86 m) was equipped with a single-hole dry self-feeder and a nipple drinker for *ad libitum* access to feed and water. There was a

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gutter (1.15 × 0.30 × 0.10 m) crossing the bottom of the pens that was emptied and filled with fresh water once a day.

A total of 72 genetically homogenous barrows originating from industrial crosses, with average initial body weight (BW) of 25.19±2.13 kg were used in a 75-day trial. Pigs were allotted to one of six dietary treatments, based on initial BW, using a completely randomized block design. Each treatment was replicated six times with two pigs per replicate. Dietary treatments included six dietary NE levels (2300, 2380, 2460, 2540, 2620, and 2700 kcal kg^{-1}).

Experimental diets (Table 1) were offered in meal form and formulated to be given in three growth phases (25 to 60, 60 to 70, and 70 to 100 kg) according to the Brazilian Tables for Poultry and Swine (Rostagno et al., 2011). For each phase, a basal diet was formulated with 2300 kcal kg^{-1} of NE. Then, to increase the dietary NE level by 80 kcal kg^{-1} (the sequential increase between treatments), 10.86 kg of soybean oil was added in place of the inert ingredient (kaolin) per 1000 kg of diet. In each phase, the same inclusion of macro- and microelements were provided in all experimental diets.

Table 1 - Composition of basal diets (as fed)

	Body weight phase		
	25 to 60 kg	60 to 70 kg	70 to 100 kg
Ingredient (g kg^{-1})			
Corn	700.3	701.4	710.1
Soybean meal (46%)	212.2	216.2	210.6
Soybean oil[1]	0.00	0.00	0.00
Kaolin	55.00	57.50	57.50
Dicalcium phosphate	12.02	8.67	7.68
Limestone	6.99	6.01	5.68
Salt	4.07	3.82	3.57
Vitamin/trace mineral premix[2,3]	4.00	4.00	4.00
L-lysine HCl	3.38	1.91	0.78
DL-methionine	0.99	0.32	0.08
L-threonine	0.97	0.19	-
L-tryptophan	0.11	-	-
Calculated analysis			
Crude protein (g kg^{-1})	155.5	155.0	151.9
Net energy (kcal kg^{-1})	2300	2300	2300
Metabolizable energy (kcal kg^{-1})	3034	3036	3040
SID lysine (g kg^{-1})	9.270	8.230	7.630
SID Met + Cys (g kg^{-1})	5.470	4.860	4.580
SID threonine (g kg^{-1})	6.030	5.350	5.110
SID tryptophan (g kg^{-1})	1.670	1.580	1.560
SID valine (g kg^{-1})	6.400	6.480	6.400
Calcium (g kg^{-1})	6.300	5.120	4.740
Available phosphorus (g kg^{-1})	3.110	2.500	2.310
Sodium (g kg^{-1})	1.800	1.700	1.600

SID - standardized ileal digestible.
[1] To increase the dietary NE level by 80 kcal kg^{-1} (the difference between each sequential treatment), 10.86 kg of soybean oil were added, to replace the inert ingredient (kaolin), per ton of diet.
[2] Provided per kg of diet from 25 to 60 kg BW: pantothenic acid, 9.20 mg; niacin, 20.00 mg; folic acid, 0.50 mg; copper, 15.00 mg; iron, 0.10 mg; zinc, 0.13 mg; iodine, 1.00 mg; selenium, 0.30 mg; manganese, 0.50 mg; vitamin A, 5000 IU; vitamin D3, 1000 IU; vitamin E, 25.00 IU; vitamin K3, 3.00 mg; vitamin B1, 2.20 mg; vitamin B2, 5.50 mg; vitamin B6, 2.00 mg; vitamin B12, 20.00 mg; BHT, 1.00 g.
[3] Provided per kg of diet: pantothenic acid, 9.20 mg; niacin, 18.00 mg; folic acid, 0.50 mg; copper, 15.00 mg; iron, 0.10 mg; zinc, 0.13 mg; iodine, 1.00 mg; selenium, 0.30 mg; manganese, 0.50 mg; vitamin A, 5000 IU; vitamin D3, 1000 IU; vitamin E, 25.00 IU; vitamin K3, 3.00 mg; vitamin B1, 1.50 mg; vitamin B2, 4.00 mg; vitamin B6, 1.50 mg; vitamin B12, 18.00 mg; BHT, 1.00 g.

