



Dietary net energy levels for growing barrows from 30 to 70 kg

Gabriela Puhl Rodrigues¹  Charles Kiefer^{1*}  Karina Márcia Ribeiro de Souza Nascimento¹ 
Anderson Corassa²  Danilo Alves Marçal¹  Marina de Nadai Bonin¹ 
Alexandre Pereira dos Santos¹  Luana Cristiane dos Santos¹ 

¹Programa de Pós-graduação em Ciência Animal, Universidade Federal de Mato Grosso do Sul (UFMS), 79070-900, Campo Grande, MS, Brasil. E-mail: charles.kiefer@ufms.br. *Corresponding author.

²Universidade Federal de Mato Grosso (UFMT), Sinop, MT, Brasil.

ABSTRACT: This study evaluated the effect of dietary net energy (NE) levels on growth performance and carcass characteristics of barrows from 30 to 70 kg of body weight (BW). Sixty barrows with initial body weight (IBW) of 31.94 ± 3.54 kg and final body weight (FBW) of 71.98 ± 5.99 kg were allotted to one of five dietary NE levels (2.40, 2.45, 2.50, 2.55, and 2.60 Mcal kg⁻¹), using a completely randomized block design with six replicates and two barrows per replicate. The experimental period was divided into phase I: 30 to 50 kg and phase II: 50 to 70 kg. The variables analyzed were average daily feed intake (ADFI), net energy intake (NEI), digestible lysine intake (LysI), average daily gain (ADG), feed conversion (FC), FBW, digestible lysine conversion: gain (LysI:G), Cost:Gain (C:G), loin eye area (LEA), muscle depth (MD), first backfat layer (BF₁), second backfat layer (BF₂), total backfat (BF_t), lean meat percentage, and carcass bonus index (BI). In phase I, there was a linear increase ($P < 0.05$) in FBW, ADG, NEI, and LysI with increasing NE levels in the diet. In phase II, increasing dietary NE levels also increased ($P < 0.05$) FBW, ADG, NEI, LysI, and FC linearly. Overall, there was a linear increase ($P < 0.05$) in ADG, NEI, LysI, and FC with increasing NE levels in the diet. The other performance variables were not affected ($P > 0.05$) by the NE levels. There was an increase ($P < 0.05$) in BF₂ with increasing NE levels, but the other carcass characteristics were not altered ($P > 0.05$). We recommended 2.60 Mcal of NE kg⁻¹ in the diet for growing barrows from 30 to 70 kg.

Keywords: calorie:nutrient ratio, energy intake, nutritional density, requirements.

Níveis de energia líquida para suínos machos castrados dos 30 aos 70 kg

RESUMO: Realizou-se este estudo com o objetivo de avaliar níveis de energia líquida (EL), mantendo a relação caloria: nutriente, no desempenho e características de carcaça de suínos dos 30 aos 70 kg. Foram utilizados 60 suínos machos castrados, com pesos iniciais de $31,94 \pm 3,54$ kg e finais de $71,98 \pm 5,99$ kg. Os animais foram distribuídos em delineamento experimental de blocos casualizados, em cinco níveis de EL (2,40; 2,45; 2,50; 2,55; 2,60 Mcal de EL kg⁻¹ de dieta), com seis repetições e dois animais por unidade experimental. O período experimental foi dividido em fase I: 30 aos 50 kg e fase II: 50 aos 70 kg. As variáveis analisadas foram os consumos de ração diária (CRD), energia líquida (CEL) e lisina digestível (CLdig), ganho de peso diário (GPD), conversão alimentar (CA), peso final (PF), conversão de lisina digestível: ganho (CLdig:G), custo: ganho (C:G), área de olho de lombo (AOL), profundidade de músculo (PM), espessura de toucinho da primeira camada (ET1), espessura de toucinho da segunda camada (ET2), espessura de toucinho total (ETt), percentual de carne magra (CM) e o índice de bonificação de carcaça (IB). Dos 30 aos 50 kg, verificou-se aumento linear ($P < 0,05$) do PF, GPD e dos CEL e CLdig com o aumento dos níveis de EL na dieta. Dos 50 aos 70 kg, o aumento dos níveis de EL na dieta promoveu melhora linear ($P < 0,05$) do PF, GPD, CEL, CLdig e da CA dos suínos. No período total, verificou-se aumento linear ($P < 0,05$) do GPD, CEL, CLdig e melhora linear ($P < 0,05$) da CA de acordo com o aumento do nível de EL na dieta. As demais variáveis de desempenho não foram afetadas ($P > 0,05$) pelos níveis de EL. Verificou-se aumento ($P < 0,05$) da ET2 de acordo com o aumento do nível de EL, porém sem alterar ($P > 0,05$) as demais características de carcaça. Recomenda-se o nível 2,60 Mcal de EL kg⁻¹ de dieta para suínos machos castrados dos 30 aos 70 kg.

