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GROWTH PERFORMANCE, CARCASS CHARACTERISTICS, MEAT QUALITY OF GROWING PIGS FED DIETS SUPPLEMENTED WITH CRUDE GLYCERIN DERIVED FROM PALM OIL

DESEMPENHO PRODUTIVO, CARACTERÍSTICAS DE CARCAÇA E QUALIDADE DA CARNE DE SUÍNOS EM CRESCIMENTO ALIMENTADOS COM DIETAS INCLUINDO GLICERINA BRUTA DERIVADA DE ÓLEO DE PALMA

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Abstract

The aim of this study was to evaluate the effect of the inclusion level of crude glycerin from palm oil in the diet of growing pigs. Diets were formulated to be isocaloric and isoproteic, with a constant content of linoleic acid within the experimental diets. A total of 36 pigs (average BW 23.05± 2.86 kg) were randomly assigned to one of the three treatments: 1) 0% of crude glycerin; 2) 5% of crude glycerin; 3) 10% of crude glycerin. Pigs were housed in 12 pens; 4 replicates (pens) per treatment and three pigs/replicate. Data were analyzed as a complete block design using the GLIMMIX procedure of SAS, with a random block effect for period. This study established that inclusion of crude glycerin from palm oil in the diet of growing pigs did not affect (P > 0.05) growth performance, carcass characteristics and meat quality. We concluded that inclusion of crude glycerin from palm oil up to 10% of the diet did not adversely affect pig performance and the quality of the meat.

Keywords: biodiesel; by-products; palm oil; swine.

Resumo

O objetivo deste estudo foi avaliar o efeito da inclusão de níveis de glicerina bruta do óleo de palma na dieta de suínos em crescimento. As dietas foram formuladas para serem isoenergéticas e isoproteicas, o teor de ácido linoléico permaneceu constante na dieta. No total, 36 suinos (com média BW de 23,05 ± 2,86 kg) foram distribuídos aleatoriamente em três tratamentos: 1) 0% de glicerina bruta; 2) 5% de glicerina bruta; 3) 10% de glicerina bruta. Os leitões foram alojados em 12 baias com quatro repetições (baias) por tratamento, três suínos/repetição. Os dados foram analisados como um delineamento em blocos casualizados utilizando-se o procedimento GLIMMIX do SAS, com um efeito aleatório de bloco por período. Notou-se que a inclusão de glicerina bruta do óleo de palma não afetou (P> 0,05) o desempenho produtivo, as características da carcaça e qualidade da carne. Concluiu-se que a inclusão de glicerina bruta do óleo de palma até 10% não afetou o desempenho dos suínos e a qualidade da carne.

Palavras-chave: biodiesel; óleo de palma; subprodutos; suínos.

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Introduction

The biodiesel industry from fatty sources generates glycerin, a by-product that can be used as an excellent source of energy for growing pigs. In Colombia, the installed capacity of biodiesel production was of 505.708 t in 2013(1). Each liter of biodiesel generates approximately 79 g of crude glycerin(2), consequently, with the installed capacity, the country will produce annually around of 51940 t of crude glycerin (80% glycerol) with a density of 1.3 g/ml(3).

In pigs, crude glycerin obtained from soybean oil has shown an energy value close to corn(4,5). Several studies have revealed that the inclusion of crude glycerin up to 16% in isoenergetic and isoproteic diets for pigs has not affected performance, carcass characteristics and meat quality(2,6-10). However, when corn was replaced by crude glycerin as the source of dietary fatty acids (FA), a reduction in the content of polyunsaturated fatty acids in the loin occurred(2). Regarding the case of crude glycerin from palm oil, no studies on the evaluation of its effect on the performance of pigs.

This study evaluated the effect of the inclusion level of crude glycerin from palm oil (PO) in the diet of growing pigs on growth performance, carcass characteristics, and meat quality.

