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Crude glycerine in diets for piglets

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ABSTRACT - Two experiments were carried out to determine the nutritional value and to evaluate performance of piglets fed two types of crude glycerine (CG), which were made from vegetable oil (CGS) and a mix of animal fat + % soybean oil (CGA). In experiment I, a digestibility assay was conducted using 32 crossbred piglets (19.20±1.52 kg). The experimental unit consisted of one pig, with a total of four experimental units per diet. The glycerine levels used in the digestibility assay were 4, 8, and 12% of the basal diet (corn + soybean based). The digestible (DE) and metabolizable energy (ME) values of glycerine were estimated by regression of DE and ME intake (kcal/kg) vs. glycerine intake (kg). The values (as-fed basis) of DE and ME (kcal/kg) obtained were: CGS = 5,070 and 4,556; CGA = 5,143 and 4,488, respectively. The results indicate that these two types of glycerine are a highly-available energy source for the feeding of piglets (15-30 kg). In experiment II, 90 piglets (BW = 15.18±0.67 to 30.28±1.68 kg), were allotted in a completely randomized design in 2 × 4 factorial arrangement, with of two types of crude glycerine (CGS and CGA) and four inclusion levels (3, 6, 9, and 12%). Five experimental units (pens with two pigs) were used for each level of crude glycerine, resulting in five replicates per treatment in the diet. Additionally, a control diet containing no glycerine (0%) was formulated. There was no interaction between levels of CG and types of crude glycerine, and the regression analysis indicates no effects of crude glycerine inclusion on performance and plasma variables. The results suggest that it is feasible to use up to 12% of both tyes of crude glycerine (obtained from soybean oil and mixed) in the diet for piglets without impairing performance, in addition to promoting a reduction of about 11% in the cost with feeding.

Key Words: biodiesel, co-product, digestibility, glycerol

Introduction

The search for biofuels from renewable energy aims to attempt to reduce the dependence on petroleum-based fuel products. Brazil is among the largest producers and consumers of biodiesel in the world, with an annual production in January 2010 of 4.7 billion liters (ANP, 2010). Glycerine is the main by-product (10% of total biodiesel volume) resulting from the biodiesel production.

Glycerine can be sold without purification (natural glycerine), crude (high content of fatty acids) or semi-purified, better known as “Blonde” glycerine (low fatty acid content).

This by-product of the biodiesel production can be used as a source of high energy potential for animal feed, for once absorbed by the body, it participates in the formation of lipids, is converted into glucose through gluconeogenesis or oxidized for energy production through glycolysis and the citric acid cycle. In addition, Groesbeck et al. (2008) emphasize that corn, wheat and glycerine energy values are similar. Glycerine can be considered an alternative ingredient to replace these traditional components of pig diets.

For this reason, since the 1990s, the use of glycerine in pig diets has been investigated, aiming to understand the effects of this by-product originated from different raw materials on pig performance, carcass characteristics and meat quality.

In studies that using glycerine in the diet of weanling pigs by Zijlstra et al. (2009), it was found that the value of digestible energy for the semi-purified glycerine is 3,510 kcal/kg and the inclusion of up to 8% in the diets does not affect animal performance. Similarly, Christopher (2009), replacing lactose by glycerine in the diet for piglets, confirms that glycerine improves pellet durability, flow and temperature and efficiency of the pelletizer, and it can be added to the diets at levels up to 5%.

Given the limited scientific information on the use of crude glycerine for feeding pigs, this study was carried out aiming to evaluate the nutritional value and effects of two types of crude glycerine (vegetable oil and mixed) on pigs performance in starting pigs feeding and its economic feasibility.

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Material and Methods

The experiments were carried out at the Pig Barn in the Fazenda Experimental de Iguatemi, belonging to Universidade Estadual de Maringá (CCA/UEM), located in the State of Paraná, Brazil (23°21'S, 52°04'W, 564 m altitude).

Two types of crude glycerine (CG) were studied: CGS - made from vegetable oil (soybean) and CGA - mix made of about 80% of animal fat + 20% soybean oil. Both were obtained from Biopar biofuels industry, located in Rolândia, Paraná, Brazil.

