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Short communication

The effect of feeding expeller-pressed canola meal on growth performance and diet nutrient digestibility in weaned pigs

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ABSTRACT

The effects of feeding increasing levels of expeller-pressed (EP) canola meal in substitution for soybean meal as an energy and amino acid source were evaluated in 240 weaned pigs with an initial body weight of 7.3 ± 0.6 kg. Five pelleted wheat-based diets containing 0, 50, 100, 150 or 200 g EP canola meal/kg were formulated to contain 10.0 MJ net energy (NE)/kg and 1.18 g standardised ileal digestible (SID) lysine/MJ NE and were fed for 4 wk starting 1 wk after weaning at 19 days of age. Expeller-pressed canola meal was added at the expense of soybean meal and the diets were balanced for NE using canola oil and for amino acids using crystalline lysine, methionine, threonine and tryptophan. Increasing inclusion of EP canola meal linearly reduced ($P<0.001$) the apparent total tract digestibility of energy, dry matter and crude protein and the digestible energy content of diets. From 0 to 28 days on trial, increasing inclusion of EP canola meal did not affect body weight gain, feed intake and feed efficiency. In conclusion, up to 200 g EP canola meal/kg can replace soybean meal in diets formulated to equal NE and SID amino acid content and fed to nursery pigs starting 1 wk after weaning without reducing growth performance.

1. Introduction

Expeller-pressed (EP) canola meal, a co-product of expeller pressing canola seed to produce oil, is a potential cost-effective feedstuff in swine diets. Compared to soybean meal (SBM), EP canola meal has a higher net energy (NE) value due to a higher residual oil content (Seneviratne et al., 2010), but a lower amino acid content due to a lower crude protein (CP) content. Based on its lower amino acid content and perceived risks associated with inclusion of canola co-products in monogastric diets, EP canola meal is sold at a discount relative to SBM.

The energy value of EP canola meal is higher than that of solvent-extracted canola meal (Seneviratne et al., 2010). However, the higher glucosinolate content in EP canola meal might limit its inclusion in diets for weaned pigs. Research in young pigs fed EP canola meal is limited. Recently, weaned pigs fed 150 g EP canola meal/kg diet to partially substitute SBM had a reduced feed intake although body weight gain was not affected (Seneviratne et al., 2011). Higher inclusion levels of EP canola meal require further validation in weaned pigs.

Abbreviations: ADFI, average daily feed intake; ADG, average daily gain; ATTD, apparent total tract digestibility; BW, body weight; CP, crude protein; DE, digestible energy; DM, dry matter; EP, expeller-pressed; G:F, feed efficiency; Lys, lysine; NE, net energy; SBM, soybean meal; SID, standardised ileal digestible.

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Table 1
Ingredient composition and analysed nutrient content (g/kg diet as fed) of experimental diets.

	Expeller-pressed canola meal (g/kg diet)				
	0	50	100	150	200
Ingredient composition					
Wheat, ground	558.6	562.4	566.3	570.2	574.1
Soybean meal, 460 g CP/kg	200.0	150.0	100.0	50.0	–
Expeller-pressed canola meal, 363 g CP/kg[a]	–	50.0	100.0	150.0	200.0
Lactose	50.0	50.0	50.0	50.0	50.0
Canola oil	50.0	45.0	40.0	35.0	30.0
Soy protein concentrate, 560 g CP/kg	50.0	50.0	50.0	50.0	50.0
Herring fish meal, 700 g CP/kg	50.0	50.0	50.0	50.0	50.0
Limestone	9.1	9.1	9.1	9.1	9.1
Celite[b]	8.0	8.0	8.0	8.0	8.0
Mono/dicalcium phosphate	8.2	8.2	8.2	8.2	8.2
Vitamin premix[c]	5.0	5.0	5.0	5.0	5.0
Mineral premix[d]	5.0	5.0	5.0	5.0	5.0
Salt	5.0	5.0	5.0	5.0	5.0
L-Lysine HCl, 780 g/kg	0.2	0.9	1.6	2.2	2.9
L-Threonine, 990 g/kg	0.3	0.6	0.9	1.2	1.5
DL-Methionine, 990 g/kg	0.3	0.4	0.4	0.5	0.5
L-Tryptophan, 990 g/kg	–	0.1	0.2	0.3	0.4
Choline chloride 600 g/kg	0.3	0.3	0.3	0.3	0.3
Analysed nutrients[e]					
Moisture	114	108	105	106	108
Crude protein	227	232	230	228	219
Ether extract	66	63	65	68	64
Crude fibre	19	21	26	30	34
Ash	58	61	62	60	62
Acid detergent fibre	33	38	48	54	60
Neutral detergent fibre	128	159	144	148	163
Gross energy (MJ/kg)	17.1	17.2	17.2	17.2	17.1

