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Neutralized semi-purified glycerin in pre-starting piglet feeding (6 To 15 kg)

Glicerina semipurificada neutralizada na alimentação de leitões na fase pré-inicial (6 A 15 kg)

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Abstract

Two experiments were carried out to determine the nutritional value of neutralized semi-purified glycerin (NSPG) and to evaluate the performance of pre-starting piglets (6-15 kg) fed on diets containing increasing levels of NSPG. In Experiment I, a digestibility trial with 30 barrows (11.80 ± 5.12 kg live weight) was conducted, in which they were allotted in a randomized block design. Replacement levels of the basal diet by NSPG were 3, 6, 9, and 12%. The values (as-fed-base) of digestible energy (DE) and metabolizable energy (ME) of NSPG were 3535 and 3279 kcal/kg, respectively. In Experiment II, 135 piglets, weaned at 21 days of age (6.85 ± 1.28 to 15.04 ± 2.06 kg), were allotted in a randomized-block design. Treatments consisted of five diets (3, 6, 9, and 12% NSPG as well as a control diet with 0% of NSPG), with nine replications, and three piglets per experimental unit. The results show that, in the pre-starting I (6-10 kg) phase, adding NSPG promoted a linear improvement in the average daily gain (ADG) and the feed-to-gain ratio (F:G). For the total period (6-15 kg), only linear improvements ($P \leq 0.05$) to ADG were observed. The plasma variables were not influenced ($P \geq 0.05$) by the inclusion of NSPG, as it remained within the biological range of the species. The results suggest that up to 12% NSPG can be included in the diets of piglets (6-15 kg) without impairing the plasmatic variables, performance, and economic feasibility.

Key words: Biodiesel, co-product, piglet, performance

Resumo

Foram conduzidos dois experimentos com o objetivo de determinar o valor nutricional da glicerina semipurificada neutralizada (GSPN) e avaliar o desempenho de suínos na fase pré-inicial (6 a 15 kg), alimentados com rações contendo níveis crescentes de GSPN. No Experimento I, foi conduzido um ensaio de digestibilidade com 30 leitões machos castrados (11,80 ± 5,12 kg), distribuídos em um delineamento em blocos casualizado. Os níveis de substituição da ração referência pela GSPN foram 3, 6, 9 e 12%. Os valores (na matéria natural) de Energia Digestível (ED) e Energia Metabolizável (EM)

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da GSPN foram 3535 kcal/kg e 3279 kcal/kg respectivamente. No Experimento II, foram utilizados 135 leitões recém-desmamados com 21 dias de idade (6,85±1,28 a 15,04±2,06 kg), distribuídos em delineamento experimental de blocos casualizado. Os tratamentos consistiram de cinco rações, (3, 6, 9, 12% de GSPN e uma ração testemunha com 0% de GSPN), com nove repetições e três leitões por unidade experimental. Os resultados demonstram que na fase pré-inicial I (6 a 10 kg) a adição de GSPN promoveu melhora linear no ganho diário de peso (GDP) e conversão alimentar (CA). Para o período total (6 a 15 kg), foi observado apenas melhora linear ($P \leq 0{,}05$) para GDP. As variáveis plasmáticas não foram influenciadas pela inclusão da GSPN. Os resultados sugerem que a GSPN pode ser incluída em até 12% em rações para leitões (6 a 15 kg) sem influenciar as variáveis plasmáticas, de desempenho e as variáveis econômicas.

Palavras-chave: Biodiesel, coproduto, desempenho, leitão

Introduction

Feeding represents approximately 70-80% of swine production costs, which suggests that the search for alternative feedstuffs that can replace traditional ingredients in pig diets would be beneficial. Among these alternative ingredients is glycerol, which is the main co-product of biodiesel production.

With the increasing demand for biodiesel production, there is an increase in the availability of glycerin, which is characterized as a sweet-tasting liquid with a similar energy to corn (GROESBECK et al., 2008); this raises interest in studies into its use in animal feeding. According to Carvalho et al. (2013), this co-product can be marketed in either its crude (high content of fatty acids) or semi-purified (low fatty acid content) form.