Material and Methods

The Bioethics Committee of the Faculty of Veterinary Medicine of the National University of Colombia (UN) approved all the procedures involving animals in this study (Act 4 of September 28, 2011). This study was developed in the swine section of the Agricultural Center "MARENGO" of the UN-Bogota. A total of 36 pigs of a commercial crossing (Yorkshire x Landrace x Pietrain, average LW of 23.05 ± 2.86 kg) were randomly assigned to pens with three pigs per pen and four pens (replicates) per treatment. Dietary treatments were assigned in a completely randomized block design as follows: 1) control - 0% crude glycerin; 2) 5% crude glycerin; 3) 10% crude glycerin from PO. Crude glycerin from PO was obtained from a biodiesel production facility (Bio-D S.A, Facatativa, Colombia). Table 1 displays the chemical composition of crude glycerin from PO. The maximum level of inclusion of CG was 10% because it is the level that has not affected the performance of pigs using other sources of crude glycerin(2,6,7,9,10), although in Australia the use of up to 16% of CG did not affect the performance of animals but there were difficulties in feed management(8).

Table 1. Characteristics of crude glycerin from PO

Item	Value[1]
Moisture, %	8.29
GE[2], kcal/kg	3696
Glycerol, %	82
Crude fat, %	0.79
Na, %	1.21
Methanol, ppm	16

[1]Analysis by CORPOICA-CBB, Mosquera, Colombia, adjusted to the methods utilized by Dozier et al. (11)

[2]GE: Gross energy

Diets were formulated to be isocaloric and isoproteic according to the method used by Araújo et al.(12). Pigs were fed diets over a 4-phase feeding program, within each phase diets were offered ad libitum in meal form. Pigs in each pen were weighed weekly, and feed residuals were used to calculate weekly feed intake and feed conversion. Consumption was corrected for the number of animals(2). The day before slaughter (100 kg BW), a pig with average weight within replicates was selected. The feed was removed but water was maintained in the pen(3,9).

Feeding phases were from 20-30 kg, 30-50 kg, 50-70 kg, and 70-100 kg LW. Experimental diets are shown in Table 2. Previous results have shown the effect of crude glycerin on the fatty acid profile of pork loin(2); therefore, the level of linolenic acid in the diet was monitored and kept constant by using as diet ingredients palm oil and full-fat soybean.

Table 2. Description of experimental diets

Ingredient	Cost. $/kg	Phase I (20 - 30 kg)			Phase II (30 - 50 kg)			Phase III (50 - 70 kg)			Phase IV (70 - 100 kg)		
		Crude glycerin level											
		0	5	10	0	5	10	0	5	10	0	5	10
Corn, %	790	55.5	50	44	54	48	42	55	49	43	58	52	46
Wheat bran, %	550	6	6	6	12	12	12	12	12	12	12	12	12
Rice bran, %	720	8	8	8	8	8	8	10	10	10	10	10	10
Full-fat soybean, %	1240				0.3	2.8	5.2	0.3	2.7	5.2	0.2	2.7	5.2
Soybean meal, %	1080	25	26	27	20	20	19	18	17	16	15	14	13
Palm oil, %	2000	2	2	2	3	2	1	3	2	1	3	2	1
Crude glycerin, %	800	0	5	10	0	5	10	0	5	10	0	5	10
Salt, %	205	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Sodium bicarbonate; %	2500	0.4	0.3	0.3	0.4	0.4	0.3	0.5	0.4	0.4	0.6	0.6	0.5
Limestone, %	140	0.9	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.6
Dicalcium phosphate, %	2450	1.0	1.0	1.0	0.8	0.8	0.8	0.5	0.5	0.6	0.4	0.4	0.5
DL-methionine	12000	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01			
L-lysine	4500	0.04	0.02	0.00	0.06	0.04	0.02	0.06	0.04	0.02	0.05	0.03	
L-threonine	6800	0.1	0.1	0.1									
Choline chloride, %	2782	0.1	0.1	0.1									
Premix[1], %	20000	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total		100	100	100	100	100	100	100	100	100	100	100	100
		Calculated composition											
ME, Mcal/kg		3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
CP, %		19	19	19	18	18	18	17	17	17	16	16	16
Digestible Lysine, %		0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7
Available phosphorus; %		0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Linoleic acid, %		2.0	1.8	1.7	2.1	2.1	2.1	2.2	2.2	2.2	2.2	2.2	2.2
Starch, %		39	36	32	40	36	33	41	37	34	43	39	36
EB[2], meq/kg		250	250	250	250	250	250	250	250	250	250	250	250