Palavras-chave: caloria: nutriente, consumo de energia, exigências, densidade nutricional.

INTRODUCTION

Considering the important relationships that dietary energy has with costs (NOBLET, 2007), growth performance, and carcass characteristics (QUINIOU & NOBLET, 2012), several studies

were developed to establish the ideal level of dietary energy for pigs (QUINIOU & NOBLET, 2012; NITIKANCHANA et al., 2015; SMITH et al., 2017; MARÇAL et al., 2018a, b; MARÇAL et al., 2019). One of the strategies adopted by nutritionists is the formulation of diets based on the net energy

(NE) values of the feedstuffs. Using the NE system allows for better precision in diet formulation by adjusting for differences in nutrient metabolism, and accurately describing the actual nutritional content of the ingredients (SAKOMURA & ROSTAGNO, 2016). In the growing and finishing phases, studies indicated that increasing the dietary energy level decreases the average daily feed intake (ADFI) and improves feed conversion of the pigs (CÁMARA et al., 2014, 2016; GONÇALVES et al., 2015; MARÇAL et al., 2018a,b). However, increasing the dietary energy density without maintaining a constant energy:nutrient ratio may not simultaneously improve the average daily gain (ADG) and increase carcass fat deposition, since the availability of essential amino acids may not be sufficient for protein synthesis. This would limit both the ADG and the extent to which excess energy consumed can be deposited as fat in the carcass (MARÇAL et al., 2019).

In addition, with the genetic improvement of pigs, it is constantly necessary to re-evaluate the dietary nutritional levels, as evidenced by the increase in the nutritional requirement for metabolizable energy (ME) ($0.12 \text{ Mcal kg}^{-1}$) when comparing the last two Brazilian Tables for Poultry and Swine (ROSTAGNO et al., 2011, 2017). For these reasons, this study evaluated the effect of dietary NE levels, while maintaining the calorie:nutrient ratio, on growth performance and carcass characteristics for pigs from 30 to 70 kg, with the aim to reduce production costs and optimize growth performance.

MATERIALS AND METHODS

Sixty commercial hybrid barrows that were genetically similar, with initial body weights (IBW) and final body weights (FW) of $31.94 \pm 3.54 \text{ kg}$ and $71.98 \pm 5.99 \text{ kg}$ respectively, were used. Two animals were housed per pen, each of which had a density of $1.47 \text{ m}^2 \text{ head}^{-1}$, a concrete floor, and a water pool; and pens were equipped with semi-automatic feeders and nipple drinkers.

Experimental treatments were allocated to pigs in a randomized block design, with five dietary NE levels (2.40; 2.45; 2.50; 2.55; $2.60 \text{ Mcal kg}^{-1}$ of diet), six replications per treatment and two pigs per experimental pen. Initial BW was adopted as the criteria for the formation of the blocks and each pen was considered as the experimental unit.

The experimental diets (Tables 1 and 2) were formulated, based on the ideal protein concept, to meet the nutritional requirements of high genetic potential barrows with superior growth performance

(ROSTAGNO et al., 2017). The increases in the NE density of the diets were achieved by the inclusion of soybean oil as a replacement for kaolin (inert). The calorie:nutrient ratio, except for the Na levels, was kept constant across all diets through the inclusion of isolated amino acids, limestone, and dicalcium phosphate to replace kaolin.

The diets, in meal form, were fed ad libitum and the animals had free access to water throughout the experimental period, which lasted 40 days and was divided in two experimental phases (phase I: 30 to 50 kg, and phase II: 50 to 70 kg). Feed waste was collected and added to the feeder leftovers at the end of each experimental phase, to determine average daily feed intake (ADFI), average daily NE intake (NEI), and average daily digestible lysine intake (LysI).

The environmental conditions inside the barn were monitored using a maximum and minimum thermometer and a portable digital thermometer (model ITWTG 2000), from which dry bulb temperature, wet bulb temperature, black globe temperature, and air relative humidity were recorded daily at 8 A.M. and 4 P.M. The black globe temperature and relative humidity index (BGHI) was calculated using the equation proposed by BUFFINGTON et al. (1981).

The ADFI was determined from the subtraction of the collected waste from the feed provided. The NEI and the LysI were obtained by multiplying the feed intake in the phase by their respective contents in each diet. The pigs were weighed in an electronic scale at the beginning and end of each experimental phase to determine their average daily gain (ADG) and FBW. LysI:G was calculated by dividing the LysI by the ADG for each phase. Feed conversion (FC) was calculated by dividing the ADFI by the ADG.