Pigs were weighed individually at the beginning and the end of each phase, and feed disappearance was recorded daily. The ADG, ADFI, and F:G were determined from these measurements. Net energy intake and standardized ileal digestible lysine (SID Lys) intake were determined by multiplying the total feed intake by the NE or SID Lys content of each diet and dividing by the number of days in each phase. Net energy:gain ratio (NE:G) and SID Lys:gain ratio (SID Lys:G) were determined by dividing the total NE intake or total SID Lys intake by the weight gain in each phase.

At the end of each phase, *in vivo* ultrasonography (Aloka SSD500 Micrus Ultrasound, Aloka Co. Ltd, Wellingtongford, CT) measurements of the loin muscle area (LMA), backfat (BF), and loin depth (LD) were taken between the last thoracic and the first lumbar vertebrae. Images from the ultrasonography were analyzed using the software LINCE® (M&S Consultoria Agropecuária Ltda.). Lean percentage was determined using the equation: lean (%) = 60 − (backfat × 0.58) + muscle depth × 0.10, described in Bridi and Silva (2007).

Data were analyzed using a completely randomized block design using PROC GLM of SAS (Statistical Analysis System, University version). Pen was the experimental unit for all data analysis. An analysis of variance was used first, followed by linear and quadratic regression analysis to evaluate the effects of the dietary NE level. Significance was set at $P<0.05$.

Results

Overall (25 to 100 kg), as dietary NE increased, ADG increased linearly ($P<0.05$) and ADFI and SID Lys intake decreased linearly ($P<0.05$) (Table 2). No effects ($P>0.05$) of dietary NE were observed on NE intake and NE:G, but SID Lys:G ratio improved linearly ($P<0.05$) as dietary NE increased.

In the first phase (25 to 60 kg), there were no effects ($P>0.05$) of dietary NE levels on final BW and ADG. However, increasing the dietary NE linearly decreased ($P<0.05$) ADFI and improved ($P<0.05$) F:G. Daily NE intake was not affected ($P>0.05$) by increasing dietary NE density, although SID Lys intake decreased ($P<0.05$) linearly. There were no significant effects ($P>0.05$) of dietary NE on NE:G, but SID Lys:G was linearly improved ($P<0.05$) by increasing dietary NE. During the first phase, increasing dietary NE density linearly increased ($P<0.05$) BF and linearly decreased (P<0.05) lean percentage (Table 3). There were no effects (P>0.05) of diets on LD and LMA.

In the second phase (60 to 70 kg), there were no effects (P>0.05) of dietary NE on BW, ADG, and F:G. As dietary NE level increased, ADFI decreased (P<0.05) linearly. Similar (P>0.05) NE intake was observed among treatments, but a linear reduction (P<0.05) in SID Lys intake relative to increasing NE density was noted. In this phase, increasing dietary NE did not affect (P>0.05) NE:G or SID Lys:G. At the end of the second phase, increasing dietary NE linearly increased (P<0.05) BF and LMA, but decreased (P<0.05) the lean percentage. No effects (P>0.05) of dietary NE on LD were observed.

During the last phase (70 to 100 kg), increasing dietary NE linearly increased (P<0.05) BW and ADG, reduced (P<0.05) ADFI, and improved (P<0.05) F:G. Diets with increased NE levels linearly increased (P<0.05) NE intake and decreased (P<0.05) SID Lys intake. Linear improvements (P<0.05) in NE:G and SID Lys:G were observed with increased dietary NE.

Discussion

Pigs are able to adjust their voluntary ADFI over a wide range of dietary energy concentrations to meet their energy requirements (Ellis and Augspurger, 2001). This

Table 2 - Dietary net energy (NE) effects on growth performance of barrows from 25 to 100 kg body weight (BW)