Density, water content (Karl Fisher) and total glycerine analysis (Table 1) were accomplished at the Paraná Technology Institute (Tecpar). The values (Table 1) of pH, protein, mineral and gross energy (adiabatic calorimeter - AC720 Parr Instrument Co.) were evaluated by the Laboratório de Nutrição Animal (LANA – UEM), according to the procedures described by Silva & Queiroz (2002). The concentration of sodium chloride was determined at the Biopar Analyses Control Laboratory. The matter organic non-glycerine was calculated using the equation given by Hansen et al. (2009) in which MONG = 100 - [glycerine content (%) + water content (%) + ash content (%)].

Table 1 - Chemical and energetic composition of crude glycerine types

Nutrients	Vegetable oil crude glycerine	Mixed crude glycerine
Moisture, %	2.54	5.45
Total glycerol, %	55.95	55.45
Crude protein, %	0.05	0,05
Gross energy, kcal/kg	5,247	5,242
Total fatty acid, %	23.30	21.50
MONG, %	37.43	34.48
Methanol, %	10.96	5.05
Ash, %	4.45	4.26
Sodium chloride, %	3.52	3.01
Calcium, ppm	83.22	82.33
Phosphorus, ppm	203.25	167.51
Potassium, %	0.174	0.023
Sodium, %	1.620	1.990
Chloride, %	0.460	0.350
Magnesium, ppm	42.78	30.72
Copper, ppm	0.168	0.197
Chrome, ppm	0.241	0.177
Iron, ppm	22.37	26.51
Zinc, ppm	1.954	0.195
Manganese, ppm	0.442	0.853
Aluminum, ppm	52.82	33.48
Cobalt, ppm	0.532	0.475
Molybdenum, ppm	0.000	0.000
Lead, ppm	0.443	0.487
pH	8.75	8.55
Density, kg/m^3	1090	1110

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

Measurements of lipids and methanol were carried out by chromatography at the Departamento de Química e Física (UEM), respectively. Because of the high levels of fatty acids in crude glycerine (CGS and CGA), they were in solid state at room temperature, making it difficult to mix with the other ingredients in the diets. For this reason, it was necessary to pre-heat the crude glycerine at a controlled temperature (30 to 40 ºC).

Two experiments were conducted: a digestibility assay (Experiment I) and a performance assay (Experiment II). In experiment I, 32 crossbred barrows from commercial line of 19.20±1.52 kg initial live weight were used. The animals were kept individually in metabolism cages similar to those described by Pekas (1968), in a room with controlled temperature. Ambient temperatures were average minimum of 20.5±0.86 °C and maximum of 23.4±1.00 °C, and average relative humidity presented minimum of 39.3±14.26% and a maximum of 61.4±14.03%. The control diet consisted of corn (70.42%), soybean meal (26.40%), salt (0.50%), limestone (0.60%), dicalcium phosphate (1.58%) and a mineral-vitamin premix (0.50%) and was formulated to meet the requirements indicated by Rostagno et al. (2005).

Four experimental units were used per treatment. The replacement levels of basal diet for glycerine were 4, 8 and 12%, resulting in six test diets.

Feed supply, feces and urine collection were according to those described by Sakomura & Rostagno (2007). In the collection period, the feed supply was calculated based on metabolic weight (kg$^{0.75}$) from each pig and on the average intake recorded in the pre-experimental phase. Feeding was offered at 08h and 15h, with 55% of the total in the morning and 45% in the afternoon. All diets were moistened with approximately 20% of water, aiming to avoid waste, reduce dustiness and improve feed acceptability by the animal. After each meal, water was provided at 3 mL of water/g of diet to avoid excessive water consumption.