An economic analysis of the studied diets was performed to determine the Cost:G (C:G), using the equation adapted from BELLAVIER et al. (1985): $Y_i = (Q_i \times P_i) / G_i$, where Y_i = feed cost per kilogram of pig gain mass in the i -th treatment; Q_i = amount of feed consumed in the i -th treatment; P_i = price per kilogram of feed used in the i -th treatment; and G_i = BW gain in the i -th treatment.

At the end of the experimental period, quantitative carcass characteristics measurements were obtained by *in vivo* ultrasonography. The ultrasound device ALOKA SSD 500 V was used, with an acoustic probe of 12 cm and frequency of 3.5 Mhz. To allow the proper coupling of the transducer with the body of the pig, a silicone coupler was used, which follows the arching of the ribs, and soy oil was used to avoid the presence of air between the probe

Table 1 - Centesimal and nutritional composition of experimental diets (30 to 50 kg).

Ingredients,%	-----Diets, NE (Mcal kg ⁻¹)-----				
	2.40	2.45	2.50	2.55	2.60
Corn (7.88%)	65.96	65.96	65.96	65.96	65.96
Soybean meal (46.5%)	26.74	26.74	26.74	26.74	26.74
Kaolin (inert)	3.200	2.427	1.657	0.888	0.115
Soybean oil	0.977	1.632	2.288	2.944	3.599
Dicalcium phosphate	1.347	1.397	1.448	1.498	1.548
Limestone	0.662	0.669	0.673	0.678	0.685
L-Lysine HCl	0.277	0.305	0.333	0.360	0.388
L-Threonine	0.094	0.108	0.123	0.138	0.153
DL-Methionine	0.100	0.113	0.126	0.138	0.151
L-Tryptophan	0.014	0.020	0.023	0.027	0.032
Vitamin-mineral premix ¹	0.150	0.150	0.150	0.150	0.150
Tiamulin	0.050	0.050	0.050	0.050	0.050
Salt	0.432	0.432	0.432	0.432	0.432
-----Calculated nutritional composition ² -----					
Net energy, Mcal kg ⁻¹	2.40	2.45	2.50	2.55	2.60
Metabolizable energy, Mcal kg ⁻¹	3.19	3.24	3.30	3.36	3.42
Crude protein, %	18.00	18.05	18.09	18.14	18.19
SID lysine, %	1.026	1.048	1.069	1.090	1.112
SID met+cys, %	0.605	0.618	0.631	0.643	0.656
SID threonine, %	0.667	0.681	0.695	0.709	0.723
SID tryptophan, %	0.205	0.210	0.214	0.218	0.222
Calcium, %	0.693	0.708	0.722	0.736	0.751
Digestible phosphorus, %	0.332	0.339	0.346	0.353	0.360
Sodium, %	0.190	0.190	0.190	0.190	0.190

¹Content per kg of diet: pantothenic acid: 9.2 mg; niacin: 18.0 mg; folic acid: 0.5 mg; copper: 15.0 mg; iron: 0.1 mg; zinc: 0.1 mg; iodine: 1.0 mg; selenium: 0.3 mg; manganese: 0.5 mg; vitamin A: 5,000 IU; vitamin D3: 1,000 IU; vitamin E: 25.0 IU; vitamin K3: 3.0 mg; vitamin B1: 1.5 mg; vitamin B2: 4.0 mg; vitamin B6: 1.5 mg; vitamin B12: 18.0 mg; BHT: 1.0 g and vehicle: 1.0 g.

²Values calculated according to Rostagno et al. (2017).

and the skin. The probe was placed between the last thoracic and the first lumbar vertebra (Point P2). All images collected were analyzed using the LINC[®] program. Lean percentage and bonification index (BI) values were determined according to the equations: Lean (%) = (60 - (backfat thickness × 0.58) + loin depth × 0.10) and BI = (23.6 + (0.286 × hot carcass weight) + lean %).

The variables analyzed were ADFI, NEI and LysI, ADG, FC, FW, LysI:G, C:G, loin eye area (LEA), muscle depth (MD), first backfat layer (BF₁), second backfat layer (BF₂) and total backfat thickness (BF_T), lean percentage, and BI. Data were submitted to analysis of variance and linear and quadratic regression analysis to determine the effects of dietary NE levels at the 5% probability level. Statistical analyses were performed in SAS version 9.1 (SAS, 2004).

