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ANIMAL PRODUCTION

Sequential metabolizable energy plans for piglets from 7 to 30 kg

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ABSTRACT: *The objective of this study was to evaluate sequential metabolizable energy (ME) plans, maintaining the lysine: calorie ratio for piglets from 7 to 30 kg. Forty eight female piglets with initial weight of 6.9 ± 1.2 kg and final weight of 30.5 ± 3.8 kg were randomly allocated in a randomized complete blocks design to three nutritional plans with eight replicates and two animals per experimental unit. Sequential plans provided four ME levels: plan 1: 3,300-3,250-3,200-3,150 kcal ME kg^{-1}, plan 2: 3,400-3,350-3,300-3,250 kcal ME kg^{-1}, and plan 3: 3,500-3,450-3,400-3,350 kcal ME kg^{-1} of feed, from 7 to 10 kg, 10 to 15 kg, 15 to 20 kg and 20 to 30 kg, respectively. From 7 to 10 kg, there was no effect (P>0.05) of the nutritional plans in the evaluated variables. From 7 to 15 kg, a higher (P<0.05) energy intake and weight gain and a better (P < 0.05) feed conversion was observed in animals fed with nutritional plans 2 and 3. Nutritional plans 2 and 3 resulted in higher (P<0.05) final weight, feed intake, energy intake, digestible lysine intake, weight gain, and better feed conversion in the 7 to 20 kg, 7 to 25 kg and 7 to 30 kg. It is recommended the sequential plan containing 3,400-3,350-3,300-3,250 kcal ME kg^{-1} of feed from 7 to 10 kg, from 10 to 15 kg, 15 to 20 kg, and from 20 to 30 kg; respectively, equivalent to levels of 2,546-2,513-2,501-2,475 kcal net energy (NE) kg^{-1} of feed for piglets.*
Key words: *calorie: nutrient, energy requirement, lysine, net energy.*

Planos sequenciais de energia metabolizável para leitões dos 7 aos 30 kg

RESUMO: *Realizou-se este estudo com o objetivo de avaliar planos sequenciais de energia metabolizável (EM), mantendo a relação lisina: caloria, para leitões dos 7 ao 30 kg. Foram utilizados 48 leitões, fêmeas, com peso inicial de 6,9 ± 1,2 kg e final de 30,5 ± 3,8 kg, distribuídos em delineamento de blocos ao acaso em três planos nutricionais, sendo: 1- 3.300-3.250-3.200-3.150 Kcal de EM kg^{-1} de ração; 2- 3.400-3.350-3.300-3.250 Kcal de EM kg^{-1} de ração; e 3- 3.500-3.450-3.400-3.350 Kcal de EM kg^{-1} de ração, dos 7 aos 10 kg, dos 10 aos 15 kg, dos 15 aos 20 kg e dos 20 aos 30 kg, respectivamente, com oito repetições e dois animais por unidade experimental. Dos 7 aos 10 kg, não houve efeito (P>0,05) dos planos nutricionais nas variáveis avaliadas. Observou-se, dos 7 aos 15 kg, maiores (P<0,05) consumos de energia e ganho de peso e melhor (P < 0,05) conversão alimentar nos animais alimentados com os planos nutricionais 2 e 3. Os leitões alimentados com os planos nutricionais 2 e 3 apresentaram maior (P<0,05) peso final, consumos de ração, de energia, de lisina digestível, ganho de peso e melhor conversão alimentar nos períodos dos 7 aos 20 kg, dos 7 aos 25 kg e dos 7 aos 30 kg. Recomenda-se o plano sequencial contendo 3.400-3.350-3.300-3.250 Kcal de EM kg^{-1} de ração dos 7 aos 10 kg, dos 10 aos 15 kg, 15 aos 20 kg e dos 20 aos 30 kg, respectivamente, equivalentes aos níveis de 2.546-2.513-2.501-2.475 Kcal de energia líquida kg^{-1} de ração.*
Palavras-chave: *caloria: nutriente, energia líquida, exigência energética, lisina.*