	Dietary NE (kcal kg⁻¹)						P-value		SEM
	2300	2380	2460	2540	2620	2700	Linear	Quadratic	
Overall (25 to 100 kg)									
Initial BW (kg)	25.05	25.18	25.68	25.07	25.05	25.10	-	-	-
Final BW (kg)[1]	101.53	103.03	102.75	102.72	103.92	106.30	0.011	0.345	1.203
ADG (kg)[2]	1.02	1.04	1.03	1.04	1.05	1.08	0.007	0.224	0.015
ADFI (kg)[3]	2.65	2.60	2.43	2.43	2.41	2.37	<0.001	0.273	0.061
F:G[3]	2.60	2.50	2.36	2.34	2.30	2.19	<0.001	0.667	0.064
NE intake (kcal)	6095	6188	5978	6172	6314	6399	0.175	0.513	159.0
SID Lys intake (g)[2]	21.54	21.06	19.61	19.92	19.53	19.17	0.001	0.553	0.001
NE:G	5975	5950	5804	5935	6014	5925	0.786	0.978	167.0
SID Lys:G[3]	21.11	20.25	19.04	19.15	18.60	17.75	<0.001	0.843	0.001
25 to 60 kg									
Initial BW (kg)	25.05	25.18	25.68	25.07	25.05	25.10	-	-	-
Final BW (kg)	58.02	58.90	57.26	58.82	57.52	59.25	0.632	0.501	0.882
ADG (kg)	0.94	0.96	0.90	0.96	0.93	0.98	0.601	0.378	0.003
ADFI (kg)[1]	1.90	1.77	1.57	1.66	1.66	1.60	0.026	0.164	0.088
F:G[1]	2.02	1.84	1.74	1.73	1.78	1.63	0.018	0.431	0.104
NE intake (kcal)	4370	4213	3862	4216	4349	4329	0.752	0.214	221.9
SID Lys intake (g)[1]	17.61	16.41	14.55	15.39	15.39	14.83	0.019	0.233	0.001
NE:G	4649	4388	4291	4392	4677	4417	0.959	0.522	256.6
SID Lys:G[1]	18.74	17.09	16.17	16.03	16.55	15.13	0.028	0.438	0.001
60 to 70 kg									
Initial BW (kg)	58.02	58.90	57.26	58.82	57.52	59.25	0.632	0.501	0.882
Final BW (kg)	72.99	73.40	72.54	73.60	72.14	74.50	0.637	0.517	1.257
ADG (kg)	1.07	1.04	1.09	1.06	1.04	1.09	0.839	0.794	0.057
ADFI (kg)[2]	3.04	3.05	2.88	2.86	2.69	2.80	0.005	0.571	0.094
F:G	2.84	2.93	2.64	2.70	2.59	2.57	0.091	0.561	0.180
NE intake (kcal)	6992	7259	7085	7264	7048	7560	0.238	0.640	239.4
SID Lys intake (g)[2]	25.02	25.10	23.70	23.54	22.14	23.04	0.007	0.649	0.001
NE:G	6535	6980	6500	6853	6777	6936	0.691	0.523	446.4
SID Lys:G	23.38	24.14	21.75	22.21	21.29	21.14	0.068	0.546	0.001
70 to 100 kg									
Initial BW (kg)	72.99	73.40	72.54	73.60	72.14	74.50	0.637	0.517	1.257
Final BW (kg)[1]	101.53	103.03	102.75	102.72	103.92	106.30	0.011	0.345	1.203
ADG (kg)[1]	1.10	1.14	1.16	1.18	1.17	1.22	0.022	0.602	0.034
ADFI (kg)[2]	3.45	3.48	3.35	3.33	3.28	3.17	0.002	0.980	0.079
F:G[3]	3.14	3.05	2.89	2.82	2.80	2.60	<0.001	0.589	0.065
NE intake (kcal)[1]	7935	8282	8241	8458	8594	8559	0.015	0.874	194.0
SID Lys intake (g)[2]	25.94	25.16	24.22	24.08	23.71	22.92	0.003	0.948	0.001
NE:G[3]	7214	7265	7104	7168	7345	7016	<0.001	0.589	0.065
SID Lys:G[3]	22.68	22.07	20.88	20.40	20.27	18.79	<0.001	0.479	0.001

BW - body weight; ADG - average daily gain; ADFI - average daily feed intake; F:G - feed to gain ratio; NE - net energy; NE:G - net energy to gain ratio; SID Lys - standardized ileal digestible lysine; SID Lys:G - standardized ileal digestible lysine to gain ratio; SEM - standard error of the mean.
[1] Linear, P<0.05.
[2] Linear, P<0.01.
[3] Linear, P<0.001.