RESULTS

The mean environmental air temperature verified during the experimental period was 26.96 ± 3.7 °C; the relative air humidity averaged 55.59% ± 20.2%, the black globe temperature 27.19 ± 3.6 °C, and the BGHI 75.48 ± 3.9.

In the first phase of the study, from 30 to 50 kg, there was a linear increase ($P < 0.05$) in FBW, ADG, NEI, and LysI with increasing dietary NE levels. However, there were no effects ($P > 0.05$) of dietary NE on ADFI, FC, and LysI:G (Table 3).

In the second phase, from 50 to 70 kg, there was a linear increase ($P < 0.05$) in FBW, ADG, NEI, and LysI, and a linear improvement ($P < 0.05$) in FC with increasing dietary NE levels. In this phase, NE levels did not affect ($P > 0.05$) ADFI and LysI:G (Table 3).

Table 2 - Centesimal and nutritional composition of experimental diets (50 to 70 kg).

Ingredients, %	-----Diets, NE (Mcal kg ⁻¹)-----				
	2.40	2.45	2.50	2.55	2.60
Corn (7.88%)	73.49	73.49	73.49	73.49	73.49
Soybean meal (46.5%)	20.61	20.61	20.61	20.61	20.61
Kaolin (inert)	3.371	2.617	1.864	1.112	0.354
Soybean oil	0.000	0.659	1.318	1.977	2.635
Dicalcium phosphate	0.917	0.953	0.996	1.032	1.076
Limestone	0.594	0.603	0.604	0.610	0.614
L-Lysine HCl	0.271	0.294	0.317	0.340	0.365
L-Threonine	0.073	0.085	0.098	0.111	0.123
DL-Methionine	0.062	0.072	0.083	0.094	0.105
L-Tryptophan	0.017	0.021	0.024	0.028	0.032
Vitamin-mineral premix ¹	0.150	0.150	0.150	0.150	0.150
Tiamulin	0.050	0.050	0.050	0.050	0.050
Salt	0.396	0.396	0.396	0.396	0.396
-----Calculated nutritional composition ² -----					
Net energy, Mcal kg ⁻¹	2.40	2.45	2.50	2.55	2.60
Metabolizable energy, Mcal kg ⁻¹	3.16	3.21	3.27	3.33	3.38
Crude protein, %	15.70	15.74	15.78	15.82	15.86
SID lysine, %	0.876	0.894	0.912	0.930	0.949
SID met+cys, %	0.517	0.527	0.538	0.549	0.560
SID threonine, %	0.569	0.581	0.593	0.605	0.617
SID tryptophan, %	0.175	0.179	0.182	0.186	0.190
Calcium, %	0.543	0.555	0.566	0.577	0.589
Digestible phosphorus, %	0.264	0.269	0.275	0.280	0.286
Sodium, %	0.176	0.176	0.176	0.176	0.176

¹Content per kg of diet: pantothenic acid: 9.2 mg; niacin: 18.0 mg; folic acid: 0.5 mg; copper: 15.0 mg; iron: 0.1 mg; zinc: 0.1 mg; iodine: 1.0 mg; selenium: 0.3 mg; manganese: 0.5 mg; vitamin A: 5,000 IU; vitamin D3: 1,000 IU; vitamin E: 25.0 IU; vitamin K3: 3.0 mg; vitamin B1: 1.5 mg; vitamin B2: 4.0 mg; vitamin B6: 1.5 mg; vitamin B12: 18.0 mg; BHT: 1.0 g and vehicle: 1,0 g.

²Values calculated according to Rostagno et al. (2017).

Overall, from 30 to 70 kg, there was a linear increase ($P < 0.05$) in ADG, NEI, and LysI and a linear improvement ($P < 0.05$) in FC with increasing dietary NE levels. However, ADFI, LysI:G, and C:G were not affected ($P > 0.05$) by dietary NE.

Among carcass characteristics, there was a linear increase ($P < 0.05$) in BF₂ with increasing dietary NE levels. No other carcass characteristics were affected ($P > 0.05$) by the experimental diets (Table 4).

DISCUSSION

The average air temperature recorded during the study was above the upper critical temperature of 22 °C (RENAUDEAU et al., 2011). In addition, the BGHI was above that of 69.6 observed in studies with pigs under thermal comfort conditions (KIEFER et al., 2010). However, considering the

ADFI and ADG observed in the present study, when compared to the standards for high genetic potential barrows with medium-superior growth performance (namely, 1.71 and 2.34 kg for ADFI, and 0.93 and 1.05 kg for ADG, from 30 to 50 kg and from 50 to 70 kg, respectively), established by ROSTAGNO et al. (2017), it can be inferred that the thermal conditions did not influence the growth performance of the pigs.