[1]Provided the following per kilogram of diet: Vitamin B6, 3 mg; Vitamin B12, 0.03 mg; Niacin, 30 mg; Pantothenic acid, 20 mg; Fitic acid, 15 mg; Biotine, 0.25 mg; Cu, 15 mg; Fe, 80 mg; Mn, 40 mg; I, 1 mg; Zn, 100 mg; Se, 0.3 mg.

[2]Electrolitic balance

Pigs were slaughtered in a commercial plant. Hot carcasses were weighed (HCW) and refrigerated overnight at 0 °C, and lean meat yield (LMY) was calculated according to the methods described by the following equation developed in Colombia[(13)].

LMY = 3872 + (- 0.3344 * BF) + 0.5623 * HCW

In which, LMY is weight of the major commercial cuts in the area of Antioquia, Colombia (loin, head loin, rib, beef bacon, hand, and leg), BF is backfat thickness measured at 6 cm from the midline at the last rib in mm, and HCW is hot carcass weight in kg.

Backfat thickness (BF), loin eye area at the last rib, and LMY were determined on the right side of the carcass[3]. *Longissimus dorsi* muscle (LDM) sample was taken and cut into chops from medium zone to determine quality attributes such as color, pH[3], water retention capacity (WRC), shear force (SF), and fatty acids profile. pH was determined 6 h postmortem by using a portable potentiometer[7].

Water retention capacity (WRC) of the loin was determined by grounding a 350 mg sample with a screen of 4.5 mm. The sample then was taken on filter paper and covered with acetate paper, the assembly was subjected to pressure with a texturometer for 5 min, keeping the pressure constant at 10 kg-f. The sample then was allowed to dry for 24 h for analysis. The analysis of images of the loin area and WRC was performed by using the Google Sketchup 8 software (Google, Inc., Mountain View, CA, USA).

Instrumental color was measured on chops using a HunterLab MiniScan EZ Spectrophotometer (Hunter Associates Laboratory Inc., Reston, West Virginia, USA). Samples were read using illuminant D65 observer and evaluated for CIE (*L**, *a** and b*) color values. Cooking losses were evaluated on loin chops by weighting changes before and after cooking, and tenderness was determined on cooked samples by measuring shear force on Warner-Bratzler according to the methods described by Della Casa et al.[7], Lammers et al.[2], and Mendoza et al.[9].

For economic analysis a partial budget was used as follow:

$$C = (B + \Sigma(cij\ (Yij))) / X$$

In which, C is cost per kg of swine in pesos, B is pig cost at 20 kg, X is body weight of pigs at the end of the experiment, Y is feed conversion, c is experiment diet cost in j phase, and i is experimental treatment in i phase.

$$PNI = [(Py * Yi) - (Px * Xi)] / n$$

$$PNC = [(Pz * (Yi * Li)) - (Px * Xi)] / n$$

In which: PNI is partial net income per pig per experimental group, PNC is partial net income per pig carcasses by experimental group, Py is price of kg of live swine, Y is body weight of pigs at the end of the experiment, Px is price cumulative weighted kg food, X is amount of food consumed before the sacrifice, n is number of pigs for slaughter/replica, i is experimental treatment, L is lean yield (%), and Pz is price of pork (kg). The prices of raw materials used for economic analysis were set according to the local market in the savannah of Bogotá, and the purchase prices of raw materials were used for testing in Colombian pesos. The price of pork was 4458 $/kg to market Bogotá in April 2011 [14].