Research conducted with poultry (GUERRA et al., 2011) and swine (BERENCHTEIN et al, 2010; SCHIECK et al., 2010) has shown that glycerin can be an energetic ingredient with great potential in animal feeding. Therefore, this study was conducted to determine the nutritional value of semi-purified neutralized glycerin (NSPG) and to evaluate the effects of its inclusion levels (3, 6, 9, and 12%) in the diets of piglets, based on the performance of piglets in the pre-starting phase (6-15 kg), as well to verify the economic feasibility of its use in piglet feeding.

Material and Methods

The experiments were carried out between May 2011 and April 2012 at the Pig Barn in the Iguatemi Experimental Farm, which belongs to Maringa State University (CCA / UEM).

The neutralized semi-purified glycerin (NSPG) studied was obtained from tBSBIOS (Marialva - PR).

Analyses of the moisture content, total glycerol, methanol, and density were performed at the Paraná Technology Institute (TECPAR). Determination of the pH, protein, mineral, gross energy (adiabatic calorimeter - Parr Instrument Co.), and sodium chloride levels was carried out in the Animal Nutrition Laboratory (LANA) at Maringa State University, according to the procedures described by Silva and Queiroz (2002). The total lipid contents, fatty acid profiles, and acidity index were analyzed at the Technology Institute of Food (ITAL). Organic matter non-glycerol (OMNG) was calculated by the equation: OMNG = 100 - (% glycerol + % humidity + % ash).

NSPG showed the following energy and chemical composition: humidity (11.89%), glycerol (80.20%), crude protein (0.90%), gross energy (3.535 kcal kg^{-1}), OMNG (1.73%), total lipids (<0.10 g 100 g^{-1}), saturated fatty acids (22.70%), monounsaturated (31.30%), polyunsaturated (43.70%), omega 3 (6.50), omega 6 (37.20), methanol (0.01%), ash (6.18%), sodium chloride (5.86%), calcium (92.18 ppm), phosphorus (158.52 ppm), potassium (0.42%), sodium (3.52%), chloride (2.34 %), magnesium (45.13 ppm), copper (0.24 ppm), chrome (0.63 ppm), iron (23.72 ppm), zinc (0.39 ppm), manganese (0.80 ppm), aluminum (30.65 ppm), cobalt (0.83 ppm), molybdenum (0.16 ppm), lead (0.98 ppm), as well as pH (6.70), density (1.27 kg m^3), and acidity index (0.20 mg KOH g^{-1}).

Experiment I: Digestibility Assay

A total of 30 barrows from a commercial line, with a live weight of 11.80 ± 5.12 kg, were used in the digestibility assay. They were individually housed in metabolism cages, similar to those described by Pekas (1968), in a room at a controlled temperature. The average minimum and maximum temperatures during the experimental period were 24.10 ± 1.03°C and 25.40 ± 0.77°C, respectively.

A basal diet, based on corn and soybean meal, was formulated according to the requirements proposed by Rostagno et al. (2011). The basal diet was replaced by 3, 6, 9, and 12% NSPG, which resulted in four test diets, thus completing five experimental diets.

The methods used to conduct the experiment were those indicated by Sakomura and Rostagno (2007). The total collection of feces method was used and 2% ferric oxide (Fe_2O_3) was added to the diets as a marker, in order to identify the beginning and the end of fecal sampling.

The digestible energy (DE) and metabolizable energy (ME) were estimated by linear regression analysis (ADEOLA; ILELEJI, 2009) of the DE and ME (kcal kg^{-1}) intake, related to glycerin versus NSPG consumption (kg), referring to 30 piglets in 5 days.

Experiment II: Performance of Piglets in the Pre-Starting Phase (6-15 kg).

A total of 135 weaned piglets, with an initial and final body weight of 6.85 ± 1.28 and 15.04 ± 2.06 kg, respectively, were used. The experimental diets (Table 1) for the pre-starting I (6-10 kg) and pre-starting II (10-15 kg) phases were formulated according to the requirements proposed by Rostagno et al. (2011).

The animals were allotted in a randomized-block design. The treatments consisted of four inclusion levels of NSPG (3, 6, 9, and 12%), with nine replications, and three piglets per pen, which represented an experimental unit. Additionally, a control diet (CD) without NSPG was formulated. Throughout the experimental period (6-15 kg), all animals received the same treatment (levels of NSPG), in which just the nutritional requirements in each phase (6-10 and 10-15 kg) were changed.