INTRODUCTION

The post-weaning phase in piglets is often associated with diarrhea and reduced feed intake, which can lead to reduced energy consumption by the animal and changes in intestinal morphology, negatively affecting digestibility and nutrient absorption (LALLES et al., 2007). Because feed intake is one of the performance-limiting factors after weaning, the initial diets tend to be more concentrated in energy and have ingredients with greater digestibility in relation to diets of other stages in swine production (ROSTAGNO et al., 2017).

While older pigs have the ability to regulate feed intake according to their energy requirement (NOBLET et al., 2001), there is evidence that weaned piglets do not yet have this control capacity, since studies have reported that increasing the energy concentration of the diet can stimulate consumption (ADEBOWALE et al., 2019) and the growth of piglets (ORENSAYA et al., 2008).

As it directly affects feeding costs (PATIENCE et al., 2013), understanding the impact of the energy fraction of the diet on the performance of piglets is fundamental to the profitability of

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the system. However, there are wide variations between the nutritional energy recommendations for piglets in the early stages. Recommendations of the authoritative nutrient requirement tables vary from 3,265 kcal of ME kg^{-1} of feed (NRC, 1998) to 3,400 kcal of ME kg^{-1} of feed (ROSTAGNO et al., 2011; NRC, 2012; ROSTAGNO et al., 2017).

In addition to the discrepancies that exist between the recommended nutrient levels, the weight ranges proposed for the starter phase in piglets also showed wide variation in these nutritional tables. Thus, defining the ideal concentration of energy for the starter phase can contribute to the establishment of new nutritional strategies. Therefore, the objective of this study was to evaluate sequential plans of ME, keeping the lysine: calorie ratio constant, for piglets from 7 to 30 kg.

MATERIALS AND METHODS

A total of 48 female piglets (Duroc / Pietrain x Large White / Landrace), 21 days old, with initial weight of 6.9 ± 1.2 kg and final weight of 30.5 ± 3.8 kg were used. Piglets were housed in a nursery equipped with cages (0.81 m^2) containing semi-automatic feeders, nipple drinkers, and heating system (lamps and electric heater). The dry and wet bulb temperatures were monitored (at 08:00 and 16:00) using maximum and minimum thermometers, and the black globe temperature and humidity index (WBGT) were calculated.

Piglets were randomly allocated in a randomized complete block design to three ME plans with eight replicates and two animals per experimental unit. Sequential plans provided four ME levels from 7 to 10 kg, 10 to 15 kg, 15 to 20 kg, and 20 to 30 kg: plan 1: 3,300-3,250-3,200-3,150 kcal kg^{-1}; plan 2: 3,400-3,350-3,300-3,250 kcal kg^{-1}; and plan 3: 3,500-3,450-3,400-3,350 kcal ME kg^{-1} of ration, from 7 to 10 kg, 10 to 15 kg, 15 to 20 kg and 20 to 30 kg, respectively. The blocking criterion was the initial body weight.

The experimental diets (Tables 1 and 2) were formulated based on the ideal protein concept, based on a corn and soybean meal diet to meet the nutritional requirements of piglets with high genetic potential and of average performance, according to the recommendations of ROSTAGNO et al. (2011). The increase in the concentration of ME between the sequential plans was accomplished through the substitution of kaolin with soya oil. The lysine: calorie ratio (based on NE values) was kept constant between diets through the inclusion of amino acids instead of kaolin. The feed and water were provided *ad libitum* to the animals during the 44 d experimental period.

The performance variables studied were daily weight gain, daily feed intake, daily intake of ME, daily intake of NE, daily intake of digestible lysine, feed conversion, and final weight. Fecal scores and the occurrence of diarrhea were also recorded.