[a] Associated Proteins, Ste. Agathe, Manitoba, Canada.
[b] Celite 281 (World Minerals Inc., Santa Barbara, CA, USA) used as acid insoluble ash.
[c] Supplied per kilogram of diet: 7500 IU of vitamin A, 750 IU of vitamin D, 50 IU of vitamin E, 37.5 mg of niacin, 15 mg of pantothenic acid, 2.5 mg of folacin, 5 mg of riboflavin, 1.5 mg of pyridoxine, 2.5 mg of thiamine, 2000 mg of choline, 4 mg of vitamin K, 0.25 mg of biotin and 0.02 mg of vitamin B_{12}.
[d] Supplied per kilogram of diet: 125 mg of Zn, 50 mg of Cu, 75 mg of Fe, 25 mg of Mn, 0.5 mg of I and 0.3 mg of Se.
[e] Diets were formulated to contain (as fed): 10.0 MJ NE/kg, 11.8 g SID lysine/kg, 4.1 g SID methionine/kg, 7.6 g SID threonine/kg and 2.6 g SID tryptophan/kg.

The hypothesis tested in the present study was that pigs offered diets containing up to 200 g EP canola meal/kg and formulated to an equal NE and standardised ileal digestible (SID) amino acid content would have a growth performance and dietary nutrient digestibility similar to pigs fed diets without EP canola meal. The objectives were to determine whether a dose response existed for growth performance and apparent total tract digestibility (ATTD) coefficients of dietary energy and CP of weaned pigs fed diets containing 0 up to 200 g EP canola meal/kg.

2. Materials and methods

2.1. Experimental design and diets

The animal procedures were approved by the University of Alberta Animal Care and Use Committee for Livestock, and followed principles established by the Canadian Council on Animal Care (CCAC, 2009) and were conducted at the Swine Research and Technology Centre.

In total, 240 pigs (Duroc × Large White/Landrace F_1; Hypor, Regina, SK, Canada) were weaned at 19 ± 1 days of age, selected based on average daily gain (ADG) during the first 7 day post weaning and body weight (BW) on day 7 after weaning (7.3 ± 0.6 kg) and divided within gender into heavy and light BW. One heavy and one light barrow and gilt were randomly placed into one of 60 pens, for 4 pigs per pen. After weaning, pigs were fed sequentially commercial phase 1 [241 g CP/kg, 11.1 MJ NE/kg, 16.4 g SID Lysine (Lys)/kg] and Phase 2 (203 g CP/kg, 11.0 MJ NE/kg, 12.4 g SID Lys/kg) diets for 2 and 5 days, respectively. Wheat, soybean meal, oats, and lactose and other highly digestible protein sources were included in these diets.

A wheat-based control diet and four diets containing 50, 100, 150 or 200 g EP canola meal/kg were formulated by replacing SBM with EP canola meal (Table 1). Diets without antimicrobials or growth promoters were formulated to provide 10.0 MJ NE/kg and 1.18 g SID Lys/MJ NE with other amino acids formulated as an ideal ratio to Lys (NRC, 1998) using established NE (Sauvant et al., 2004) and SID AA (NRC, 1998) values. For EP canola meal, a content of 10.03 MJ/kg NE and 1.66 g SID Lys on an as fed basis were used (Seneviratne et al., 2010). Acid-insoluble ash (Celite 281; World Minerals, Santa Barbara, CA, USA) at 8 g/kg was included in diets as an indigestible marker. Diets were mixed and steam pelleted at 70 °C (70 hp; California Pellet Mill, Crawfordsville, IN, USA).

The study was conducted as a randomised complete block design with 60 pens in four nursery rooms filled 2 wk apart. The rooms were ventilated using negative pressure and were maintained within the thermo-neutral zone for the pigs, with a 12-h light (0600–1800 h), 12-h dark cycle. Pens of pigs within block (representing areas within room) were randomly allocated to be fed one of five diets during the 4-wk study, starting 7 day post weaning for a total of 12 pen-replicates per diet. Pens (1.1 m × 1.5 m) were equipped with a multiple-space self-feeder, a nipple drinker and plastic slatted flooring. Pigs had free access to feed and water.

Individual pigs, feed added and orts were weighed weekly. These data were used to calculate ADG, average daily feed intake (ADFI), and feed efficiency (G:F) for the pen. Freshly voided faeces were collected from 0800 to 1600 h by grab sampling from pen floors on days 15 and 16. Faeces were pooled by pen and frozen at −20 °C. Upon completion of the growth trial, faeces were thawed, homogenised, sub-sampled and freeze-dried.