At the beginning (baseline) and end of each experimental period, blood samples from the cranial vena cava were harvested to analyze triglycerides, alanine aminotransferase (ALT), aspartate aminotransferase (AST), plasma urea nitrogen (PUN), and creatinine levels. For the determination of glucose, samplings were performed at the end of each experimental period, after 8 h of fasting, and the blood was placed in tubes containing sodium fluoride and potassium oxalate.

For plasma and serum analysis, commercial kits (Gold Analisa Diagnostica Inc.) were used. The baseline values of PUN, analyzed at the beginning of the experiment, were used as the covariate for statistical analysis.

In order to evaluate the economic feasibility of NSPG, the prices of raw materials were obtained from a local market. The cost of feed per kilogram of live weight gain (BELLAVER et al., 1985), the economic efficiency index (EEI), and cost index (CI) were calculated, according to the methodology proposed by Gomes et al. (1991).

The results were submitted to analysis of variance using the statistical model Y*jkm* = μ + S*j* + N*k* + e*jkm*, where Y*jkm* is the observation of animal *m* at inclusion level *k*, μ is a constant associated with all observations, N*k* is the effect of NSPG levels with *k* = 3, 6, 9, or 12%; e*jkm is the* random error associated with the observation.

Table 1. Chemical and energetic composition (as fed basis) and costs of diets containing different inclusion levels of neutralized semi-purified glycerin (NSPG) for pigs in the pre-starting phase I (6-10 kg)/ pre-starting phase II (10-15 kg).

Item, %	Inclusion levels of NSPG, %				
	0,0	3,0	6,0	9,0	12,0
Corn	47,67/49,27	44,46/46,07	41,13/43,97	37,65/40,70	34,09/37,46
Neutralized glycerin	-/-	3,00/3,00	6,00/6,00	9,00/9,00	12,0/12,0
Soybean meal	25,94/33,82	26,49/34,34	27,14/33,69	27,65/33,95	28,26/34,22
Whey	13,00/10,00	13,00/10,00	13,00/10,00	13,00/10,00	13,00/10,00
Skimmed milk	6,00/-	6,00/-	6,00/-	6,00/-	6,00/-
Soybean oil	3,20/3,12	3,07/2,99	2,94/2,85	2,91/2,83	2,89/2,81
Limestone	0,81/0,92	0,81/0,91	0,81/0,91	0,81/0,91	0,80/0,90
Calcium phosphate	1,51/1,44	1,51/1,44	1,51/1,45	1,51/1,46	1,51/1,46
Salt	0,35/0,34	0,17/0,16	0,00/0,00	0,00/0,00	0,00/0,00
L-Lysine HCL	0,45/0,26	0,43/0,25	0,42/0,27	0,41/0,27	0,39/0,27
DL-Methionine	0,25/0,16	0,25/0,17	0,25/0,18	0,26/0,19	0,26/0,19
L-Threonine	0,23/0,12	0,22/0,12	0,22/0,13	0,22/0,14	0,22/0,14
L- Tryptophan	0,04/0,00	0,04/0,00	0,03/0,00	0,03/0,00	0,03/0,00
Calculate values[1]					
ME[1], Kcal kg^{-1}	3,400/3,374	3,400/3,374	3,400/3,375	3,400/3,375	3,400/3,375
Crude protein[1], %	20,00/21,16	20,00/21,15	20,00/20,73	20,00/20,61	20,00/20,49
Lactose	12,10/7,00	12,10/7,00	12,10/7,00	12,10/7,00	12,10/7,00
Calcium[1], %	0,85/0,82	0,85/0,82	0,85/0,82	0,85/0,82	0,85/0,82
Available phosphorus[1], %	0,50/0,44	0,50/0,45	0,50/0,45	0,50/0,45	0,50/0,45
Available lysine[1], %	1,45/1,33	1,45/1,33	1,45/1,33	1,45/1,33	1,45/1,33
Available Met + Cys[1],%	0,81/0,74	0,81/0,74	0,81/0,74	0,81/0,74	0,81/0,74
Available threonine[1], %	0,91/0,83	0,91/0,83	0,91/0,83	0,91/0,83	0,91/0,83
Available Tryptophan[1], %	0,26/0,23	0,26/0,23	0,26/0,23	0,26/0,23	0,26/0,23
Sodium %	0,28/0,22	0,28/0,22	0,28/0,23	0,35/0,30	0,41/0,37
Glycerol[1], %	-/-	2,40/2,40	4,81/4,81	7,21/7,21	9,62/9,62
Cost[2], R$ kg^{-1}	2,15/1,44	2,14/1,44	2,13/1,43	2,13/1,42	2,12/1,42

[#-] All diets contained: vitamin and mineral supplement for starting pigs (0,5%); Lincomycin -30 (0,05%); [1-] Calculated based on the composition of foods indicated by Rostagno et al. (2011) and/or estimated; [2-] Cost in the local market.