The animals were weighed without fasting at the beginning and end of each phase of the experimental period. The feed waste and leftovers were quantified daily to determine the feed intake. The daily weight gain was obtained by subtracting the final weight of each period and the initial body weight of the piglets at the beginning of the experiment and dividing by the number of days.

The intake of ME, NE, digestible lysine, and crude protein were obtained by multiplying the consumption of feed in the period by the respective contents in each nutritional plan and dividing by the number of days in the period. To obtain the fecal consistency score, a daily visual assessment was performed in the morning and afternoon, with a score ranging from 0 to 3 being assigned to each bird, where 0 = solid feces, 1 = pasty feces, 2 = liquid / pasty feces, and 3 = liquid feces. Scores 2 and 3 indicated the occurrence of diarrhea. In the experiment, all piglets diagnosed with diarrhea were treated with an injectable antibiotic (Agemox® / Borgal®).

An economic analysis of the diets was carried out using an equation adapted from BELLAVER et al. (1985):

$$Y_i = (Q_i \times P_i) / G_i, \quad (1)$$

where Y_i = feed cost per kilogram of piglet mass gained 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 Gi = mass gain of piglets in the i-th treatment.

The Economic Efficiency Index (EEI) was calculated according to an equation adapted from FIALHO et al. (1992):

$$EEI = (LCe i / TCe_i) / 100, \quad (2)$$

where LCe_i = lowest feed cost per kilogram gained, $TCce_i$ = Cost of treatment i considered.

The data were submitted to analysis of variance (ANOVA) using the general procedure of the linear model in the statistical program Statistical Analysis System (SAS, version 9.0). The following model was used:

$$Y_{ij}: \mu + t_i + b_j + e_{ij}, \quad (3)$$

where: Y_{ij} = estimate of the studied variables; μ = general average; t_i = effect of the i-th of the sequential plan; b_j = effect of block j; e = random error associated with observation Y_{ij}. The initial body weight was used

Table 1 - Centesimal and nutritional composition of experimental diets from 7 to 15 kg.

Ingredients (%)	---Phases---	
	7 to 10 kg	10 to 15 kg
Corn (7.88%)	50.570	53.097
Soybean meal (46.5%)	23.210	24.754
Dried whey	12.000	10.000
Spray dry blood plasma	6.000	4.000
Soy oil	2.271-3.471-4.671	2.280-3.480-4.690
Dicalcium phosphate	1.675	1.510
Limestone	0.644	0.788
Salt	0.000	0.027
Premix mineral and vitamin[1]	0.150	0.150
L-Lysine HCl	0.307-0.372-0.438	0.268-0.320-0.371
DL-Methionine	0.151-0.179-0.208	0.122-0.145-0.168
L-Treonine	0.071-0.104-0.138	0.054-0.081-0.108
L-Tryptophan	0.001-0.009-0.018	0.001-0.009-0.018
Probiotic	0.200	0.200
Halquinol	0.050	0.050
Kaolin	2.700-1.366-0.028	2.699-1.389-0.070
---Nutritional composition[2]---		
Crude protein, %	19.02-19.12-19.22	20.03-20.12-20.20
Metabolizable energy, kcal kg^{-1}	3,300-3,400-3,500	3,250-3,350-3,450
Net energy, kcal kg^{-1}	2,440-2,532-2,624	2,421-2,513-2,605
Digestible lysine, %	1.407-1.457-1.508	1.281-1.321-1.361
Digestible meth + cyst, %	0.788-0.816-0.845	0.717-0.740-0.762
Digestible treonine, %	0.887-0.918-0.950	0.807-0.833-0.858
Digestible tryptophan, %	0.253-0.262-0.271	0.230-0.238-0.245
Calcium, %	0.850	0.825
Digestible phosphorus, %	0.450	0.410
Sodium, %	0.296	0.230

[1]Content per kilogram of product: vit. A: 1,250,000 UI, vit. D3: 250,000 UI, vit. E: 6,250 UI, vit. K3: 750 mg, vit. B1: 375 mg, vit. B2: 1,000 mg, vit. B6: 375 mg, vit. B12: 4,500 mg, pantothenic acid: 2,300 mg, folic acid: 125 mg, iron: 25 mg, copper: 3,750 mg, manganese: 12.5 g, zinc: 31.25 g, iodine: 250 mg, selenium: 75 mg, and excipient.