Table 3 - Dietary net energy (NE) effects on carcass characteristics of barrows from 25 to 100 kg body weight

	Dietary NE (kcal kg^{-1})						P-value		SEM
	2300	2380	2460	2540	2620	2700	Linear	Quadratic	
25 to 60 kg									
BF (mm)[1]	7.05	7.54	7.65	8.06	8.90	8.88	0.012	0.921	0.653
LD (mm)	35.69	37.51	37.71	37.52	36.71	37.84	0.268	0.342	0.899
LMA (cm^2)	25.64	27.34	28.65	27.31	26.54	28.49	0.268	0.533	1.142
Lean (%)[1]	59.48	59.38	59.34	59.07	58.51	58.63	0.028	0.747	0.391
60 to 70 kg									
BF (mm)[1]	9.17	9.38	9.51	10.33	10.86	11.03	0.034	0.757	0.970
LD (mm)	38.58	40.31	38.85	39.68	40.81	40.15	0.273	0.889	1.047
LMA (cm^2)[1]	34.11	35.86	35.69	36.38	37.36	36.30	0.040	0.500	0.999
Lean (%)[1]	58.54	58.59	58.38	57.98	57.78	57.62	0.049	0.731	0.552
70 to 100 kg									
BF (mm)[1]	13.24	13.11	13.21	13.44	15.51	15.89	0.012	0.292	0.953
LD (mm)	48.83	48.48	49.33	50.34	50.04	49.96	0.242	0.868	1.025
LMA (cm^2)	37.92	38.53	38.53	36.78	39.52	38.31	0.706	0.750	1.086
Lean (%)[1]	57.20	57.25	57.27	57.23	56.00	55.78	0.018	0.263	0.539

BF - backfat; LD - loin depth; LMA - loin muscle area; SEM - standard error of the mean.
[1] Linear, $P<0.05$.

feeding behavior was confirmed in the first and second phases (25 to 70 kg), in which ADFI decreased while NE intake was similar among treatments. A linear decrease in ADFI was also reported by Quiniou and Noblet (2012) when growing-finishing barrows were fed diets varying from 1935 to 2651 kcal NE kg^{-1}. They observed that the lowest NE levels had a poorer NE intake, but there were no differences in NE intake above 2221 kcal NE kg^{-1}. In our study, the lowest NE level was 2300 kcal kg^{-1}.

Although we observed a reduction in SID Lys intake as dietary NE increased, there were no negative effects on ADG in the first and second phases (25 to 70 kg). Research has documented increases in ADG as a result of increasing dietary energy concentration (Zhang et al., 2011; Nitikanchana et al., 2015).

The positive response observed in ADG in the last phase, from 70 to 100 kg, probably was an effect of the greater NE intake as dietary NE increased. Low energy diets can negatively affect pig growth performance (Smith et al., 1999). To consume the same amount of NE available from diets with higher NE densities, pigs feeding diets with lower NE densities would have to increase their feed intake, which would result in a rise in the heat increment of the diets (Noblet and van Milgen, 2013).

Although no difference was observed in NE intake in the first and second phases, there was an increase in BF as a result of feeding pigs with increased dietary NE. This might be due to the use of soybean oil to increase the energy level of the diets. Lipids are energy sources with lower heat increment than those of carbohydrates. As intake of SID Lys and other aminoacids decreased with the poorer ADFI as a result of increase in dietary NE, the excess energy consumed was directed toward fat deposition.

The greater NE intake in the last phase resulted in fatter carcasses in pigs fed the diets with the highest NE levels. This result agrees with the findings of Beaulieu et al. (2009), who also observed thicker BF as a result of increasing dietary DE from 30 to 115 kg in diets given to pigs.

The increased ADG in the last phase is likely because of the greater amount of fat deposited in the carcass as dietary NE increased. Finishing pigs show low lean accretion and increased carcass fat deposition (Kil et al., 2013). Moreover, digestibility of energy is improved as pigs grow (Noblet and van Milgen, 2004).

As ADG and NE intake were similar among treatments in phases 1 and 2, NE:G was not affected in these phases. In the last phase, pigs consumed less energy per unit of weight gain. This result confirms that finishing pigs are more efficient in depositing fat than growing pigs (Apple et al., 2009; Kil et al., 2013).

Increasing dietary energy density without maintaining SID Lys:NE ratio improved the F:G ratio, but impaired carcass quality by increasing fat deposition. On the other hand, pigs fed low NE diets had leaner carcasses, but showed lower F:G ratios. Therefore, low NE diets may be a preferable alternative as energy is an expensive nutritional component.

Conclusions

Barrows from 25 to 100 kg BW consume less feed if dietary net energy is increased from 2300 to 2700 kcal kg^{-1}

without impairments in growth performance, but with increase in carcass fat.

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