Statistical analyses were performed using the statistical package SAEG (Federal University of Viçosa, 1997). The degrees of freedom regarding the inclusion levels of NSPG were deployed in orthogonal polynomials in order to obtain the regression equations. In the performance experiment, the initial body weight of the pigs was used as a covariate. In the study of economic feasibility, the Dunnett's test was applied to compare the cost of feed per kilogram live weight gain (Cost, R$ kg

BW^{-1}) of the control diet (0% of NSPG) with each inclusion level of NSPG.

Results and Discussion

The chemical and energetic composition of NSPG was similar to that obtained by Kerr et al. (2009), who found 86.95% glycerol and 0.03% methanol. The amount of glycerol (80.20%) was similar to that established by MAPA (2010) (80%) and that found by Berenchtein et al. (2010) (80%), who evaluated the inclusion of semi-purified glycerin (from beef tallow) in pigs diets during the growing and finishing phases.

Owing to the different steps in the biodiesel production, glycerin (co-product) shows a large variation in its chemical and physical composition. This can be observed in the studies conducted by Carvalho et al. (2012), who studied two kinds of crude glycerin (a vegetable source as well as a mixed source of animal and vegetable sources) and obtained 5247 and 5242 kcal kg^{-1} gross energy, 55.95 and 55.45% glycerol, respectively. Likewise, Piano et al. (2013) studied two types of semi-purified glycerin (vegetable and mixed sources) and found 3760 and 3217 kcal kg^{-1} gross energy and 74.94 and 68.66% glycerol, respectively.

In the composition of crude glycerin, there may be fond residues of NaCl (3%) and a considerable amount of free fatty acids (KERR, 2011), which contribute to an increase in the gross energy and methanol values of the glycerin. On the other hand, semi-purified glycerin has a low amount of fatty acids and catalytic residues in its composition, which make it a better-quality ingredient for use in the diets for animals, especially non-ruminants such as pigs (LAMMERS et al., 2008a; SHIELDS et al., 2011; HANSEN et al., 2009), broilers (GUERRA et al., 2011), and rabbits (RETORE et al., 2012).

We do not observe any symptom of intoxication in the animals that consumed glycerin. Different studies performed previously (KERR et al., 2009; LAMMERS et al., 2008b; SCHIECK et al., 2010; SHIELDS et al., 2011; BERENCHTEIN et al., 2010) also did not report any injuries related to the toxicity of methanol in the organs of animals.

In the digestibility assay, the coefficient of digestibility (digestibility coefficient of dry matter, DCDM: 88.08%; digestibility coefficient of organic matter, DCOM: 106.93%; digestibility coefficient of gross energy, DCGE: 99.99%), the GE metabolizability coefficient (92.77%) and the digestible nutrients of NSPG (Table 2) showed that this co-product can be a great energy source for pre-starting piglets (6-15 kg).

The values of the metabolizability (Table 2) of GE (92.77%) and the digestible nutrients (DDM: 77.61%; DE: 3535 kcal kg^{-1}; ME/DE: 93%) are higher than those obtained (71.60%; 74.73%; 3298 kcal kg^{-1}; 77%, respectively) by Gallego et al. (2014), who studied NSPG for pigs from 15 to 30 kg body weight. Furthermore, the digestibility coefficient of organic matter (106.93%) was similar to that found by Piano et al. (2013) for vegetal semi-purified glycerin.

Table 2. Apparent digestibility coefficients (DC), metabolizability coefficient (MC), digestible dry matter (DDM), organic matter (DOM) and digestible (DE) and metabolizable energy (ME) of neutralized semi-purified glycerin obtained by conventional method (total collection) for pre-starting piglets.