[2]Values calculated based on the nutritional composition of raw materials (ROSTAGNO et al., 2011).

as a covariate in the statistical model to analyze the performance variables. The Student Newman Keuls test was used to compare the means of the performance variables. The Friedman test was used to compare the fecal scores and the occurrence of diarrhea. The 5% level of significance was applied.

RESULTS AND DISCUSSION

The average values recorded for environmental conditions were 25.9 ± 1.76 °C, 78.6 ± 2.26, and 87.7 ± 9.25 for temperature, WBGT, and relative humidity, respectively. Results observed in the present study indicated that temperatures remained within the temperature range (22 to 26 °C) considered ideal for this category of piglets (KUMMER et al., 2009).

There was no effect (P>0.05) of the increase in energy density in sequential plans on the performance of piglets from 7 to 10 kg (Table 3). From 7 to 15 kg, there was no effect (P>0.05) of the sequential plans feeding on final weight, daily feed intake, and daily intake of digestible lysine. Conversely, the intake of

Table 2 - Centesimal and nutritional composition of experimental diets from 15 to 30 kg.

Ingredients (%)	------------------------------------Phases-------------------------------------	
	15 to 20 kg	20 to 30 kg
Corn (7.88%)	62.119	67.096
Soybean meal (46.5%)	23.465	25.373
Dried whey	5.000	0.000
Spray dry blood plasma	2.000	0.000
Soy oil	1.523-2.728-3.933	0.993-2.198-3.403
Dicalcium phosphate	1.453	1.656
Limestone	0.798	0.759
Salt	0.204	0.457
Premix mineral and vitamin[1]	0.150	0.150
L-Lysine HCl	0.238-0.282-0.326	0.360-0.404-0.448
DL-Methionine	0.070-0.089-0.108	0.100-0.119-0.138
L-Treonine	0.031-0.053-0.075	0.093-0.115-0.138
L-Tryptophan	0.000-0.006-0.012	0.012-0.018-0.024
Probiotic	0.200	0.200
Halquinol	0.050	0.050
Kaolin	2.699-1.403-0.107	2.701-1.405-0.108
---Nutritional composition[2]---		
Crude protein, %	18.03-18.10-18.17	17.44-17.51-17.59
Metabolizable energy, kcal kg^{-1}	3,200-3,300-3,400	3,150-3,250-3,350
Net energy, kcal kg^{-1}	2,410-2,501-2,593	2,384-2,475-2,567
Digestible lysine, %	1.071-1.105-1.139	1.054-1.088-1.122
Digestible meth + cyst, %	0.600-0.619-0.637	0.590-0.609-0.627
Digestible treonine, %	0.675-0.696-0.717	0.664-0.685-0.706
Digestible tryptophan, %	0.196-0.201-0.207	0.189-0.195-0.201
Calcium, %	0.773	0.773
Digestible phosphorus, %	0.370	0.370
Sodium, %	0.200	0.200

[1]Content per kilogram of product: vit. A: 1,250,000 UI, vit. D3: 250,000 UI, vit. E: 6,250 UI, vit. K3: 750 mg, vit. B1: 375 mg, vit. B2: 1,000 mg, vit. B6: 375 mg, vit. B12: 4,500 mg, pantothenic acid: 2,300 mg, folic acid: 125 mg, iron: 25 mg, copper: 3,750 mg, manganese: 12.5 g, zinc: 31.25 g, iodine: 250 mg, selenium: 75 mg, and excipient.