Considering the evaluated NE levels, it was expected that the difference of 0.20 Mcal kg⁻¹ between the minimum and maximum levels that were studied (2.40 and 2.60 Mcal kg⁻¹, respectively) would provide an effect on the ADFI, as studies indicate that pigs are able to adjust their voluntary feed intake in response to changes in the nutritional density of the diet (NYACHOTI et al., 2004; LI & PATIENCE, 2017). Usually, high levels of dietary energy result in a reduction in the ADFI of growing-finishing pigs

Table 3 - Growth performance of barrows from 30 to 70 kg fed with diets with different net energy levels.

Variables	Diets, NE (Mcal kg ⁻¹)					P value		CV, %
	2.40	2.45	2.50	2.55	2.60	L	Q	
-----Phase I (30 to 50 kg)-----								
IBW, kg	32.01	31.91	31.97	31.99	31.83	0.129	0.133	3.21
FBW, kg*	49.46	49.43	49.68	49.82	49.89	0.020	0.250	3.14
ADG, kg*	0.92	0.92	0.93	0.94	0.95	0.027	0.785	5.33
AADFI, kg	1.90	1.91	1.95	1.89	1.86	0.953	0.131	6.81
FC	2.07	2.07	2.09	2.01	1.96	0.055	0.133	6.20
NEI, Mcal d ^{-1*}	4.56	4.69	4.87	4.81	4.84	0.006	0.129	6.94
LysI, g d ^{-1*}	19.50	20.06	20.82	20.56	20.71	0.006	0.127	6.95
LysI:G	21.22	21.71	22.35	21.91	21.79	0.208	0.136	6.32
-----Phase II (50 to 70 kg)-----								
BFW kg**	71.11	70.68	72.10	72.88	73.32	0.001	0.655	3.59
ADG, kg**	1.03	1.01	1.07	1.10	1.12	<0.001	0.698	6.84
AADFI, kg	2.65	2.59	2.67	2.70	2.66	0.395	0.817	8.91
FC**	2.56	2.55	2.51	2.46	2.38	<0.001	0.222	4.43
NEI, Mcal d ^{-1**}	6.35	6.34	6.68	6.89	6.92	0.003	0.835	9.02
LysI, g d ^{-1**}	23.19	23.13	24.35	25.14	25.24	0.003	0.840	9.01
LysI:G	22.46	22.84	22.85	22.90	22.53	0.722	0.196	4.45
-----Overall (30 to 70 kg)-----								
ADG, kg***	0.98	0.97	1.00	1.02	1.04	<0.001	0.817	4.73
AADFI, kg	2.29	2.27	2.33	2.31	2.28	0.564	0.504	7.66
FC***	2.33	2.33	2.31	2.25	2.18	<0.001	0.096	4.31
NEI, Mcal d ^{-1***}	5.50	5.56	5.82	5.90	5.93	0.002	0.502	7.80
LysI, g d ^{-1***}	21.44	21.67	22.68	22.97	23.09	0.003	0.470	7.70
LysI:G	21.90	22.32	22.62	22.43	22.19	0.328	0.094	4.37
Cost:G, R\$	0.20	0.21	0.20	0.20	0.20	0.167	0.401	4.76

NE: Net Energy; IBW: Initial Body Weight; FBW: Final Body Weight; ADG: Average Daily Gain; AADFI: Average Daily Feed Intake; FC: Feed Conversion; NEI: Average Daily Net Energy Intake; LysI: Average Daily Digestible Lysine Intake; LysI:G: Average Daily Digestible Lysine Intake:G; Cost:G: Diet Cost per kg of Diet; L: Linear Effect; Q: Quadratic Effect; CV: Coefficient of Variation.

*Linear effect (Phase I, 30 to 50 kg): FBW, $Y = 0.0025x + 43.393$, $R^2 = 0.91$; ADG, $Y = 0.0002x + 0.535$, $R^2 = 0.97$; NEI, $Y = 0.0014x + 1.350$, $R^2 = 0.71$; LysI, $Y = 0.0058x + 5.724$, $R^2 = 0.71$.

**Linear effect (Phase II, 50 to 70 kg): FBW, $Y = 0.0133x + 38.886$, $R^2 = 0.87$; ADG, $Y = 0.0005x - 0.205$, $R^2 = 0.87$; FC, $Y = -0.0009x + 4.815$, $R^2 = 0.93$; NEI, $Y = 0.0034x - 1.753$, $R^2 = 0.90$; LysI, $Y = 0.0122x - 6.3532$, $R^2 = 0.90$.