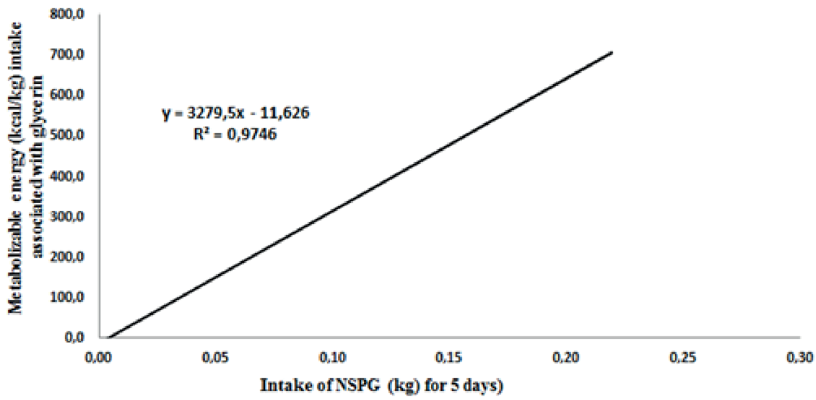
Digestibility (%)	NSPG	Digestible amount (%)	As feed basis
DC of dry matter	88,08	DDM, %	77,61
DC of organic matter	106,93	DOM, %	90,07
DC of gross energy	99,99	DE, kcal kg^{-1}	3535
MC of gross energy	92,77	ME, kcal kg^{-1}	3279

DDM: Digestible dry matter; DOM: Digestible organic matter; DE: Digestible energy; ME: Metabolizable energy. ED:EM= 0,93.

Studying the inclusion of semi-purified glycerin in pig feed containing 80% glycerol, Lammers et al. (2008b) found a ME value of 3638 kcal kg^{-1}. On the other hand, Bartelt and Schneider (2002), working with different inclusion levels (5, 10, and 15%) of semi-purified glycerin, obtained ME values of 4177, 3436, and 2524 kcal/kg, respectively.

The glycerin intake increased according to the increasing levels of NSPG in the diets. The ME value of NSPG, estimated by regression analysis (Figure 1), was 3279 kcal kg^{-1} (Table 2). The ME/DE ratio was higher (93%) compared to that obtained (77%) by Gallego et al. (2014) for pigs in the growing phase.

Figure 1. Regression equation of the ME of neutralized semi-purified glycerin (NSPG), obtained from the regression of metabolizable energy (kcal/kg) intake associated with glycerin vs. intake of NSPG (kg) during 5 days.



Considering the performance study (Table 3), the feed intake was not affected ($P > 0.05$) by the inclusion levels of NSPG. However, the regression analysis for the pre-starting phase showed that the average daily gain (ADG) increased linearly, according to the increasing levels of NSPG, which also improves the feed-to-gain (F:G) ratio.

Table 3. Performance of piglets in the pre-starting I (6-10 kg) phase and the total period (6-15 kg) fed with neutralized semi-purified glycerin (NSPG).

Item	Inclusion levels of NSPG, %					Mean ±SE	Regression	
	0	3	6	9	12		Lin	Quad
Pre-Starting I (6 to 10 kg) Phase								
DFI[1], kg	0,368	0,388	0,379	0,380	0,398	0,387±0,007	0,171	0,868
ADG[2], kg	0,240	0,268	0,262	0,276	0,299	0,269±0,005	0,001	0,798
G:F[3]	1,61	1,50	1,51	1,45	1,38	1,51±0,024	0,015	0,829
Total period (6 to 15 kg)								
DFI[1], kg	0,469	0,522	0,497	0,518	0,518	0,505±0,008	0,170	0,427
ADG[2], kg	0,305	0,347	0,346	0,356	0,361	0,343±0,005	0,005	0,179
G:F[3]	1,60	1,52	1,45	1,48	1,45	1,50±0,024	0,077	0,406

[1]DFI = Daily feed intake; [2]ADG = Average Daily Gain; [3]G:F= Gain:Feed ratio; Pre-Starting Phase - ADG: (Y=0,24715 + 0,00363762X); G:F: (Y= 1,59310 - 0,0164028X); Total period - ADG: (Y= 0,321829 + 0,00350389X).

In a similar study of NSPG inclusion levels up to 14%, in pigs from 15 to 30 kg body weight, Gallego et al. (2014) did not find any effect of glycerin on the average daily feed intake (DFI), ADG, or F:G ratio.