[2]Values calculated based on the nutritional composition of raw materials (ROSTAGNO et al., 2011).

ME and NE was influenced (P<0.05) by the plan, in which the increase in the energy of the diets resulted in an increase in the daily consumption of ME and NE, even without significant variation in feed intake. This result is related to the nutrient density of the diets that directly affected the energy intake of the animals.

Nutritional plans also influenced (P<0.05) daily weight gain, in which piglets fed sequential plans 2 (3,400-3,350 kcal ME) and 3 (3,500-3,450 kcal ME) showed a higher gain compared to the plan sequential 1 (3,300-3,250 kcal ME). Considering the increase in daily weight gain without changing the daily feed intake, feed conversion was better in phase plans 2 and 3 than in plan 1 (P<0.05).

Sequential plans influenced (P < 0.05) the final weight, daily feed intake, daily intake of ME, daily intake of NE, daily intake of digestible lysine, daily weight gain, and feed conversion, from 7 to 20 kg, from 7 to 25 kg, and from 7 to 30 kg. Final weight, daily weight gain, daily feed intake, daily intake of ME, and daily intake of digestible lysine were higher (P<0.05) and feed conversion was improved (P<0.05) in piglets fed sequential plans 2 and 3 in comparison to plan 1. A higher daily intake of NE (P<0.05) was

Table 3 - Performance of piglets fed with sequential ME plans from 7 to 30 kg.

Phases	Variables	--------------Sequential ME plans----------------			CV, %	P value
		1	2	3		
7 to 10 kg	IW, kg	7.10	6.90	6.94	-	-
	FW, kg	10.47	10.79	10.83	9.38	0.652
	DFI, kg	0.318	0.439	0.425	24.17	0.400
	DMEI, kcal	1,261	1,486	1,486	25.07	0.254
	DNEI, kcal	937	1,112	1,120	25.26	0.222
	DDLI, g	5.375	6.390	6.403	24.71	0.211
	DWG, kg	0.281	0.324	0.325	26.77	0.387
	FC, kg kg^{-1}	1.361	1.366	1.339	13.68	0.919
7 to 15 kg	FW, kg	14.19	14.87	15.10	7.42	0.144
	DFI, kg	0.495	0.538	0.532	11.92	0.222
	DMEI, kcal	1,618^{b}	1,817^{a}	1,846^{a}	12.02	0.036
	DNEI, kcal	1,205^{c}	1,362^{b}	1,393^{a}	12.05	0.021
	DDLI, g	6.611	7.457	7.592	15.31	0.329
	DWG, kg	0.338^{b}	0.380^{a}	0.389^{a}	14.03	0.044
	FC, kg kg^{-1}	1.458^{b}	1.432^{b}	1.366^{a}	6.67	0.050
7 to 20 kg	FW, kg	20.14^{b}	22.12^{a}	21.84^{a}	5.45	<0.001
	DFI, kg	0.627^{b}	0.699^{a}	0.690^{a}	6.42	<0.001
	DMEI, kcal	2,029^{b}	2,333^{a}	2,372^{a}	6.48	<0.001
	DNEI, kcal	1,518^{b}	1,758^{a}	1,817^{a}	7.01	<0.001
	DDLI, g	7.574^{b}	8.712^{a}	8.868^{a}	8.88	0.036
	DWG, kg	0.408^{b}	0.476^{a}	0. 466^{a}	8.06	<0.001
	FC, kg kg^{-1}	1.536^{b}	1.473^{a}	1.482^{a}	4.44	0.048
7 to 25 kg	FW, kg	24.32^{b}	27.28^{a}	27.00^{a}	4.90	<0.001
	DFI, kg	0.695^{b}	0.799^{a}	0.782^{a}	5.77	<0.001
	DMEI, kcal	1,893^{b}	2,260^{a}	2,265^{a}	8.20	<0.001
	DNEI, kcal	1,421^{c}	1,708^{b}	2,044^{a}	7.02	<0.001
	DDLI, g	8.117^{b}	9.606^{a}	9.697^{a}	7.66	0.008
	DWG, kg	0.441^{b}	0.522^{a}	0.514^{a}	6.67	<0.001
	FC, kg kg^{-1}	1.579^{b}	1.532^{a}	1.521^{a}	3.98	0.046
7 to 30 kg	FW, kg	28.37^{b}	31.71^{a}	31.13^{a}	4.61	<0.001
	DFI, kg	0.774^{b}	0.867^{a}	0.855^{a}	4.69	<0.001
	DMEI, kcal	2,478^{b}	2,862^{a}	2,908^{a}	4.62	<0.001
	DNEI, kcal	1,637^{c}	1,906^{b}	2,228^{a}	5.75	<0.001
	DDLI, g	8.863^{b}	10.238^{a}	10.413^{a}	5.98	0.004
	DWG, kg	0.483^{b}	0.564^{a}	0.550^{a}	5.93	<0.001
	FC, kg kg^{-1}	1.603^{b}	1.542^{a}	1.555^{a}	3.62	0.042
	R$ kg^{-1} of WG	0.591^{a}	0.502^{b}	0.529^{b}	13.07	0.013
	IEE, %	66.40^{b}	78.36^{a}	73.34^{b}	12.97	0.017

