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Dietary corn germ containing phytic acid prevents pork meat lipid oxidation while maintaining normal animal growth performance

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Abstract

The effects of dietary defatted corn germ meal (DCGM) containing phytic acid (PA) on pig health during development and on its *Longissimus dorsi* m. (LD) lipid oxidative stability has been evaluated. Rations of DCGM were prepared at the level of substitution of 0%, 10%, 20% and 40% and offered to twenty four animals of Landrace x Large White crossbreds throughout 25 days before slaughtering. Animals were sacrificed at an average weight of 91.24 kg (±0.950) and samples for meat lipid oxidation analysis were taken after seven days under refrigeration at 3 °C. Animals fed with DCGM did not show any significant difference, in comparison to the control, in carcass characteristics, such as cold carcass weight, backfat depth, muscle depth, lean meat percentage and carcass dress yielding ($p \leqslant 0.05$). Finally, no difference in meat proximate chemical composition was detected solely arising from lipid oxidation since LD from DCGM-treated pigs revealed an inhibition of 63.0%.

Keywords: Lipid oxidation; Phytic acid; Corn germ; Pork meat

1. Introduction

Phytic acid (PA; Inositol hexaphosphate) is present in cereals and legumes at a concentration of 1–5% in weight (Empson, Theodore, & Graf, 1991) and its phosphorus residues comprise 60–90.0% of the total phosphorus present in grain as calcium, magnesium or potassium phytates (Graf & Eaton, 1990). Its strong chelating properties for polyvalent cations arise from its polyphosphate structure which inhibits the formation of hydroxyl radicals (Empson et al., 1991). The role of PA as an antioxidant in meat has been pointed out in several reports (Lee & Hendricks, 1995; Lee, Hendricks, & Conforth, 1998a; Soares, Olivo, Shimokomaki, & Ida, 2004a) and hence its role in the inhibition of lipid oxidation is potentially crucial for retaining meat quality (Lee et al., 1998a ; Morrissey, Sheehy, Galvin, Kerry, & Buckley, 1998). The antinutrional effect of PA in the animal diet in relation to the bio-availability of minerals is also well described (Seynaeve, Janssen, Hesta, Van Nevel, & De Wilde, 2000) although, according to some reports, it depends on the relative proportion of phytate metal ions and other dieting components (Febles, Arias, Hardisson, Rodriguez-Alvarez, & Sierra, 2002; Graf & Eaton, 1990).

Defatted corn germ meal (DCGM) is an industrial subproduct, resulting from oil extraction, and is a potential corn substitute (Moreira, Ribeiro, Furlan, Scapinello, & Kutschenko, 2002; Soares et al., 2004b). It is relatively rich in PA (Graf & Eaton, 1990).

The objective of this work was to investigate the effect, of the endogenous presence of phytic acid, by the addition of defatted corn germ meal to the pig diet, on animal health and thereafter on the carcass characteristics and *Longissimus dorsi* m. lipid oxidation.

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2. Materials and methods

2.1. Animals test

Castrated (12 male and 12 female) crossbred pigs of Landrace X Large White were used with initial average weight of 70.870 ± 3.90 kg. Animals were kept in an individual pen of 3 m^2 area on a compact floor. They were divided into four treatments, with six repetitions each, comprising a DCGM-supplemented diet at levels of 0%, 10%, 20% and 40% during the terminal phase. The prepared rations of four treatments were all isoproteic, isolysinic and isoenergetic and, except for the metabolizable energy, feeds were formulated according to the animal nutritional demand specifically related to this particular phase as described in Table 1 (NRC, 1988). Drinking water and ration were offered ad libitum. Animals were slaughtered at the averaged weight of 91.246 kg ±0.95, using routine commercial techniques in a local abattoir. The technique consisted essentially of electrical stunning, slaughtering, scalding, evisceration and final cleaning.

2.2. Phytic acid determination

Phytic acid was determined in defatted corn germ and each ration according to the methodology described by Latta and Eskin (1980).

2.3. Weight gain determination

Weight gain, ration consumption and feed conversion were evaluated daily and animals were weighed at the starting and final experimental points.