***Linear effect (Overall, 30 to 70 kg): ADG, $Y = 0.0003x + 0.156$, $R^2 = 0.91$; FC, $Y = -0.0008x + 4.208$, $R^2 = 0.86$; NEI, $Y = 0.0024x - 0.292$, $R^2 = 0.91$; LysI, $Y = 0.0092x - 0.602$, $R^2 = 0.91$.

(QUINIQU & NOBLET, 2012; MARÇAL et al., 2018a, b). However, this response was not observed in either of the phases in the present study.

Another hypothesis is that the difference between the evaluated NE levels (2.4 to 2.6 Mcal kg⁻¹) was sufficient to affect the ADFI of the pigs. A similar result was reported by KERR et al. (2003) who reported no effect of dietary NE levels ranging from 2.4 to 2.5 Mcal Kg⁻¹ of diet for growing pigs (25 to 58 kg).

The linear increase observed for NEI and LysI in phases 1 and 2 and in the overall period of the present study can be explained by the nutritional adjustments made in the diets to keep the

calorie: nutrient ratio constant. Studies indicated that increasing the dietary NE level without maintaining the calorie: nutrient ratio result in a decrease in ADFI and an improvement in FC, with no effect on ADG and FW (GONÇALVES et al., 2015; MARÇAL et al., 2018a). Results of the present study is contrary to the studies cited, in which, regardless of the period evaluated, a linear increase in dietary NE was associated with increased ADG and FW. However, care is needed in practical situations when the dietary NE level is reduced, to avoid limited amounts of nutrients since diets containing very low energy densities can fill the gastrointestinal tract before meeting energy and

Table 4 - Carcass characteristics of barrows from 30 to 70 kg fed with diets with different net energy levels.

Variables	Diets, NE (Mcal kg ⁻¹)					P value		CV, %
	2.40	2.45	2.50	2.55	2.60	L	Q	
LEA, cm ²	31.06	31.30	31.10	30.96	31.10	0.960	0.978	14.85
MD, mm	40.07	40.11	39.75	40.46	39.19	0.745	0.759	10.39
BF ₁ , mm	3.37	3.97	3.40	3.19	3.98	0.616	0.586	26.32
BF ₂ , mm*	4.21	4.79	4.93	5.09	6.09	0.019	0.688	32.98
BF _t , mm	7.58	8.76	8.33	8.28	10.07	0.060	0.614	27.17
Lean, %	59.61	58.93	59.15	59.24	58.08	0.081	0.599	2.60
BI	103.87	102.52	103.37	103.65	103.02	0.752	0.721	2.29

NE: Net Energy; LEA: Loin Eye Area; MD: Muscle Depth, BF₁: First Backfat Layer Thickness; BF₂: Second Backfat Layer Thickness; BF_t: Total Backfat Thickness; BI: Bonification Index; L: Linear Effect; Q: Quadratic Effect; CV: Coefficient of Variation.

*Linear effect: BF₂ 70 kg, Y = -15.278 + 0.008x.

nutrient requirements, thereby impairing growth performance (AYMERICH et al., 2020).

During digestion, the presence of chylomicrons stimulates the release of apolipoprotein A-IV (apoA-IV) from jejunal cells (WANG et al., 2012). This substance acts together with other peptides (PYY, GLP-1, and OXM) to slow down gastric emptying and intestinal motility (TORRALLARDONA & ROURA, 2009). Thus, an increase in lipid concentration in the diet can promote a lower rate of passage through the gastrointestinal tract and; consequently, increase the overall digestibility of the diet (KIL et al., 2011).

Considering the maintenance of the calorie:amino acids ratio in the evaluated diets, it can be inferred that diets with higher NE levels may provide greater input of energy and amino acids for protein synthesis, as well as longer time for action of enzymes on nutrients due to the deceleration of gastric emptying, which may have contributed to the linear improvement in ADG and FBW and; consequently, in FC.

The C:G was not influenced ($P > 0.05$) by dietary NE levels. Thus, it can be inferred that diets with higher NE and amino acids concentrations, even with a higher cost per kilogram of diet, resulted in similar costs when compared to those with lower nutritional concentrations, since there was a proportional improvement in the nutritional efficiency of these diets as the cost increased. This result could be attributed to the greater supply of energy and amino acids, which promoted greater efficiency in protein synthesis when compared to the lower NE level.

The highest NEI and amino acids intake did not result in increased protein synthesis, and

consequently there were no statistical effects for the variables LEA, MD, lean, and BI. However, the pigs that consumed more energy and nutrients deposited more fat in the second layer of backfat (BF₂). The pigs probably did not increase protein deposition once their genetic potential was reached; and therefore, the nutrients ingested in excess were used for fat deposition.