Data were analyzed as a complete block design[15] with a random block effect for period. When significant differences occurred, analysis was performed using the linear and quadratic polynomial effect ($P < 0.05$).

Results and Discussion

The effects of inclusion of crude glycerin from PO in commercial diets of pigs on the productive performance are summarized in Table 3. According to the results, the level of PO crude glycerin in the diet, up to 10%, did not affect pig performance (P> 0.05) or feeding cost per kilogram of live pigs (P > 0.05).

Results in carcass quality of pigs fed different levels of crude glycerin from PO were summarized in Table 4. Dietary treatments did not affect carcass characteristics (P>0.05) or feeding cost to produce one kilogram of lean meat (P>0.05).

Results of growing, carcass characteristics, and meat quality obtained in the present study are similar to those observed with crude glycerin from soybean oil(2). The study of Lammers et al.(2) evaluated crude glycerin in growing pigs and described animal growth, feed intake, conversion, fat in the 10^{th} rib, loin area and free fat percentage showing no effects due to treatments, similarly to the results found in the present study. Contrary, in piglets, the inclusion of crude glycerin improved average daily gain in linear form, without affecting consumption and conversion(16), similar to the results obtained with 8% glycerol in diet(10) and growing pigs(8).

In another study, a slight reduction in weight gain in the early stages of development of fattening pigs was noticed; however, at slaughter, there were no significant differences in the performance of the animals. Carcass characteristics were not affected by the recommended inclusion of crude glycerol up to 9% of the diet(3), similar to the results obtained with 8% glycerol in the diet(10). Contrary to the results observed in the present experiment, Della Casa et al.(7) verified that 5% glycerin inclusion in the diet did not affect the performance heavy pigs (46-160 kg) at fattening; however, glycerin inclusion at 10% reduced weight gain and adversely affected feed conversion. Mendoza et al.(9) observed there was no effect of refined glycerin on characteristics of carcass or meat quality of finishing pigs.

There was no effect (P>0.05) of crude glycerin from PO on the parameters of meat quality (Table 5). The findings of this study show that the inclusion of crude glycerin to a level of 10% did not affect most of the meat quality features analyzed (P> 0.05). However, we observed an increase (P <0.05) in the cooking losses with the increase in the level of crude glycerin from PO in the diet.

The effects of glycerin on meat quality were similar to those observed in the study of fattening heavy pigs(7), where treatments did not affect the characteristics of meat or fat ham. The sensory responses were not very consistent to lead to any conclusions, as noted by Della Casa et al.(7). Observations in meat quality were similar to those verified with crude glycerin derived from soybean oil, which were not affected by treatments including crude glycerin. But contrary to the present results, in that study, the pH of the loin increased with the inclusion of crude glycerin(2).

Table 3. Performance of pigs fed different levels of crude glycerin from PO during a complete cycle

Item	Crude glycerin level, %[1]			P[2]	
	0	5	10	L	Q
Replicates	4	4	4		
Initial weight, kg	23.03±1.6	23.26±1.6	22.88±1.6		
Final weight, kg	100.52±2.2	102.45±2.2	98.75±2.2	0.523	0.257
ADG[3], kg/d	0.849±0.02	0.867±0.02	0.828±0.02	0.508	0.303
ADFI[4], kg/d	2.28±0.13	2.46±0.13	2.34±0.13	0.516	0.099
Feed conversion, g/g	2.69±0.11	2.84±0.11	2.84±0.11	0.244	0.444
20 to 30 kg BW					
ADG, kg/d	0.713±0.06	0.803±0.06	0.796±0.06	0.370	0.544
ADFI, kg/d	1.19±0.06	1.39±0.06	1.29±0.06	0.287	0.077
Feed conversion, g/g	1.68±0.12	1.76±0.12	1.66±0.12	0.894	0.568
30 to 50 kg BW					
ADG, kg/d	0.860±0.05	0.8723±0.05	0.891±0.05	0.609	0.952
ADFI, kg/d	1.95±0.05	2.06±0.05	2.03±0.05	0.283	0.284
Feed conversion, g/g	2.27±0.1	2.38±0.1	2.29±0.1	0.852	0.270
50 to 70 kg BW					
ADG, kg/d	0.956±0.05	0.911±0.05	0.854±0.05	0.189	0.917
ADFI, kg/d	2.49±0.21	2.47±0.21	2.66±0.21	0.423	0.593
Feed conversion, g/g	2.60±0.22	2.69±0.22	3.16±0.22	0.084	0.448
70 to 100 kg BW					
ADG, kg/d	0.822±0.06	0.895±0.06	0.779±0.06	0.561	0.167
ADFI, kg/d	2.73±0.07	3.13±0.07	2.76±0.07	0.771	0.002
Feed conversion, g/g	3.33±0.2	3.56±0.2	3.58±0.2	0.363	0.669
Feeding cost, $/Kg BW	2494.8±96.2	2598.8±96.2	2553.8±96.2	0.591	0.440

