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Semipurified glycerins on starting piglets feeding (15-30 kg)

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ABSTRACT. The nutritional value and the performance of piglets fed on diets with semipurified glycerin (SPGV) and mixed (SPGM) vegetable oil was determined and evaluated. Thirty-two crossbred piglets, allotted in a completely randomized block design, were used in the digestibility trial. Two types of glycerin (SPGV and SPGM) and three levels of diet (4, 8 and 12%) were studied. The experimental unit consisted of one piglet. Glycerins' metabolizable energy (ME) was estimated by regression of ME (kcal kg^{-1}) intake associated with glycerin *vs*. glycerin intake (kg). ME as-feed-basis rates were 3,373 for SPGV and 2,932 for SPGM, or rather, the glycerins are highly available energy source for piglets. In the performance trial, 90 piglets were allotted in a completely randomized blocks design in a 2 x 4 + 1 factorial scheme, two glycerins, four levels (3, 6, 9 and 12%), five replicates (pens) and two piglets per pen. A control diet with no glycerin (0%) was additionally formulated. Since no effect of glycerin inclusion on pig performance occurred, it was feasible to use up to 12% of both types of glycerin on piglets feeding.

Keywords: co-product, energy feedstuff, glycerol.

Glicerinas semipurificadas na alimentação de leitões (15-30 kg)

RESUMO. Determinou-se o valor nutricional e avaliou-se o desempenho de leitões alimentados com rações contendo glicerinas semipurificadas de origem vegetal (GSPV) e mista (GSPM). Na digestibilidade foram utilizados 32 leitões, machos castrados, distribuídos em delineamento em blocos ao acaso. Foram estudadas duas glicerinas (GSPV e GSPM) e três níveis de inclusão na dieta-teste (4, 8 e 12%). A unidade experimental consistiu de um leitão. A energia metabolizável (EM) das glicerinas foi estimada pela análise de regressão do consumo de EM (kcal kg^{-1}) associada à glicerina *vs*. o consumo de glicerina (kg). Os valores de EM (kcal kg^{-1}), na matéria natural, obtidos foram 3.373 para GSPV e 2.932 para GSPM, indicando que as duas glicerinas são fontes de alta energia disponível para a alimentação de leitões. No desempenho, foram utilizados 90 leitões, distribuídos em blocos ao acaso, em esquema fatorial 2 x 4 + 1, sendo duas glicerinas, quatro níveis de inclusão (3, 6, 9 e 12%), cinco repetições e dois leitões por unidade experimental. Adicionalmente foi formulada uma ração-testemunha sem glicerina (0%). Não houve efeito do nível de inclusão de glicerina sobre o desempenho, sugerindo que é viável a utilização em até 12% de ambas as glicerinas na alimentação de leitões.

Palavras-chave: alimento energético, coproduto, glicerol.

Introduction

The price of oil and the discussions on pollution generated by its use have boosted interest in alternative but renewable energy sources. This is the case of biodiesel, a biofuel produced from vegetable oils or animal fats. Brazil is among the greatest producers and consumers of biodiesel in the world. Glycerin, the main byproduct of biodiesel production, may be marketed in crude (with high contents of fatty acids) or in semipurified (with low contents of fatty acids) form (CARVALHO et al., 2012).

Since the energy value of glycerin may be similar to corn (GROESBECK et al., 2008), it may replace corn in rations as energy source for animal feed. The use of glycerin from different raw materials in feed for pigs has been analyzed to evaluate its effects on pigs' performance, carcass yield and meat quality.

Semipurified glycerin contains water, residues of fatty acids and methane as well as varying levels of sodium chloride (NaCl). It may be used in animal nutrition since it is an alternative source of energy in diet formulation for pigs at all production stages.

Current study was conducted to determine the nutritional value of vegetal semipurified and mixed glycerin, to evaluate the effects of its inclusion in practical diets on the performance of starter pigs (15-30 kg) and to study the economic feasibility in its use.

Material and methods

The experiments were carried out at the Pig Barn on the Experimental Farm of the Estadual University of Maringá (CCA/UEM), in Iguatemi, Paraná State, Brazil.

Two semipurified glycerins were studied: SPGV - vegetable oil (soybean), and SPGM - mixed, made from 80% animal fat + 20% soybean oil. Both were obtained from Biopar biofuel industry, Rolândia, Paraná State, Brazil.