To mark the start and the end of the total feces collection period, 3% of Fe_3O_2 was used as a marker. Feces were collected once a day, packed in plastic bags and stored in a freezer (-18 ºC). Subsequently, the material was thawed, homogenized and dried (about 350 g) in a forced-ventilation oven 55 ºC for 72 h and ground in a knife mill (1 mm sieve). The urine was collected in plastic buckets containing 20 mL of HCl 1:1 to prevent bacterial proliferation and possible volatility losses.

The coefficient of dry matter digestibility, organic matter, gross energy and the metabolization coefficient of gross energy were calculated according to Matterson et al. (1965). The digestible (DE) and metabolizable energy (ME) values were estimated by regression analysis (Adeola & Ileleji, 2009) of DE and ME intake (kcal/kg) associated of crude glycerine vs. crude glycerine intake. To evaluate differences between the digestibility of CGS and CGA, the data were subjected to variance analysis using the statistical package SAEG (Sistema para Análises Estatísticas e Genéticas, version 7.1) according to the following statistical model: $Y_{ij} = \mu + T_i + e_{ij}$, in which: Y_{ij} = digestibility coefficient of the treatment i, of replication j; μ = constant associated with all observations; T_i = effect of inclusion level of feed *i*, with *i* = 4; 8; 12%; e_{ij} = random error associated with each observation.

In Experiment II, 90 crossbred pigs (45 castrated males and 45 females) from commercial line with initial live weight of 15.18±0.67 and final weight of 30.28±1.68 kg were used.

The average maximum and minimum temperatures recorded in the experimental period were 17.6±2.76 °C and 27.4±3.59 °C, respectively. The average relative humidity of the experimental period, during the morning and afternoon periods, were 82.5±11.92% and 59.7±16.78%, respectively. The total rainfall during the experimental period was 555 mm.

Pigs were housed in a nursery barn, arranged in three rooms, each having ten stalls, divided by a central corridor. Stalls were had elevated plastic floors partially slatted, with semi-automatic frontal feeders and nipple-type drinkers on the back. Each stall measured 1.32 m^2. Diets and water were provided *ad libitum* throughout the experimental period.

Diets based on corn and soybean meal (Table 2) were formulated to meet the recommended by Rostagno et al. (2005), for piglets.

The crude glycerine chemical and energetic compositions (CGS and CGA) obtained in the digestibility assay (Table 1) were used in the diet formulation.

The animals were allotted in a completely randomized block design with repetitions in time, in a 2 × 4 factorial arrangement, two types of crude glycerine (CGS and CGA) and four levels of inclusion (3, 6, 9 and 12%), with five repetitions and two pigs per experimental unit. Additionally, a control diet containing 0% glycerine was formulated.

Animals were weighed at the beginning and end of the experiment and the total feed intake was computed, whereby the daily feed intake (DFI), daily weight gain (DWG) and the feed:gain ratio of each experimental unit were calculated.

At the beginning (baseline), middle (14 days) and end (22 days) of the experimental period, blood samples were collected via the cranial vena cava and transferred to tubes with heparin (Cai et al., 1994).

Blood samples were centrifuged (3,000 rpm for 15 min) to obtain the plasma. Then, 3 mL of plasma (in duplicate) were

Table 2 - Centesimal and chemical composition of diets containing increasing levels of two types of crude glycerine (vegetable oil and mixed) in the feeding of piglets