2.2. Chemical analyses

The EP canola meal, diets and lyophilized faeces were ground through a 1-mm screen in a centrifugal mill (Retsch GmbH, Haan, Germany). The EP canola meal was analysed for CP (method 984.13A-D), total dietary fibre (method 985.29), acid detergent fibre inclusive of residual ash (method 973.18), ash (method 942.05), calcium (method 968.08), phosphorus (method 946.06), amino acids (method 982.30E) and available Lys (method 975.44) as described by AOAC (2006), starch (assay kit STA-20; Sigma, St. Louis, MO, USA), neutral detergent fibre assayed without a heat stable amylase and expressed inclusive of residual ash (Holst, 1973), glucosinolates by gas chromatography (Daun and McGregor, 1981) and non-starch polysaccharides (Englyst and Hudson, 1987). Diets and faeces were analysed for dry matter (DM; method 930.15; AOAC, 2006), CP (N × 6.25; method 988.05; AOAC, 2006), acid-insoluble ash (McCarthy et al., 1974) and gross energy content using an adiabatic bomb calorimeter (model 5003; Ika-Werke GMBH & Co. KG, Staufen, Germany). Based on results of chemical analyses, the ATTD coefficients of CP, gross energy and DM were calculated using the acid-insoluble ash concentration of faeces relative to feed using the indicator method (Adeola, 2001).

2.3. Statistical analyses

Data were analysed using the MIXED procedure (SAS Inst. Inc., Cary, NC, USA), using the pen as the experimental unit. Diet was the fixed effect and block was the random factor in the statistical model. Growth performance was analysed as repeated measures using initial BW as a covariate. Two single degree of freedom orthogonal contrasts tested the linear or quadratic effects of increasing EP canola meal inclusion. To test the hypotheses, $P<0.05$ was considered significant. Two pens, by chance both fed the 100 g EP canola meal/kg diet, had pigs with diarrhea, were outliers for growth performance data and were excluded from statistical analyses of growth and digestibility data.

3. Results

The diet with 200 g EP canola meal/kg had 15, 27 and 35 g/kg more crude fibre, acid detergent fibre and neutral detergent fibre, respectively, than the diet with 0 g EP canola meal/kg (Table 1). The EP canola meal sample contained 363 g CP/kg on as fed basis and 85% of the 19.8 g Lys/kg was chemically defined as available (Table 2).

Increasing dietary inclusion of EP canola meal linearly reduced ($P<0.001$) the ATTD of gross energy, DM and CP and DE content of the diet (Table 3). For the entire experiment (days 0–28) or for each week, increasing the inclusion of EP canola meal did not affect ADG, ADFI and G:F (Table 4). Final BW of pigs was 20.1, 19.8, 19.8, 19.7 and 20.1 kg for 0, 50, 100, 150, and 200 g EP canola meal/kg, respectively, and was not affected by increasing EP canola meal inclusion.

4. Discussion

Expeller-pressed canola meal is usually produced by heat-conditioning canola seed with a steam roller, followed by (double-)pressing the seed in an expeller press to maximize oil extraction. In Canada, only 3% of the canola seed was expeller-pressed producing a meal that contains more oil than solvent-extracted canola meal (Canola Council of Canada, 2009), but the number of local biorefineries is increasing due to the growth of the biodiesel industry. Indeed, EP canola meal has a higher NE value than solvent-extracted canola meal (10.68 *vs.* 7.29 MJ/kg DM; Sauvant et al., 2004; Seneviratne et al., 2010) but slightly lower SID Lys due to its higher residual oil content (Seneviratne et al., 2010), although their SID Lys content was similar in other reports (Woyengo et al., 2010). The inclusion of EP canola meal with 100–150 g residual oil/kg in late nursery diets could therefore potentially help weaned pigs to reach their high energy requirement.

In the present study, the reduced nutrient digestibility for diets with EP canola meal likely resulted from the higher fibre content in EP canola meal than soybean meal consistent with that previously reported for fibre (Fernandez and Jorgensen, 1986) or for solvent-extracted canola meal (Landero et al., 2011). The EP canola meal contained three times more fibre than values reported for soybean meal (Sauvant et al., 2004). Nutrient utilisation in EP canola meal thus can be improved further by reducing its fibre content or increasing fibre digestibility.

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Table 2
Analysed nutrient content (g/kg, as is) of the expeller-pressed canola meal included in the experimental diets.