Density, moisture content (Karl Fisher) and total glycerol analysis (Table 1) were carried out at the Paraná Technology Institute (TECPAR). Further, pH, protein, mineral and gross energy (adiabatic calorimeter - AC720 Parr Instrument Co.) rates (Table 1) were evaluated by the *Laboratório de Nutrição Animal* (LANA - UEM), following procedures by Silva and Queiroz (2002). The concentration of sodium chloride was determined at the Biopar Analyses Control Laboratory. The non-glycerin organic matter was calculated by equation provided by Hansen et al. (2009) in which MONG = 100 - [glycerin content (%) + water content (%) + ash content (%)].

Table 1. Chemical and energetic composition of semipurified glycerin types.

Nutrients	Vegetable oil semipurified glycerin	Mixed semipurified glycerin
Moisture, %	4.38	15.07
Total glycerol, %	74.94	68.66
Crude protein, %	0.06	0.04
Gross energy, kcal kg^{-1}	3,760	3,217
Total fatty acid, %	9.0	5.1
MONG, %[1]	18.62	13.05
Methanol, %	10.32	6.28
Ash, %	2.06	3.22
Sodium chloride, %	0.23	0.35
Calcium, ppm	26.25	79.81
Phosphorus, ppm	157.43	653.44
Potassium, %	0.116	0.006
Sodium, %	0.870	1.040
Chloride, %	0.360	0.381
Magnesium, ppm	7.07	38.99
Copper, ppm	0.132	0.532
Chrome, ppm	0.000	8.571
Iron, ppm	14.01	256.57
Zinc, ppm	0.194	2.234
Manganese, ppm	0.464	1.487
Aluminum, ppm	1.90	13.86
Cobalt, ppm	0.100	0.220
Lead, ppm	0.294	0.526
pH	5.60	1.67
Density, kg m^{-3}	1.183	1.189

[1]MONG: matter organic non-glycerol, defined as 100 – [glycerol content (%) + water content (%) + ash content (%)].

Two experiments were conducted: a digestibility (Experiment I) and a performance assay (Experiment II). In experiment I, thirty-two commercial crossbred barrows with 19.20 ± 1.52 kg initial body weight were used. The animals were housed individually in metabolism cages, similar to those described by Pekas (1968), in a room with controlled temperature. Average room temperatures featured minimum temperature 20.5 ± 0.86°C and maximum temperature 23.4 ± 1.00°C. Minimum and maximum average relative air humidity was respectively 39.3 ± 14.26% and 61.4 ± 14.03%.

Control diet comprised corn (70.42%), soybean meal (26.40%), salt (0.50%), limestone (0.60%), dicalcium phosphate (1.58%) and mineral vitamin supplement (0.50%), calculated according to the requirements indicated by Rostagno et al. (2005).

Four experimental units were used per treatment. The replacement levels of basal diet for glycerin were 4, 8 and 12%, resulting in six diets. The provision of diets and feces-urine collection were performed according to procedures by Sakomura and Rostagno (2007). During the collection period the supply of food was based on metabolic weight ($w^{0.75}$) of each piglet and the average consumption recorded during the adaptation period. Feeding schedule was performed at 8 and 15h. Both meals were divided into two percentages: 55% in the morning and 45% in the afternoon (ratio was based on the intake between morning and afternoon during the adjustment period).

Dry matter (DMD), organic matter (OMD), gross energy (GED) digestibility and gross energy metabolization coefficient (GEMC) and SPGV and SPGM were calculated according to Matterson et al. (1965). Rates for digestible (DE) and metabolizable (ME) energy were estimated by linear regression analysis (ADEOLA; ILELEJI, 2009) of DE and ME intake (kcal kg^{-1}), associated with glycerin *vs.* glycerin intake (kg).

Experiment II was conducted between November 2009 and January 2010. The average minimum and maximum temperatures during the experimental period were respectively 24.10 ± 2.45ºC and 32.71 ± 2.87°C.

In Experiment II, 90 commercial crossbred piglets (45 castrated males and 45 females), initial weight 15.27 ± 0.99 and final weight 29.82 ± 3.02 kg, were used.