[1]Mean±Standar Error (SE)

[2]P= P value for lineal (L) and quadratic (Q) effect

[3]ADG= Average daily gain

[4]ADFI= Average daily feed intake

Table 4. Features of carcass quality of pigs fed different levels of crude glycerin for a complete cycle

Item	Crude glycerin level,%[1]			P[2]	
	0	5	10	L	Q
Replicates	4	4	4		
HCW[3], kg	82±6.3	83±6.3	81.13±6.3	0.850	0.721
Carcass yield, %	82.2±1.7	83.5±1.7	83.05±1.7	0.492	0.426
Backfat, mm	14.5±1.3	15.1±1.3	13.4±1.3	0.553	0.466
Loin area, cm^2	49.93±4.6	56.27±4.6	47.3±4.6	0.672	0.186
Loin depth, mm	62.38±4.6	74.24±4.6	70.06±4.6	0.269	0.189
Lean yield, %	43.87±2.5	45.5±2.5	45.48±2.5	0.377	0.593
Lean Weight, Kg	36±4.1	38.1±4.1	37.54±4.1	0.651	0.651
Lean Cost, $ / Kg	5389±577	5526±577	5489±577	0.858	0.858

[1]Mean±Standar Error (SE)
[2]P= P value for lineal (L) and quadratic (Q) effect
[3]HCW= Hot carcass weight

Table 5. Meat quality of pigs fed different levels of crude glycerin for a complete cycle

Item	Crude glycerin level, %[1]			P[2]	
	0	5	10	L	Q
Replicates	4	4	4		
pH	5.5±0.07	5.5±0.07	5.4±0.07	0.474	0.696
Shear Force, kg-f	4.9±0.8	6.01±0.8	5.9±0.8	0.279	0.226
WHC, mm/mm[3]	6.9±1.1	5.68±1.1	6.53±1.1	0.803	0.433
Cooking losses, %	25.2±0.02	30.7±0.02	29.9±0.02	0.037	0.082
Color					
*L**	55.84±1.9	51.77±1.9	52.2±1.9	0.220	0.365
*a**	14.3±0.7	14.1±0.7	14.9±0.7	0.421	0.501
*b**	7.0±0.497	6.8±0.503	6.6±0.497	0.076	0.968

[1]Mean±Standar Error (SE)
[2]P= P value for lineal (L) and quadratic (Q) effect
[3]Water Holding Capacity

The increase in cooking losses was contrary to what was previously observed: that the inclusion of glycerin could reduce water loss from the carcass and cooking[6]. However, more recent studies have not shown this condition[2,7]. This increase in cooking losses could be explained by hyperhydration in the tissues caused by increased consumption of glycerol, a result that is consistent with that observed in athletes[17]. Several experiments[2,3,7-10] did not reveal effects of the inclusion of crude glycerin on lightness (L *), red index (a *), and yellow index (b *) of pork loins, similarly to the results of the present study.

Based on the findings of the present study, the inclusion of crude glycerin up to a level of 10% did not affect the fatty acid composition of intramuscular fat of the loin (P> 0.05) (Table 6).