	Inclusion levels of crude glycerine, %								
		Vegetable oil crude glycerine				Mixed crude glycerine			
Item, %	0	3	6	9	12	3	6	9	12
Corn	62.32	59.71	57.52	54.29	51.58	59.65	57.63	54.10	51.33
Crude glycerine	-	3.00	6.00	9.00	12.00	3.00	6.00	9.00	12.00
Soybean meal	31.39	31.82	31.74	32.73	33.19	31.83	31.52	32.77	33.23
Soybean oil	3.071	2.298	1.541	0.820	0.081	2.350	1.638	0.977	0.291
Limestone	0.385	0.383	0.383	0.378	0.376	0.383	0.384	0.378	0.376
Dicalcium phosphate	1.713	1.716	1.724	1.723	1.727	1.717	1.726	1.724	1.727
Common salt	0.400	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	0.163	0.155	0.163	0.137	0.129	0.154	0.170	0.137	0.128
DL-methionine	0.034	0.037	0.045	0.042	0.045	0.037	0.047	0.042	0.045
L-threonine	0.024	0.023	0.030	0.021	0.020	0.023	0.033	0.021	0.020
Calculated values[3]									
Metabolizable energy, kcal/kg[3]	3300	3300	3300	3300	3300	3300	3300	3300	3300
Crude protein, %[3]	18.70	18.70	18.70	18.70	18.70	18.70	18.70	18.70	18.70
Calcium, %[3]	0.742	0.742	0.742	0.742	0.742	0.742	0.742	0.742	0.742
Available phosphorus, %[3]	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412
Available lysine, %[3]	1.022	1.022	1.022	1.022	1.022	1.022	1.022	1.022	1.022
Available methionine + cystine, %[3]	0.572	0.572	0.572	0.572	0.572	0.572	0.572	0.572	0.572
Available threonine, %[3]	0.643	0.643	0.643	0.643	0.643	0.643	0.643	0.643	0.643
Glycerol, %[3]	-	1.679	3.357	5.036	6.714	1.662	3.324	4.986	6.648
Methanol, %[3]	-	0.329	0.658	0.986	1.315	0.152	0.303	0.455	0.606
Diet cost, R$/kg[3]	0.516	0.491	0.481	0.470	0.459	0.492	0.483	0.473	0.463

[1] Vitamin and mineral premix for piglets.
[2] Leucomycin.
[3] Calculated based on Rostagno et al. (2005) and/or determined.

transferred to Eppendorf tubes, which were properly identified and stored in a freezer (-18 °C) for further analysis by the Laboratório de Nutrição Animal at Universidade Estadual de Maringá.

For cholesterol analysis of glucose, plasma urea nitrogen (PUN) and triglycerides, a Gold Analisa Diagnóstica Ltda kit was used. The baseline results obtained at the beginning of the experiment were used as co-variable in the statistical analysis.

Using the DWG and DFI data, the economic analysis was made based on the equation proposed by Guidoni (1994):

$$PMCG \leq [PRS(Gain_i - Gain_0) - \sum_{J \neq L=1}^{N} P_J \, (C_{ji} * CR_i - C_{j0} * CR_0)] / (C_{li} * CR_i)$$

in which: PMCG = maximum price of crude glycerine (CGS and CGA) so that the diet in which it will be used has the same economic efficiency that the crude glycerine-free diet (zero level of inclusion); PRS = price per kilogram of pig; $Gain_i$ = average weight gain of pigs from treatment containing the i level of crude glycerine (CG); $Gain_0$ = average weight gain of pigs from treatment without CG (zero level of inclusion); P_j = price of the remaining ingredients in each diet; C_{ji} = percentage of the ingredient j in diet i; CRi = Average total feed intake per animal inherent to diet i; C_{j0} = percentage of the ingredient j in the diet without glycerine; CR0 = Average total feed intake per animal in the diet without CG; C_{li} = percentage of CG in the diet i.

The input prices (R$) were collected in Maringá, Paraná: 1.6 kg of piglet; 0.272 for corn; 0.629 for soybean meal; 1.98 for soybean oil; 0.16 for limestone; 1.12 for dicalcium phosphate; 0.34 for salt; 9.00 for lysine; 14.0 for methionine; 11.46 for threonine; 97.00 for the growth promoter and 0.29 for CGS and CGA.

The values obtained were subjected to analysis of variance, adopting the following statistical model: $Y_{ijlk} = \mu + B_i + S_j + N_k + F_l + NF_{kl} + e_{ijkl}$, in which Y_{ijkl} = observation of animal *l*, within block i, inclusion level *k* and crude glycerine type *l*; μ = constant associated to all observations; B*i* = block effect, with *i* = 1, 2, 3, 4, 5; S_j = effect of sex j (1= male, 2 = female); N*k* = effect of crude glycerine level, with *k* = 3, 6, 9, 12%; F*l* = effect of the type of crude glycerine, with *l* = CGS and CGA; NF*kl* = interaction effect of the inclusion levels k and the crude glycerine type *l* and e_{ijkl} = random error associated with each observation.