The animals were allotted in a completely randomized block design with repetitions in time, in a factorial 2 x 4 + 1, two types of semipurified glycerin (SPGV and SPGM) and four levels of inclusion (3, 6, 9, and 12 %), with five repetitions and two piglets per experimental unit. Additionally, a control diet was formulated without glycerin (0%), used for statistical analysis of glycerin SPGV and SPGM.

The experimental diet (Table 2), comprising corn and soybean meal, was formulated according to Rostagno et al. (2005) for piglets (15-30 kg). The chemical composition and energy of glycerin (SPGV and SPGM) obtained in the digestibility experiment were used to formulate the diet.

Table 2. Centesimal, nutritional, energetic composition and diet costs containing different levels of two types of semipurified glycerin (vegetable oil and mixed) for starting pigs feeding.

Item	Vegetable oil semipurified glycerin (%)					Mixed semipurified glycerin (%)			
	0	3	6	9	12	3	6	9	12
Corn	67.47	63.96	60.37	56.79	53.12	63.63	59.72	55.81	51.90
Semipurified glycerin	0.00	3.00	6.00	9.00	12.00	3.00	6,00	9.00	12.00
Soybean meal	28.05	28.57	29.16	29.75	30.42	28.62	29.27	29.91	30.56
Soybean oil	1.117	1.112	1.110	1.108	1.109	1.386	1.656	1.927	2.198
Limestone	0.602	0.590	0.588	0.578	0.572	0.596	0.583	0.578	0.565
Dicalcium phosphate	1.632	1.642	1.652	1.660	1.668	1.643	1.653	1.663	1.672
Common salt	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350
Mineral-vitamin premix[1]	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Growth promoter[2]	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
L-Lysine HCl, 99%	0.218	0.210	0.200	0.189	0.181	0.209	0.197	0.186	0.174
DL-Methionine, 99%	0.026	0.031	0.035	0.040	0.045	0.031	0.036	0.041	0.046
L-Threonine, 98%	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Calculated values[3]									
Metabolizable energy[3], kcal kg^{-1}	3,230	3,230	3,230	3,230	3,230	3,230	3,230	3,230	3,230
Crude protein[3], %	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13
Calcium[3], %	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720
Available phosphorus[3], %	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
Available lysine[3], %	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991	0.991
Available methionine + cystine[3],%	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555
Available threonine[3], %	0.624	0.624	0.624	0.624	0.624	0.624	0.624	0.624	0.624
Glycerol[3], %	0.00	2.248	4.496	6.745	8.993	2.060	4.120	6.179	8.239
Diet costs[3], R$ kg^{-1}	0.614	0.606	0.599	0.592	0.585	0.612	0.611	0.610	0.609

[1]Vitamin and mineral premix for starting pigs; [2]Leucomycin 30%; [3]Calculation based on Rostagno et al. (2005) and/or determined.

Crude protein, phosphorus, calcium and gross energy rates were determined for corn and soybean meal. ME rates were then obtained by metabolization coefficient, following Rostagno et al. (2005).

Animals were weighed at the beginning and end of the experimental period and the total feed intake was computed. Daily feed intake (DFI), daily weight gain (DWG) and feed conversion (FC) of each experimental unit were thus calculated.

So that the economic feasibility for SPGV and SPGM inclusion in the feeding of piglets could be evaluated, prices of raw materials in the market were retrieved and feed costs per kilogram of body weight gain were calculated, according to Bellaver et al. (1985): Yi (R$ kg^{-1}) = Qi X Pi/Gi, where: Yi = feed cost per kg of body weight gain in the i-nth treatment ; Qi = amount of feed consumed in the i-nth treatment; Pi = price per kg of feed used in the i-nth treatment; Gi = weight gain in the i-nth treatment.

Index of Economic Efficiency (IEE) and Cost Index (CI) were also calculated: IEE (%) = MCe/CTei x 100 and IC (%) = CTei/MCe x 100, where MCe = lower feed cost per kg gain reported between the treatments, Ctei = cost of i treatment considered.

Analysis of variance was applied to results of the different variables, according to the following statistical model: $Y_{ijk} = \mu + B_i + N_j + F_k + NF_{jk} + e_{ijkl}$, where Y_{ijk} = observation of animal l, within the block i, inclusion level j and type of semipurified glycerin k; μ = constant associated to all observations; B_i = block effect, being i = 1, 2, 3, 4 and 5; N_j = effect of semipurified levels of glycerin, in which j = 0, 3, 6, 9 and 12%; F_k = effect of semipurified glycerin type, in which k = SPGV and SPGM; NF_{jk} = interaction effect of inclusion level j and type of semipurified glycerin k and e_{ijkl} = random error associated with observation.