Table 1
Composition of diets given to pigs during their terminal phase

Ingredients (%)	Treatments			
	0%	10%	20%	40%
Corn	73.395	65.971	58.547	43.698
Soybean meal	15.262	14.333	13.404	11.546
Defatted corn germ meal	0.000	10.000	20.000	40.000
Hull's rice	6.705	5.029	3.353	0.000
Dicalcium phosphate	2.264	2.212	2.162	2.061
Soybean oil	1.300	1.300	1.300	1.300
Vitamin supplement[a]	0.400	0.400	0.400	0.400
Mineral supplement[b]	0.050	0.050	0.050	0.050
Limestone	0.363	0.432	0.500	0.637
Salt	0.250	0.250	0.250	0.250
L-lysine-HCl-78%	0.011	0.023	0.034	0.058
Total	100.000	100.00	100.00	100.00

Diets were composed of 0%, 10%, 20% and 40% of defatted corn germ meal.

[a] Vitamin supplement per kg feed: vitamin A 550,000 IU; vitamin D3 150,000 IU; vitamin E 2500 IU; vitamin K3 550 mg; vitamin B1 175 mg; vitamin B2 900 mg; vitamin B12 3000 mg; Folic acid 150 mg; Pantonenic acid 30 mg; Niacin 475 mg; Selenium 75 mg; Antioxidant 2.5%.

[b] Mineral supplement per kg feed (mg/kg): Fe 90; Cu 16; Mg 30; Zn 140; Co 200 mg; I 850; Se 120.

2.4. Carcass characteristics

2.4.1. Gross weights

Cold carcass weight, backfat depth, muscle depth, measured at the height of last rib from 6 cm of cut medium line, were determined in refrigerated carcasses at 0.0 °C ± 1. The lean meat percentage and carcass dress yielding were determined using an automated system (FAT-O-MEATER-FOM) with typifying Stork-SKF model S97.

2.4.2. Proximate chemical composition

The moisture, lipid, protein and ash compositions of the meat were determined according to AOAC methodology (1996).

2.4.3. Lipid oxidation

Meat lipid oxidation was measured in *L. dorsi* samples stored for 7 days at 3 °C ±1 using the method described in Tarladgis, Pearson, and Dugan (1964).

2.5. Statistical analysis

The experimental design used was a randomized block design involving four treatments and six repetitions, taking into account the initial weight of the animal. The statistical analysis was performed using the STATISTICA software packet. The effect of DGCM inclusion in the diet was evaluated through variance analysis. The Tukey test was applied for the comparison of mean values among pig diet treatments ($p \leqslant 0.05$).

3. Results and discussion

3.1. Phytic acid involvement and animal performance

The DCGM contained a PA amount of 2.85 ± 0.06 g/100 g dry weight. Table 2 shows the amount of PA in the ration prepared with different levels of DCGM. The starting ration-free DCGM contained 0.875 g/100 g of PA because of the corn and soy presence in the original formulation. This amount of PA increased substantially ($p \leqslant 0.05$) after adding DCGM, providing evidence of the endogenous presence of PA in DCGM. Taking into consideration the pig daily consumption (Table 3) it was possible to estimate that daily consumption of PA were 25.80; 36.97; 44.56 and 50.44 g for treatments with 0%, 10%, 20% and 40% of added DCGM, respectively.

Table 2
Amount of phytic acid (PA) offered to pigs fed with varying amounts of defatted corn germ meal (DCGM)

Fed with DCGM (%)	Amount of PA wet basis (g/100 g)
0	$0.875^{c} \pm 0.109$
10	$1.256^{bc} \pm 0.072$
20	$1.556^{ab} \pm 0.128$
40	$1.750^{a} \pm 0.160$

[a–c] Means followed by different letters are significantly different by the Tukey test ($p \leqslant 0.05$).

Table 3
Effect of indirect addition of phytic acid through the defatted corn germ meal (DCGM) inclusion in the pig ration on daily weight gain, daily feed consumption and feed conversion

Fed with DCGM (%)	Daily weight gain (g)	Daily feed consumption (g)	Feed conversion
0	840[a] ± 0.148	2949[a] ± 0.210	3.667[a] ± 0.638
10	836[a] ± 0.082	2943[a] ± 0.280	3.525[a] ± 0.158
20	826[a] ± 0.264	2864[a] ± 0.268	3.515[a] ± 0.334
40	836[a] ± 0.131	2882[a] ± 0.339	3.473[a] ± 0.276

[a] Means followed by different letters are significantly different by the Tukey test ($p \leqslant 0.05$).

Table 5
Effect of indirect addition of phytic acid through the defatted corn germ meal (DCGM) inclusion in the pig ration on proximate chemical composition, of refrigerated *L. dorsi* m.