Previous studies have showed an increase in oleic acid in the backfat at the expense of linoleic and linolenic acids and consequently a reduction in the ratio polyunsaturated fatty acids (PUFA): saturated fatty acids (SA). This result could be explained by variations in the fatty acid content of the experimental diets where the PUFA were reduced to include crude glycerin from soybean oil in place of corn[2]. Contrasting results were obtained in the present study in which the level of linoleic acid was kept constant in the diet by varying inclusion levels from palm oil and full-fat soybean. Therefore, since the linolenic acid was constant within the experimental diets, the fatty acid profile of pork loin did not change due to the inclusion level of PO crude glycerin.

Table 6. Profile of long chain fatty acids in the intramuscular fat of loin from pigs fed different levels of crude glycerin for a complete cycle

	Crude glycerin level, %[1]			P[2]	
Item	**0**	**5**	**10**	**L**	**Q**
Replicates	4	4	4		
Ether extract, %	9.96±2.08	11.93±2.08	13.37±2.08	0.060	0.845
Myristic, %	1.4±0.08	1.3±0.08	1.4±0.08	0.998	0.292
Palmitic, %	25.6±0.6	24.9±0.6	25.5±0.6	0.927	0.346
Stearic, %	12.1±0.9	13.2±0.9	12.8±0.9	0.594	0.526
Oleic, %	48.8±0.9	49.6±0.9	50.2±0.9	0.222	0.978
Linoleic, %	7.9±0.7	7.3±0.6	5.9±0.6	0.090	0.657
Saturated, %	39.2±1.2	39.3±1.2	39.8±1.2	0.739	0.947
Unsaturated, %	57.0±1.2	56.9±0.9	56.2±0.9	0.596	0.829
Uns/sat[3]	1.53±0.07	1.47±0.06	1.42±0.06	0.242	0.969

[1]Mean±Standar Error (SE)

[2]P= P value for lineal (L) and quadratic (Q) effect

[3]Unsaturated/Saturated

In piglets, the inclusion of up to 15% crude glycerin in the diet showed a linear increase in the content of PUFA and a linear reduction in the content of the saturated acids (SA). In addition, the relationship PUFA:SA increased linearly, which indicates glycerol is metabolized for glucose synthesis and not for the synthesis of fatty acids(18). These results were also observed in lactating sows, where the inclusion of crude glycerin increased the lactose content in milk demonstrating a gluconeogenic effect of glycerol(19).

According to the results of this study (Table 7), the inclusion of up to 10% PO crude glycerin in the diet did not affect the economic analysis variables reviewed in this study (P> 0.05).

The economic analyses were consistent with those performed by Carvalho et al.(20), who observed a reduction in the cost of feed when the inclusion of crude glycerin in the diet increased. However, the results of the economic viability of including glycerin were not clear. It depends on other market variables, including, especially, the cost of corn and soybean meal. The reduction in feed costs by including crude glycerin(20) is also one of the justifications given in another study on the inclusion of crude glycerin. Nevertheless, the impact of such inclusion on revenues and feeding costs has been reconsidered(3,16).

Table 7. Economic analysis of the inclusion of PO crude glycerin in the diet of growing pigs during a complete cycle[1]

	Crude glycerin level, %[2]			P[3]	
Item	0	5	10	L	Q
Replicates	4	4	4		
PNI[4], $	254652±9790	250719±9790	247184±9790	0,645	0,988
PNC[5], $	286003±22639	279279±22639	281294±22639	0,883	0,875

[1] Values in Colombian pesos
[2]Mean±Standar Error (SE)
[3]P= P value for lineal (L) effect and quadratic (Q)
[4]PNI = partial net income per pig per experimental group
[5]PNC= partial net income per pig carcasses by experimental group

Conclusions

The use of crude glycerin from palm oil up to 10% in diets of growing pigs did not adversely affect pig performance, carcass characteristics, and meat quality. Therefore, crude glycerin from palm oil can be safely utilized as a source of energy for swine.

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