The results obtained for ADG, FC, and FBW in the present study indicated that the ideal dietary NE level for barrows from 30 to 50 kg and from 50 to 70 kg is 2.60 Mcal kg⁻¹. This result is higher than the recommendations of 2.48 Mcal of NE kg⁻¹ for pigs from 25 to 75 kg (NRC, 2012) and 2.40 Mcal of NE kg⁻¹ for pigs from 20 to 60 kg (FEDNA, 2013), and is also higher than the 2.50 and 2.54 Mcal NE kg⁻¹ levels established by ROSTAGNO et al. (2017) for pigs from 30 to 50 kg and from 50 to 70 kg, respectively.

CONCLUSION

The dietary NE level of 2.60 Mcal kg⁻¹ is recommended for barrows from 30 to 70 kg, as it increases ADG, improves FC and does not affect feed cost, lean percentage, nor the bonification index of the carcass.

ACKNOWLEDGMENTS

The authors thank the Fundação de Apoio ao Desenvolvimento do Ensino, Ciência e Tecnologia do Estado de Mato Grosso do Sul (FUNDECT), Universidade Federal de Mato Grosso do Sul (UFMS), and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES; Finance Code 001) for the financial support in the execution of the research project.

BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

The project was approved by the ethics committee in the use of animals, protocol number 957/2018, of the Universidade Federal de Mato Grosso do Sul (UFMS).

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

REFERENCES

- AYMERICH, P. et al. The implications of nutritional strategies that modify dietary energy and lysine for growth performance in two different swine production systems. *Animals*, v.10, p.1638, 2020. Available from: <<https://doi.org/10.3390/ani10091638>>. Accessed: Oct. 20, 2020. doi: 10.3390/ani10091638.
- BELLAVER, C. et al. Malt rootlets as ration ingredients for swine on growing and finishing stages. Radícula de malte na alimentação de suínos em crescimento e terminação. *Pesquisa Agropecuária Brasileira*, v.20, p.969-974, 1985. Available from: <<https://ainfo.cnptia.embrapa.br/digital/bitstream/item/160468/1/Radricula-de-malte-na-alimentacao-de-suinos-em-crescimento-e-terminacao.pdf>>. Accessed: Mar. 20, 2020.
- BUFFINGTON, D. E. et al. Black globe humidity index (BGHI) as comfort equation for dairy cows. *Transaction of the American Society of Agricultural Engineers*, v.24, p.711-714, 1981. Available from: <<https://elibrary.asabe.org/abstract.asp?aid=34325>>. Accessed: Feb. 17, 2021. doi: 10.13031/2013.34325.
- CÁMARA, L. et al. Influence of net energy content of the diets on productive performance and carcass merit of gilts, boars and immunocastrated males slaughtered at 120 kg BW. *Meat Science*, v.98, p.773-780, 2014. Available from: <<https://doi.org/10.1016/j.meatsci.2014.07.025>>. Accessed: Mar. 20, 2020. doi: 10.1016/j.meatsci.2014.07.025.
- FEDNA – Fundación Española para el Desarrollo de la Nutrición Animal. *Necesidades nutricionales para ganado porcino normas Fedna*. 2nd ed. 109p. 2013.
- GONÇALVES, L. M. G. et al. Net energy levels for finishing barrows. *Ciência Rural*, v.45, p.464-469, 2015. Available from: <<https://doi.org/10.1590/0103-8478cr20131573>>. Accessed: Mar. 20, 2020. doi: 10.1590/0103-8478cr20131573.
- KERR, B. J. et al. Influence of dietary protein level, amino acid supplementation, and dietary energy levels on growing-finishing pig performance and carcass composition. *Journal of Animal Science*, v.81, p.3075-3087, 2003. Available from: <<https://doi.org/10.2527/2003.81123075x>>. Accessed: Mar. 20, 2020. doi: 10.2527/2003.81123075x.
- KIEFER, C. et al. Response of finishing swine maintained in different thermal environments. *Revista Brasileira de Saúde e Produção Animal*, v.11, p.496-504, 2010. Available from: <<https://portalseer.ufba.br/index.php/rbspa/article/view/40250/22420>>. Accessed: Mar. 20, 2020.
- KIL, D. Y. et al. Net energy of soybean oil and choice White grease in diets fed to growing and finishing pigs. *Journal of Animal Science*, v.89, p.448-459, 2011. Available from: <<https://doi.org/10.2527/jas.2010-3233>>. Accessed: Mar. 20, 2020. doi: 10.2527/jas.2010-3233.
- LI, Q.; PATIENCE, J. F. Factors involved in the regulation of feed and energy intake of pigs. *Animal Feed Science and Technology*, v.233, p.23-33, 2017. Available from: <<https://doi.org/10.1016/j.anifeedsci.2016.01.001>>. Accessed: Mar. 20, 2020. doi: 10.1016/j.anifeedsci.2016.01.001.
- MARÇAL, D. A. et al. Dietary net energy plans for barrows from 25 to 100 kg body weight. *Revista Brasileira de Zootecnia*, v.47, p.e20180038, 2018a. Available from: <<https://doi.org/10.1590/rbz4720180038>>. Accessed: Mar. 20, 2020. doi: 10.1590/rbz4720180038.
- MARÇAL, D. A. et al. Dietary net energy plans for gilts from 25 to 100 kg body weight. *Revista Brasileira de Zootecnia*, v.47, p.e20170341, 2018b. Available from: <<https://doi.org/10.1590/rbz4720170341>>. Accessed: Mar. 20, 2020. doi: 10.1590/rbz4720170341.
- MARÇAL, D. A. et al. Diet formulation method influences the response to increasing net energy in finishing pigs. *Translational Animal Science*, v.3, p.1349-1358, 2019. Available from: <<https://doi.org/10.1093/tas/txz147>>. Accessed: Mar. 20, 2020. doi: 10.1093/tas/txz147.
- NITIKANCHANA, S. et al. Regression analysis to predict growth performance from dietary energy in growing-finishing pigs. *Journal of Animal Science*, v.93, p.2826-2839, 2015. Available from: <<https://doi.org/10.2527/jas.2015-9005>>. Accessed: Mar. 20, 2020. doi: 10.2527/jas.2015-9005.
- NOBLET, J. Recent developments in net energy research for swine. In: *Advances in Pork Production*, v.18, p.149-156, 2007. University of Alberta, Edmonton.
- NRC - National Research Council. *Nutrient requirements of swine*. ed. 11th ed. National Academy Press, Washington. 2012.
- NYACHOTI, C. M. et al. Voluntary feed intake in growing-finishing pigs: A review of the main determining factors and potential approaches for accurate predictions. *Canadian Journal of Animal Science*, v.84, p.549-566, 2004. Available from: <<https://doi.org/10.4141/A04-001>>. Accessed: Mar. 20, 2020. doi: 10.4141/A04-001.
- QUINIOU, N.; NOBLET, J. Effect of the dietary net energy concentration on feed intake and performance of growing-finishing pigs housed individually. *Journal of Animal Science*, v.90, p.4362-4372, 2012. Available from: <<https://doi.org/10.2527/jas.2011-4004>>. Accessed: Mar. 20, 2020. doi: <https://doi.org/10.2527/jas.2011-4004>.