Studying the replacement of crude glycerin by increasing levels of lactose for pigs after weaning, Shields et al. (2011) observed an increase in ADG and improvements in the F:G ratio 14 days after weaning. Additionally, Groesbeck et al. (2008) indicated that inclusion levels of crude glycerin up to 12% in piglet diets improved the DFI and ADG, but no differences were observed in terms of the F:G ratio.

In another study on the inclusion levels of two kinds of crude glycerin (vegetal and mixed sources) in pigs (15-30 kg), Carvalho et al. (2012) observed no effect on pig performance. Similar results were obtained by Piano et al. (2013), who evaluated the inclusion levels of semi-purified glycerin (vegetal and mixed sources) in pig diets during the growing and finishing phases, and observed that this co-product can be included at levels up to 16% without impairing the pigs performance.

In this study, with increased inclusion levels of NSPG, there were changes in the diet structure, especially for 9 and 12% NSPG, which presented a large amount of pellets, and thus a high consistence. Probably, the mixture of glycerin with powder milk and milk whey in the diets contributed to this characteristic; however it did not affect the average DFI of piglets during pre-starting phase I and in throughout the total period.

The results from plasmatic analysis (Table 4) show that the inclusion levels of NSPG in pre-starting phase I (6-10 kg) promoted a linear increase ($P \leq 0.05$) for triglycerides and aspartate aminotrasnferase (AST), and a quadratic effect ($P \leq 0.05$) for alanine aminotransferase (ALT), in which the maximum value was observed to be 5.49% NSPG. No effects ($P \geq 0.05$) were observed for glucose, PUN, and creatinine. Probably, the increase in plasma triglycerides is associated with the increase in the concentration of glycerol and free fatty acids, and a part of them is driven from the bloodstream to the tissue for energy production. Glycerol, on the other hand, is captured by the liver together with remaining free fatty acids to be metabolized into triglycerides, which are stored in adipocytes and fat globules before being released from the adipose tissue when necessary to obtain energy in tissues such as the skeletal muscle and heart (NELSON; COX, 2011). However, Lin et al. (1976) reported that glycerol does not affect the synthesis of triglycerides, showing a negative effect on the synthesis of fatty acids.

The increase in AST for cytoplasmic and mitochondrial enzymes is probably related to energy production in the Krebs cycle, as this enzyme is responsible for the catalysis and transformation of the amino acid aspartate to oxaloacetate, which can be used to obtain energy through the Krebs cycle.

The plasmatic levels of ALT (28-32 U L^{-1}) are within the normal biologic range (23-45 U L^{-1}) for pigs in the pre-starting phase, according to Shields et al. (2011), which is indicative that the inclusion levels of NSPG did not cause liver damage.

In the pre-starting phase II (10-15 kg), PUN and ALT decreased linearly ($P \leq 0.05$) with the inclusion levels of NSPG. This can be related to a reduction in the crude protein concentration in the diet, according to the increased inclusion levels of NSPG. Moreover, the triglycerides increased linearly with inclusion levels of NSPG.

Table 4. Serum chemistry of pigs in the pre-starting phase I (6-10 kg) and pre-starting phase II (10 to 15 kg) fed diets containing increasing levels of neutralized semi-purified glycerin (NSPG).

	Inclusion levels of NSPG, %							
Parameters	0	3	6	9	12	Mean ±SE[1]	Lin[2]	Quad[3]
			Pre-starting I (6 to 10 kg)					
Glucose (mg dL^{-1})	98,722	90,417	94,222	92,065	91,898	93,465±0,88	0,057	0,166
PUN[4] (mg dL^{-1})	10,023	9,630	9,435	9,622	9,534	9,649±0,14	0,409	0,353
Creatinine (mg dL^{-1})	1,020	0,987	0,968	0,948	0,843	0,953±0,02	0,060	0,554
Triglycerides (mg dL^{-1})	28,269	28,323	32,798	39,034	35,157	32,716±0,74	0,010	0,327
ALT[5] (U L^{-1})	28,796	31,491	31,213	30,037	28,352	29,978±0,49	0,502	0,020
AST[6] (U L^{-1})	38,583	42,102	40,635	40,787	44,906	41,403±0,81	0,050	0,680
			Pre-starting II (10 to 15 kg)					
Glucose (mg dL^{-1})	93, 741	94,917	96,537	94,342	94,435	94,794±0,94	0,902	0,451
PUN[4] (mg dL^{-1})	12,393	13,134	11,377	11,459	11,673	12,007±0,18	0,018	0,659
Creatinine (mg dL^{-1})	0,938	0,902	0,950	0,885	0,889	0,913±0,00	0,073	0,659
Triglycerides (mg dL^{-1})	28,972	37,120	39,843	38,704	40,315	36,991±0,95	0,010	0,036
ALT[5] (U L^{-1})	32,278	31,204	31,574	30,324	28,148	30,706±0,50	0,011	0,365
AST[6] (U L^{-1})	45,806	41,167	42,296	43,380	37,787	42,087±1,03	0,060	0,821