Fed with DCGM (%)	Moisture (%)	Lipid (%)	Protein (%)	Ash (%)
0	72.70[a] ± 0.73	3.15[a] ± 0.58	22.6[a] ± 0.73	1.20[a] ± 0.10
10	72.85[a] ± 0.61	2.80[a] ± 0.78	22.7[a] ± 0.53	1.20[a] ± 0.12
20	72.86[a] ± 0.73	3.23[a] ± 0.80	22.1[a] ± 0.81	1.18[a] ± 0.10
40	72.31[a] ± 0.63	3.31[a] ± 0.75	22.7[a] ± 0.59	1.18[a] ± 0.11

[a] Means followed by different letters are significantly different by the Tukey test ($p \leqslant 0.05$).

Table 6
Effect of indirect addition of phytic acid through the defatted corn germ meal (DCGM) inclusion in the pig ration on refrigerated *L. dorsi* m. lipid oxidation

Fed with DCGM (%)	TBARS (mg/kg)
0	0.640[a] ± 0.235
10	0.479[ab] ± 0.257
20	0.370[ab] ± 0.092
40	0.237[b] ± 0.086

[a–b] Means followed by different letters are significantly different by Tukey test ($p \leqslant 0.05$).

Table 3 shows the effect of the diet with DCGM containing PA on the pig performance. In the variance analysis, no significant effect of the dietary treatments was observed ($p \leqslant 0.05$). Animals undergoing four treatments showed no significant differences in relation to the daily weight gain, daily ration consumption and feed conversion parameters. This indicates that a relatively high consumption of PA in the terminal phase is harmless in relation to the animal's development. Conversely Moreira et al. (2002) observed a decrease in weight gain after adding 45% of DCGM to pig diet from the initial development to the end of experimental phases. Feeding the animals according to this scheme may explain the difference to our results. In the earlier developmental phase, the demand for feed nutrients is higher (NRC, 1988).

Table 4 shows the effect of addition of the ration with DCGM on the carcass characteristics. Cold carcass weight, backfat depth, muscle depth, lean meat percentage and carcass dress yielding showed no significant difference ($p \leqslant 0.05$) among the four evaluated treatments. These results clearly demonstrate that the ration containing DCGM did not affect pig carcass characteristics.

3.2. Proximate chemical composition of L. dorsi m.

Table 5 shows that moisture, lipid, protein and ash contents in animal feed, under both rations, produced *L. dorsi* m. with similar proximate chemical compositions ($p \leqslant 0.05$).

3.3. Lipid oxidation

Table 6 shows that the addition of 40% of DCGM promoted inhibition of lipid oxidation by 63.0%, as measured by TBARS (thiobarbituric acid reactive substances) in *L. dorsi* m. from animals fed with PA ($p \leqslant 0.05$). This result shows the important role of PA in the inhibition of meat oxidative rancidity by chelating minerals, particularly iron from myoglobin pigments (Lee & Hendricks, 1995; Soares et al., 2004a). In fact, it has been shown that phytate is a powerful inhibitor of iron-driven hydroxyl radical formation because of its ability to form a unique iron chelate that becomes catalytically inactive (Graf & Eaton, 1990, for review see Conforth, 2002). Although not observed in our current study, Lee, Hendricks, and Conforth (1998b) reported that added sodium phytate helped the uncooked beef rolls to become redder than controls.

4. Conclusions

Our results demonstrate that phytic acid, endogenously present in dietary industrial defatted corn germ meal in the terminal phase, did not bring about any nutritional hazard in the pig. Carcass performance was maintained and substantial inhibition of the meat lipid oxidation (TBARS) was observed.

Table 4
Effect of indirect addition of phytic acid through the defatted corn germ meal (DCGM) inclusion in the pig ration on cold carcass weight, backfat depth, muscle depth, lean meat percent and carcass dress yield

Fed with DCGM (%)	Cold carcass weight (kg)	Backfat depth (mm)	Muscle depth (mm)	Lean meat percent (%)	Carcass dress yield (kg)
0	67.52[a] ± 4.49	11.43[a] ± 2.32	54.47[a] ± 6.33	58.82[a] ± 1.17	39.68[a] ± 2.19
10	67.72[a] ± 4.78	12.26[a] ± 3.52	56.49[a] ± 6.09	58.54[a] ± 1.78	39.61[a] ± 2.32
20	66.52[a] ± 5.64	12.62[a] ± 2.22	56.03[a] ± 2.39	58.28[a] ± 1.19	38.70[a] ± 2.60
40	67.88[a] ± 4.79	13.02[a] ± 1.53	61.33[a] ± 4.81	58.58[a] ± 0.99	39.75[a] ± 2.49

[a] Means followed by different letters are significantly different by the Tukey test ($p \leqslant 0.05$).

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