RENAUDEAU, D. et al. A meta-analysis of the effects of high ambient temperature on growth performance of growing-finishing pigs. **Journal of Animal Science**, v.89, p.2220-2230, 2011. Available from: <<https://hal.inrae.fr/hal-02646507/document>>. Accessed: Mar. 20, 2020. doi: 10.2527/jas.2010-3329.

ROSTAGNO, H. S. et al. **Brazilian tables for poultry and swine: Food composition and nutritional requirements**. 3th ed. Viçosa, MG. 2011.

ROSTAGNO, H. S. et al. **Brazilian tables for poultry and swine: Food composition and nutritional requirements**. 4th ed. Viçosa, MG. 2017.

TORRALLARDONA, D.; ROURA, E. **Voluntary feed intake in pigs**. Wageningen Academic Publishers, 365p. 2009.

SAKOMURA, N. K.; ROSTAGNO, H. S. **Research methods in monogastric nutrition**. 2.ed. Funep, Jaboticabal. 262p. 2016.

SAS - **Statistical Analysis System. Version 9.1**. Cary: SAS Institute Inc., 2004.

SMITH, M. N. et al. Feeding diets with reduced net energy levels to growing-finishing barrows and gilts. **Canadian Journal of Animal Science**, v.97, p.30-41, 2017. Available from: <<https://cdnsciencepub.com/doi/pdf/10.1139/cjas-2016-0045>>. Accessed: Mar. 20, 2020. doi: 10.1139/cjas-2016-0045.

WANG, F. et al. Apolipoprotein A-IV improves glucose homeostasis by enhancing insulin secretion. **Proceedings of the National Academy of Sciences**, v.109, p.9641-9646, 2012. Available from: <<https://doi.org/10.1073/pnas.1201433109>>. Accessed: Mar. 20, 2020. doi: 10.1073/pnas.1201433109.