Means followed by different letters on the same line differ by the SNK test ($P < 0.05$).

IW: initial weight, FW: final weight, DFI: daily feed intake, DMEI: daily metabolizable energy intake, DNEI: daily net energy intake, DDLI: daily digestible lysine intake, DWG: daily weight gain, FC: feed conversion, WG: weight gain, IEE: economic efficiency index. Sequential ME plans: 1: 3,300-3,250-3,200-3,150 kcal kg^{-1} (7-10 kg; 10-15 kg; 15-20 kg; 20-30 kg), 2: 3,400-3,350-3,300-3,250 kcal kg^{-1} (7-10 kg; 10-15 kg; 15-20 kg; 20-25 kg), and 3: 3,500-3,450-3,400-3,350 Kcal kg^{-1} (7-10 kg; 10-15 kg; 15-20 kg; 20-30 kg).

observed in sequential plan 3, which was higher than plan 2, which was higher than plan 1.

Animals tend to adjust feed intake on energy content of the diet. Increase in the energy level of the diet causes feed intake to decrease such that energy intake remains constant (OLIVEIRA et al., 2005, BEAULIEU et al., 2009; PEREIRA et al., 2011).

There is also the hypothesis that for weaned piglets, due to their limited stomach capacity, the increased concentration of energy in the diet stimulates energy intake and increases weight gain (ORENSAYA et al., 2008). Consumption adjustments have been observed in the literature in diets formulated both for digestible energy (BEAULIEU et al., 2009), and for ME (HASTAD et al., 2001a; PEREIRA, 2011) or NE (GONÇALVES et al., 2015). However, this adjustment of daily intake according to the energy density of the diet was not obtained in the present study from 7 to 10 kg and from 7 to 15 kg.

From 7 to 20 kg, from 7 to 25 kg, and from 7 to 30 kg, there was an influence ($P<0.05$) of energy density on daily feed intake in the phase plans. Contrary to that reported in the literature (SCHNEIDER et al., 2010, PEREIRA et al., 2011) where an increase in energy in the diet reduced feed intake, phase feeds with a higher energy content increased daily feed intake. This may indicate that piglets in the starter phase do not demonstrate this “nutritional wisdom” for energy adjustments, possibly due to their physiological immaturity.

Nevertheless, the improvements in weight gain and final weight responses obtained in plans 2 and 3 at 20, 25, and 30 kg, can be explained by the increase in feed intake and, therefore, intake of energy and nutrients such as amino acids. However, the effect of increasing the energy density of the diet on the performance of weaned piglets is not resolved.