The freedom degrees of level of inclusion (CGS and CGA) were decomposed in orthogonal polynomials, to obtain the regression equations. To compare the results of the control diet (0% crude glycerine) at each level of inclusion of CGS and CGA, the Dunnett test was applied (Sampaio, 1998). Statistical analysis was performed using the statistical package SAEG (Sistemas para Análises Estatísticas e Genéticas, version 7.1). In the performance assay, the initial weight of piglets was used as co-variable.

Results and Discussion

The physical, chemical and energetic composition of crude glycerine (CGS and CGA) (Table 1) are in agreement with the results cited by Kerr et al. (2009) for the levels of glycerine (51.54%), moisture (4.99%), gross energy (5,581 kcal/kg), total fatty matter (24.28%), methanol (14.99%) and ash (4.20%) in the crude glycerine obtained from chicken fat. Values show that crude glycerine has a wide variation in its chemical composition. Gott & Eastridge (2010), analyzing sixteen samples of glycerine, obtained from different raw materials and industries, state that the ash content has a wide variation in the chemical composition of glycerine, due to the amount of catalysts used in each industry. For this reason, Hansen et al. (2009) emphasize that the use of crude glycerine will be influenced by the level and type of glycerine used in the diets and the amount of minerals, the variation of parameters such as pH and matter organic non-glycerine must be taken into account when formulating diets.

By not receiving any purification process, the crude glycerine is characterized by the presence of high levels of fatty acids and catalyst residues (sodium or potassium) in its chemical composition. Another peculiar feature of crude glycerine is the high methanol content, not meeting the recommendations of 150 ppm of methanol for glycerine use in animal feed (FDA, 2010). However, no disturbance in the animal behavior was observed in any of the experiments. In addition, in the literature (Kijora et al., 1995; Lammers et al., 2008b; Lammers et al., 2008c), there are no reports of increased incidence in the frequency of injuries associated with the toxicity of methanol in the eyes, kidneys, liver or histology of tissues in pigs fed crude glycerine.

The digestibility coefficient values, metabolism and digestible nutrients (Table 3) of crude glycerine (CGS and CGA) showed that both are excellent energy sources to feed pigs in the initial phase and with high utilization by animals.

The presence of elevated levels of total fatty acids in CGS and CGA promotes a high energy content. These data were confirmed by Kerr et al. (2009), who obtained results of gross energy (6,021 and 5,581 kcal/kg), digestible energy (5,228 and 4,336 kcal/kg) and metabolizable energy (5,206 and 4,446 kcal/kg) studying crude glycerine from animal fat. On the other hand, recent reports pointed out that the semi-purified glycerine (80-90% glycerine) has 3,436 kcal ME/kg (Lammers et al., 2008b) and purified glycerine 4,463 kcal ME/kg (Bartelt & Schneider, 2002).

Table 3 - Apparent digestibility coefficients (DC), metabolization coefficient (MC) and digestible values of nutrients of two types of crude glycerin (vegetable oil and mixed) used in the feeding of piglets

Digestibility coefficients, %	Vegetable oil crude glycerine	Mixed crude glycerine
Digestible coefficients of dry matter	93.10	85.77
Digestible coefficients of organic matter	91.78	91.05
Digestible coefficients of fat	89.88	88.95
Digestible coefficients of gross energy	96.60	98.10
Dry matter of gross energy	87.54	85.98
Digestible nutrients	As fed basis	As fed basis
Dry matter, %	90.74	81.10
Organic matter, %	87.69	87.17
Fat,%	20.94	19.12
Digestible energy, kcal/kg	5.070	5.143
Metabolizable energy, kcal/kg	4,556	4,488
ME:DE ratio	0.90	0.87

ME - metabolizable energy; DE - digestible energy.