Dunnett test was applied to compare the results of control diet with each inclusion level of SPGV and SPGM (SAMPAIO, 1998). Statistical analyzes were performed with the system of statistical and gene analysis (SAEG, 1997) developed by the Federal University of Viçosa, Minas Gerais State, Brazil.

Results and discussion

Rates for physical, chemical and energy composition and for SPGV and SPGM glycerin (Table 1) were lower than those by Berenchtein et al. (2010) for glycerol (80%) and ash (10%) contents in semipurified glycerin. Since mixed semipurified glycerin used in current study had high water contents, this factor provided lower energy content when compared to semipurified vegetable glycerin.

Rates showed that the type of semipurified glycerin available on the market had variations in its chemical composition. The ash content widely varied in chemical composition depending on the amount of catalysts used by each industry. However, the values of glycerol, methanol, humidity and pH did not show great variations. Hansen et al. (2009) noted that the use of glycerin may be influenced by the level and type of glycerin used in diets. In fact, it must be taken into account when formulating the diet with regard to the amount of minerals and the variation of parameters, such as pH and MONG.

The digestibility coefficients (DM, OM, EE and EB), metabolizable energy and digestible nutrients (Table 3) of semipurified glycerin demonstrated that both are good energy sources to feed pigs at initial phase.

Table 3. Apparent digestibility coefficients (DC), metabolization coefficient (MC) of nutrients and energetic values of two types of semipurified glycerin (vegetable oil and mixed) used in starting pigs feeding.

Digestibility coefficients, %	Vegetable oil semipurified glycerin	Mixed semipurified glycerin
DC of dry matter	95.87	89.44
DC of organic matter	106.87	100.89
DC of fat	108.43	96.08
DC of gross energy	100.88	100.09
MC of gross energy	89.69	91.15
Digestible nutrients[1]		
Dry matter,%	91.67	76.63
Organic matter,%	99.53	83.16
Fat,%	9.76	4.90
Digestible energy, kcal kg^{-1}	3,793	3,220
Metabolizable energy, kcal kg^{-1}	3,373	2,932
ME:DE ration	0.89	0.91

[1]As feed basis.

The linear relationship between metabolizable energy (kcal kg^{-1}) associated with the use of glycerin *vs* semipurified glycerin (kg) (Figure 1) showed that SPGV and SPGM had ME equivalent to 3,373 and 2,932 Kcal kg^{-1}, respectively.

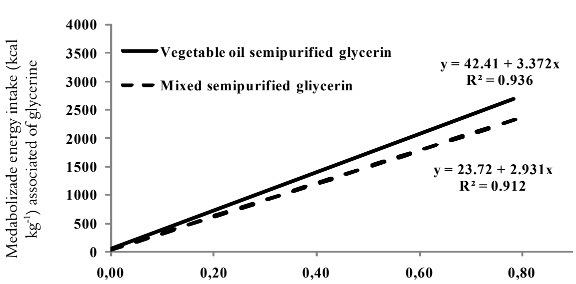

Figure 1. Equations of ME of two types of semipurified glycerin, obtained from intake of ME (kcal kg^{-1}), associated to glycerin *vs.* glycerin intake (kg), for 24 starting pigs, during five days.

Total fatty acids levels in SPGV were higher than those in SPGM, which provided higher energy value than SPGV (3,373 kcal ME kg^{-1}), or rather, 15% above SPGM (2,932 kcal ME kg^{-1}).

The ratio MS: ED for both glycerin (SPGV and SPGM) was similar to that obtained by Lammers et al. (2008b) for crude glycerin (92%).

With regard to performance, there was no interaction ($p > 0.05$) between inclusion levels and types of semipurified glycerin (SPGV and SPGM) for any variable studied (Table 4).

Regression analysis did not indicate any effect ($p > 0.05$) of inclusion level of semipurified glycerin DFI for variables DWG and FC. Likewise, Dunnett test showed no difference ($p > 0.05$) between inclusion levels of glycerin and control diet (0% glycerol). The above suggested that the nutritional values used in the glycerin were real, since diets were isonutritional and glycerin did not have any detrimental components for pig performance.