Similar to the present study, the results obtained by HASTAD et al. (2001a) and BEAULIEU et al. (2009) also showed an improvement in weight gain by increasing the energy concentration of the diet. However, other researchers such as TOKACH et al. (1995), HASTAD et al. (2001b), and BEAULIEU et al. (2006) did not improve performance with an increase in the energy density of the diets.

The sequential feeding plans did not change the efficiency of nutrient use from 7 to 10 kg in the trial period. However, increasing the experimental period resulted in improved feed conversion. Only 7 to 15 kg piglets fed phase plan 3 showed an improved feed conversion.

Piglets on sequential plans 2 and 3 showed a better feed conversion compared to plan 1. With the increase in the daily feed intake, the pigs on the higher energy concentrations showed higher daily weight gain and final weight, from 7 to 20 kg, from 7 to 25 kg, and from 7 to 30 kg.

Response in feed conversion to energy density was only evidenced over longer periods, demonstrating a residual effect of the previous phase. An improvement in feed conversion with increased energy concentration was also reported in piglets of a similar weight range by SCHNEIDER et al. (2010) and PEREIRA et al. (2011). However, these researchers attributed the improvement in feed conversion to the reduction in feed intake, since weight gain was similar among energy levels.

The recommended sequential plan is the one that contains an intermediate energy density (plan 2) because it is more economically viable, since the increase in energy density from plan 2 to 3 does not promote an improvement in animal performance. Sequential plan 2 showed a better economic efficiency index (78.36%), even though the cost of feed per kilogram of weight gain between plans 2 and 3 did not differ statistically. The feed cost of 0.50s R$ kg^{-1} of weight gain in plan 2 rose to 0.529 R$ kg^{-1} of weight gain in sequential plan 3, and this is due to the fact that increasing the energy density of the diet increased the cost of the feed.

Most of the studies in the literature have evaluated the energy density of the diets without using sequential feeding, i.e., they have evaluated unique levels from the beginning to the end of the experimental period. The study by RIBEIRO et al. (2016) recommends a single level of 3,400 kcal ME kg^{-1} of feed for piglets from 6 to 18 kg. Likewise, other studies have also established unique levels of ME kg^{-1} of feed for the initial stages of growth, such as 3,264 kcal ME kg^{-1} proposed by OLIVEIRA et al. (2005) for piglets from 15 to 30 kg, and 3,250 kcal ME kg^{-1} recommended by ARNAIZ et al. (2009) for piglets from 5 to 17 kg.

Sequential plan 2, considered ideal for piglets from 7 to 30 kg in the present study, suggested levels above the recommendations of 3,265 kcal ME kg^{-1} for piglets from 5 to 50 kg (NRC, 1998) and of 3,325 and 3,230 kcal ME kg^{-1} for piglets from 7 to 15 kg and from 15 to 30 kg, respectively (ROSTAGNO et al., 2005), but it is close to the ME levels recommended by ROSTAGNO et al. (2011), NRC (2012) and ROSTAGNO et al. (2017).

There was no effect ($P > 0.05$) of the plans on the fecal score and on the incidence of diarrhea. It is possible to infer that even the sequential plans containing higher concentrations of energy (and soybean oil) did not cause digestive disorders to the point of causing diarrhea. Furthermore, diets didn't cause diarrhea, since all sequential plans had an average score less than one.

CONCLUSION

It is recommended the sequential plan containing 3,400-3,350-3,300-3,250 kcal ME kg^{-1} of feed be used from 7 to 10 kg, from 10 to 15 kg, 15 to 20 kg and from 20 to 30 kg, respectively, which is equivalent to the levels of 2,546-2,513-2,501-2,475 kcal NE kg^{-1} of feed for starter period.

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BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

The project was approved by the ethics committee in the use of animals, protocol number 874/2017 – Universidade Federal de Mato Grosso do Sul (UFMS).

DECLARATION OF CONFLICT OF INTERESTS

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.

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