The slope of the linear relationship between metabolizable energy intake and crude glycerine (CGS and CGA) intake (Figure 1) was estimated to obtain the ME of each type of crude glycerine, showing that the CGS and CGA have similar ME (4,555 and 4,488 kcal/kg, respectively). Cerrate et al. (2006) proved that the glycerine ME value was 95 to 100% of its gross energy to formulate diets. However, there is limitation in glycerine metabolism, verified by the increased energy excretion in urine and the losses in metabolism (Mendoza et al., 2010).

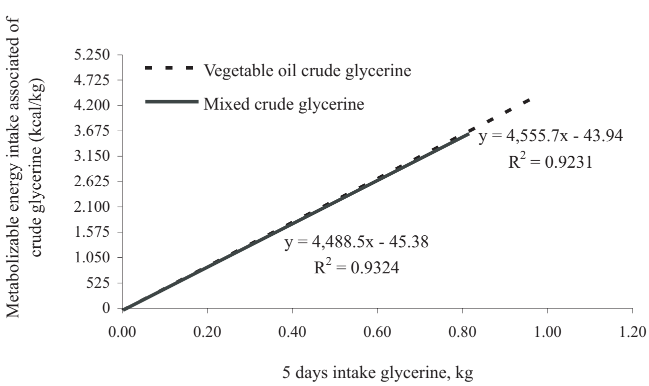

Figure 1 - Equations of metabolizable energy (ME) of two types of crude glycerine, obtained from regression of ME (kcal/kg) intake associated of crude glycerine *vs.* crude glycerine intake (kg), for 24 piglets, in five days.

The difference in crude glycerine chemical composition may affect its metabolizable energy value; however, it is not clear if the raw material will also affect this value.

The ME:DE ratio (Table 3) for both types of glycerine (CGS and CGA) were similar to results obtained by Kerr et al. (2009), who assert that the values of 82-85% of ME:DE in crude glycerine derived from chicken fat was reduced by the amount of fatty acids present. By comparison, the ME:DE ratio for the semi-purified glycerine was 92% (Lammers et al., 2008a) and 97% referent to corn and soybean oil (Rostagno et al., 2005).

There was no interaction ($P \geq 0.05$) between inclusion levels and the types of crude glycerine (CGS and CGA) for the variables studied (Table 4).

Regression analysis indicates that there was no effect ($P \geq 0.05$) of the inclusion level of crude glycerine on the DFI, DWG and feed:gain ratio variables. Likewise, the Dunnett test indicated no difference ($P \geq 0.05$) between the inclusion levels of glycerine and the control diet (0% glycerine). This response suggests that the nutrient values used for glycerine are real, since the diets had the same amount of nutrients and these by-products have no components harmful to the pig performance.

Lammers et al. (2008b), using semi-purified glycerine, found that the inclusion of up to 10% did not affect the performance (DFI, DWG and feed:gain ratio) of pigs during

Table 4 - Performance of piglets, fed diets with crude glycerine (vegetable oil and mixed)

	Inclusion level of crude glycerine (%)													
		Vegetable oil crude glycerine				Mixed crude glycerine								
Item	0	3	6	9	12	3	6	9	12	Mean ± SE	CV	TG	TG × Lev	Linear	Quadratic
DFI, kg	1.234	1.276	1.250	1.200	1.226	1.244	1.284	1.208	1.278	1.244±0.016	11.48	NS	NS	NS	NS
DWG, kg	0.686	0.732	0.712	0.666	0.668	0.664	0.734	0.678	0.726	0.696±0.012	8.74	NS	NS	NS	NS
Feed:gain	1.81	1.75	1.78	1.80	1.86	1.88	1.76	1.82	1.77	1.80±0.014	5.16	NS	NS	NS	NS

SE - standard error; CV - coefficient of variation; TG - type of crude glycerine; TG × Lev - interaction between type of crude glycerine and crude glycerine levels; Linear- linear effect; Quadratic - quadratic effect; DFI - daily feed intake; DWG - daily weight gain; NS - non-significant.

the growth phase (7.9 to 133kg). Likewise, previous studies evaluating the addition of glycerine in barley- and soybean meal-based diets (Kijora et al., 1995; Kijora & Kupsch, 1996) and wheat bran and soybean meal (Mourot et al., 1994) did not observe effect on performance of growing pigs.