According to Lammers et al. (2008a), the inclusion of up to 10% did not affect the performance (DFI, DWG and FC) of pigs (between 7.9 and 133 kg). Likewise, previous studies, which evaluated the addition of glycerin in diets based on barley and soybean meal (KIJORA et al. 1995; KIJORA; KUPSCH, 1996) and wheat bran and soybean (MOUROT et al., 1994), did not show any effect on the performance of growing pigs.

Results of economic analysis (Table 5) showed that in the case of SPGV and SPGM there was no change ($p > 0.05$) on feed costs per kilogram of body weight gain (FC) for pigs in the initial phase, albeit with increasing inclusion levels of glycerin.

Dunnett test indicated that there was no difference ($p > 0.05$) between SPGV and SPGM levels (3, 6, 9 and 12%) when compared to those of control diet (0%). Results indicated that, as a rule, the use of up to 12% in SPGV and SPGM in isoenergetic diets did not interfere in the costs of feeding pigs (15-30 kg) when compared to the diet without glycerol (0%).

Table 4. Performance of starting pigs fed on diets with semipurified glycerin (vegetable oil and mixed).

	Inclusion of semipurified glycerin levels, (%)													
		Vegetable oil semipurified glycerin				Mixed semipurified glycerin								
Item	0	3	6	9	12	3	6	9	12	Mean±SE[1]	TG[2]	TG x Lev[3]	Lin[4]	Quad[5]
DFI[6], kg	1.223	1.235	1.178	1.199	1.216	1.224	1.233	1.188	1.196	1.210±0.01	NS	NS	NS	NS
DWG[7], kg	0.623	0.622	0.597	0.568	0.620	0.609	0.640	0.606	0.628	0.613±0.01	NS	NS	NS	NS
Feed: gain	1.970	1.992	1.981	2.118	1.968	2.024	1.928	1.962	1.906	1.983±0.02	NS	NS	NS	NS

[1]Standard error; [2]TG = Type of semipurified glycerin; [3]Interaction between type of semipurified glycerin and semipurified glycerin levels; [4]Linear effect; [5]Quadratic effect; [6]DFI = Daily Feed Intake; [7]DWG = Daily Weight Gain; NS = not significant.

Table 5. Diet cost (R$ kg^{-1}), feed cost per kg of body weight gain (FC), economic efficiency index (EEI) and cost index (CI) of diets containing different levels of two types of semipurified glycerin (vegetable oil and mixed) for starting pigs feeding.

Item	Levels of glycerin inclusion (%)							
	0	3	6	9	12	CV[1]	Dun[2]	Reg[3]
Vegetable oil semipurified glycerin								
Initial weight, kg	15.50	15.49	15.36	15.29	15.20			
Final weight, kg	30.44	30.25	29.47	28.64	29.83			
Diet cost	0.614	0.606	0.599	0.592	0.585	-	-	-
FC, R$ kg^{-1} BW[4]	1.209	1.208	1.187	1.174	1.152	6.94	NS	NS
EEI	95.28	95.35	97.03	98.14	100.0	-	-	-
CI	104.9	104.9	103.1	101.9	100.0	-	-	-
Mixed semipurified glycerin								
Initial weight, kg	15.50	15.24	15.19	15.16	15.00			
Final weight, kg	30.44	29.83	30.38	29.50	29.98			
Diet cost	0.614	0.612	0.611	0.610	0.609	-	-	-
FC, R$ kg^{-1} BW[4]	1.209	1.239	1.194	1.181	1.161	5.89	NS	NS
EEI	96.01	93.65	97.22	98.26	100.0	-	-	-
CI	104.2	106.8	102.9	101.8	100.0	-	-	-

[1]Coefficient of variation; [2]Dunnett; [3]Regression analysis; [4]FC, R$ kg^{-1} BW: Feed cost per kg of body weight gain; NS = Not significant.

Conclusion

Semipurified vegetable and mixed glycerin are good metabolizable energy sources (3,373 and 2,932 kcal kg^{-1}, respectively) for piglets. Results suggest that, in the case of diets for starter pigs, up to 12% of semipurified vegetal and mixed glycerin may be used without any impairment of performance. However, the economic feasibility of their use will depend on the price relation between ingredients, especially corn and soy oil (or other energy source).

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