[1-] Standard error; [2-] Linear effect; [3-] Quadratic effect; [4-] Plasma Urea Nitrogen; [5-]Alanine aminotrasnferase; [6-]Aspartate aminotransferase; Pre-starting phase I - Triglycerides: (Y= 27,8183 + 0,81628X); ALT: (Y= 29,0667 + 0,841666X - 0,0766461X^2); AST: (Y= 39,1366 + 0,377701X); Pre-starting phase II - PUN: (Y=12,6434 - 0,105989X); Triglycerides: (Y= 32,1370 + 0,808950X), (Y= 29,7178 + 2,42181X - 0,134405X^2); ALT: (Y= 32,5333 - 0,304630X).

During the two first weeks of their study, Shields et al. (2011) observed a linear reduction in the glycerol and bilirubin levels, and no effect on parameters such as PUN, total protein, albumin, alkaline phosphatase, alanine aminotransferase, aspartate aminotransferase, creatine phosphokinase, cholesterol, Ca, P, Na, K, Cl, albumin, and globulin was observed. The obtained values in the present study (Table 4) were different compared to this previous study (SHIELDS et al., 2011).

The values obtained for plasmatic variables in the present study are within the normal range for pre-starting piglets (6-15 kg), which means that the animals showed no obvious problems caused by the inclusion levels of NSPG in the diets. Similar results were shown by Shields et al. (2011), who indicated that all serum concentrations were within the normal range, suggesting that is possible include crude glycerin in the diets of pigs after weaning.

Economic analysis (Table 5) showed that the inclusion of NSPG does not affect ($P \geq 0.05$) the cost per kilogram live weight gain (R\$ kg BW^{-1}), the economic efficiency index, or the cost index, which shows its economic potential as an alternative feed for pre-starting piglets (6-15 kg). These results are dependent on ingredient prices (NSPG, corn, and soybean oil).

Table 5. Cost per kilogram of feed, feed cost per kilogram of live weight gain (FC), economic efficiency index (EEI) and cost index (CI) of piglets in the pre-starting I (6-10 kg) and the total period (6-15 kg), fed with increasing levels of neutralized semi-purified glycerin (NSPG).

Item	Inclusion levels of NSPG, %					CV[1]	Dun[2]
	0	3	6	9	12		
Pre-Starting I (6 to 10 kg) Phase							
Initial weight, kg	6,50	6,45	6,44	6,44	6,46		
Finish weight, kg	10,35	10,66	10,66	10,67	11,18		
Feed cost, R$	2,157	2,149	2,136	2,131	2,127		
FC[3]	3,432	3,219	3,235	3,109	2,955	22,725	P≥0,05
EEI	85,85	91,52	90,41	95,06	100,00		
CI	116,48	109,27	110,61	105,19	100,00		
Total period (6 to 15 kg)							
Initial weight, kg	6,50	6,45	6,44	6,44	6,46		
Finish weight, kg	14,28	15,14	15,10	15,20	15,47		
Feed cost, R$	1,791	1,776	1,769	1,758	1,767		
FC[3]	2,897	2,689	2,583	2,580	2,535	15,884	P≥0,05
EEI	87,50	94,27	98,12	98,24	100,00		
CI	114,29	106,08	101,91	101,79	100,00		

[1]- Coefficient of Variation; [2]- Dunnett's test; [3]- feed cost per kilogram of live weight gain.

Conclusion

Neutralized semi-purified glycerin is a great source of metabolizable energy (3279 kcal/kg, as fed basis) for pre-starting piglets (6-15 kg) and it can be included up to 12% in piglet diets without impairing the plasmatic variables, performance, or economic feasibility.

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