The results (Table 4) suggest that the addition of increasing concentrations of glycerine in diets did not affect the palatability of diets. In other research studies, Groesbeck et al. (2008) says that crude glycerine has a sweetish taste, which improves the diet palatability and consequently feed intake.

No interaction (P≥0.05) was observed between inclusion levels and types of crude glycerine (CGS and CGA) for plasma glucose (Table 5). These results were similar to those obtained by Hansen et al. (2009), who observed no effect on plasma levels of glucose in pigs fed up to 16% inclusion of semi-purified glycerine. Schieck et al. (2010) showed that plasma glucose concentrations were not affected in lactating females fed up to 9% inclusion of glycerine, indicating that there was excess glycerine metabolism of plasma via gluconeogenesis, which is basically used in the production of lactose by the mammary gland. In general, it is known that glycerine can be converted into glucose through gluconeogenesis or oxidized into energy through glycolysis or the citric acid cycle.

In addition, there was interaction for triglycerides (P<0.05) between the inclusion levels and the type of crude glycerine used and quadratic effect for CGS. For CGA, higher triglyceride concentrations were observed, compared with treatments with CGS at the 14th day of sampling.

For triglyceride levels, there was an increase in plasma levels in relation to the sampling period (sample of the 14th and 22nd days). Possibly, these responses are due to the need of animals for a longer period of adaptation to diets with glycerine.

Contradictory results were obtained by Mourot et al. (1994) with the addition of up to 5% glycerine, derived from rapeseed oil, in which they found no effect on the concentration of plasma triglycerides, indicating that there was no relationship between circulating levels and the concentration of triglycerides in the liver tissue and the semimenbranosus muscle of pigs. Similar results were found by Christopher (2009), at replacement levels of lactose by glycerine fed to weanling pigs.

Table 5 - Plasma levels (mg/dL) of glucose, triglycerides, cholesterol and plasma urea nitrogen (PUN) of piglets fed diets with crude glycerine (vegetable oil and mixed)

	Inclusion level of crude glycerine, %													
		Vegetable oil crude glycerine				Mixed crude glycerine								
Harvest	0	3	6	9	12	3	6	9	12	X±SE	TG	TG × Lev	Lin	Quad
Glucose														
Baseline	103.31	91.32	99.28	101.50	94.53	93.82	102.23	85.46	93.28	96.08±1.41	-	-	-	-
14th day	93.03	97.68	86.15	95.69	105.73	97.63	98.32	90.90	101.82	96.33±1.37	NS	NS	NS	NS
22th day	103.16	101.03	97.38	107.02	103.69	103.27	102.72	106.84	103.65	103.20±1.56	NS	NS	NS	NS
Mean[1]	98.10	99.36	91.77	101.36	104.71	100.45	100.52	98.87	102.74	98.48±0.92	NS	NS	NS	NS
Triglycerides														-
Baseline	66.76	82.26	68.84	72.37	85.44	74.14	74.09	74.20	72.28	74.49±1.58	-	-	-	
14th day	51.21	48.85	47.46	40.35	67.10	55.38	54.30	54.47	61.34	53.39±1.46A	0.03	NS	NS	CGS 0.01
22th day	53.01	54.59	65.93	50.28	91.60	68.45	69.41	73.26	70.48	66.33±2.77B	NS	NS	NS	NS
Mean[1]	52.11	51.72	56.70	45.32	79.35	61.92	61.86	63.87	65.91	59.86±1.65	NS	0.03	NS	CGS 0.01
Cholesterol														
Baseline	81.00	78.92	80.10	81.93	87.77	75.26	80.39	85.57	74.05	80.55±1.68	-	-	-	-
14th day	69.45	68.28	60.62	69.23	80.48	72.14	77.71	69.37	86.12	72.60±1.20	0.01	NS	NS	CGS 0.03
22th day	71.29	74.63	73.47	70.23	78.18	80.58	76.19	77.43	87.14	76.57±1.45	0.01	NS	NS	NS
Mean[1]	70.37	71.46	67.05	69.73	79.33	76.36	76.95	73.40	86.63	74.59±1.00	0.02	NS	NS	CGS 0.03
Plasma urea nitrogen														
Baseline	11.53	12.91	12.66	13.67	11.38	12.80	11.70	11.91	11.88	12.27±0.29	-	-	-	-
14th day	11.86	13.85	12.31	13.47	12.78	14.50	12.70	12.15	13.62	13.03±0.29	NS	NS	NS	NS
22th day	12.21	13.40	13.85	12.62	13.75	13.69	12.30	11.87	15.91	13.29±0.32	NS	NS	NS	CGA 0.01
Mean[1]	12.04	13.63	13.08	13.05	13.27	14.10	12.50	12.01	14.77	13,16±0,20	NS	NS	NS	CGA 0.01

NS - non-significant; SE - standard error; TG - type of crude glycerine; TG × Lev - Interaction between type of crude glycerine and crude glycerine levels; Lin - linear effect; Quad - quadratic effect (triglycerides CGS 14th day = $72.6025 - 9.74616X + 0.76198X^2$; cholesterol CGS 14th day = $86.6163 - 7.50428X + 0.582684X^2$; PUN CGA 14th day = $18.6114 - 2.0086X + 0.147106 X^2$).

[1] Mean for the harvest of 14th and 28th days (triglycerides CGS mean = $82.9245 - 11.2424X + 0.883890 X^2$; cholesterol CGS mean = $84.2045 - 5.29764X + 0.40616X^2$; PUN CGA mean = $18.3638 - 1.73582X + 0.118750X^2$).

Mean with different letters in the same row differ (P<0.05) by the F test.

In cholesterol, there was a quadratic effect for CGS. The mixed crude glycerine had higher cholesterol concentrations (P<0.05) than the CGS on the 14th and 22nd days of sampling. Narayan & Mcmullen (1979) said that the chronic glycerine metabolism in the liver of mice and birds has a stimulatory effect on the synthesis of free fatty acids, triglycerides, cholesterol, chylomicrons and plasmatic lipoproteins

For the variable PUN, there was a quadratic effect for CGA; however, overall, the results indicate that there was maintenance of the protein quality of diets, since this variable reflects an adequate supply of amino acids in quantity and quality (Coma et al. 1995). Similar values were found by Lammers et al. (2008b) in pigs (7.9 to 133 kg) fed semi-purified glycerine; these authors concluded that up to the level of 10%, there was no mobilization of protein from lean tissue.

Applying the prices prevailing during the experimental period to the equations (Table 6), the maximum prices (R$) of CGS and CGA were obtained, so experimental diets had the same economic efficiency of the diet without the addition of glycerine. Thus, the maximum prices of 2.143, 1.056, 0.617 and 0.503 were obtained for CGS and 2.710, 0.801, 0.546 and 0.297 for CGA, referring to the inclusion levels of 3, 6, 9 and 12%. It was observed that glycerine is economically viable for all inclusion levels.

The economic analysis indicates that the use of up to 12% of CGS and CGA in diets with the same amount of energy can reduce the feeding costs of piglets (15-30 kg) in up to 11% (0.459/0.516 = 0.89; Table 2) compared with the diet without glycerine (0%).

Conclusions

The values of metabolizable energy, as-fed basis, for vegetable oil and mixed crude glycerine for piglets are 4,556 and 4,488 kcal/kg, respectively. It is possible to use up to 12% of either types of crude glycerine in diets for piglets without impairing with performance and plasmatic variables such as plasma glucose, triglycerides, cholesterol, and plasma urea nitrogen. In addition, the inclusion of crude glycerine can promote reduction of up to 11% in the cost with feeding. However, the economic feasibility of its use will depend on the price ratio of the ingredients, especially corn and soybean oil (or other energy sources).

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