Item	
Moisture	56
Crude protein	363
Ether extract	103
Crude fibre	69
Acid detergent fibre	160
Neutral detergent fibre	242
Total dietary fibre	305
Non-starch polysaccharides[a]	178.4
Insoluble[b]	140.9
Soluble[c]	37.5
Starch	0
Ash	68.9
Calcium	6.5
Phosphorus	11
Indispensable amino acids	
Arginine	21.5
Histidine	9.6
Isoleucine	15.0
Leucine	25.2
Lysine	19.8
Methionine	7.1
Phenylalanine	14.3
Threonine	15.1
Tryptophan	4.4
Valine	18.8
Total amino acids[d]	328
Available lysine	16.8
Total glucosinolates[e], μmol/g	10.87

[a] Constituent sugar profile (mg/g of EP canola meal): rhamnose, 2.5; ribose, 1.0; fucose, 2.4; arabinose, 50.1; xylose, 21.1; mannose, 4.5; glucose, 77.1 and galactose, 19.7.
[b] Constituent insoluble sugar profile (mg/g of EP canola meal):rhamnose, 1.6; fucose, 1.8; arabinose, 34.1; xylose, 18.0; mannose, 3.4; glucose, 68.7 and galactose, 13.3.
[c] Constituent soluble sugar profile (mg/g of EP canola meal): rhamnose, 0.9; ribose, 1.0; fucose, 0.6; arabinose, 16.0; xylose, 3.1; mannose, 1.1; glucose, 8.4 and galactose, 6.4.
[d] Dispensable amino acid (g/kg of EP canola meal): alanine, 15.6; aspartic acid, 25.0; cysteine, 8.6; glutamic acid, 59.0; glycine, 18.2; proline, 21.5; serine, 14.0; tyrosine, 9.5.
[e] Analysed glucosinolates (μmol/g of EP canola meal): 3-butenyl, 3.1; 4-pentenyl, 0.22; 2-OH-3-butenyl, 4.39; CH_3-thiobutenyl, 0.17; phenylethyl, 0.15; 3-CH_3-indolyl, 0.23; 4-OH-3-CH_3-indolyl, 2.61.

Limited information exists regarding the feeding value of EP canola meal in young pigs. Recently, weaned pigs fed diets formulated to an equal NE and SID amino acid content, partially replacing soybean meal with 150 g/kg EP canola meal, did not reduce weight gain although feed intake was depressed (Seneviratne et al., 2011). In the present study, the upper inclusion was pushed further by replacing up to 200 g/kg soybean meal entirely with EP canola meal. This high inclusion of EP canola meal did not reduce growth performance of weaned pigs, similar to our recent results with for solvent-extracted canola meal (Landero et al., 2011). The lack of detrimental effects of EP canola meal on growth performance might be explained partially by diet formulation based on the NE and SID amino acid systems that reduce the risks associated with increasing inclusions of high fibre, high protein co-products in swine diets (Zijlstra and Payne, 2007).

Glucosinolates in rapeseed meal were a limiting factor for its inclusion in swine diets (Bell, 1984). However, plant breeding has reduced glucosinolates in modern canola cultivars. Recently, the total content of glucosinolates in EP canola ranged from 5.3 to 13.6 μmol/g (Mullan et al., 2000; Spragg and Mailer, 2007; Seneviratne et al., 2010, 2011). The EP canola meal in the

Table 3
Apparent total tract digestibility coefficients (CATTD) of nutrients and digestible energy (DE) value of diets resulting from feeding increasing levels of expeller-pressed canola meal in substitution for soybean meal to weaned pigs.[a]

Variable	Expeller-pressed canola meal, g/kg diet					SEM[b]	P-value	
	0	50	100	150	200		Linear	Quadratic
CATTD								
Crude protein	0.811	0.817	0.793	0.788	0.788	0.004	<0.001	0.647
Gross energy	0.849	0.853	0.836	0.829	0.825	0.003	<0.001	0.606
Dry matter	0.846	0.849	0.832	0.824	0.818	0.002	<0.001	0.208
DE, MJ/kg	14.7	14.8	14.5	14.6	14.4	0.050	<0.001	0.329

[a] Least-squares means based on 12 pen observations of 4 pigs per diet, except 10 observations for 100 g expeller-pressed canola meal/kg.
[b] Standard error of the mean.

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Table 4
Growth performance of weaned pigs fed diets with increasing level of expeller-pressed canola meal in substitution for soybean meal.[a]

Variable	Expeller-pressed canola meal, g/kg diet					SEM[b]	P-value	
	0	50	100	150	200		Linear	Quadratic
ADFI[b] (g/day)								
Days 0–7	288	278	265	269	277	12	0.420	0.233
Days 8–14	556	528	521	526	535	15	0.304	0.107
Days 15–21	781	768	782	756	779	20	0.784	0.654
Days 22–28	1024	999	990	1009	999	19	0.479	0.404
Days 0–28	661	643	642	640	648	10	0.246	0.109
ADG[b] (g/day)								
Days 0–7	242	221	226	210	221	17	0.235	0.437
Days 8–14	390	370	367	370	393	14	0.888	0.083
Days 15–21	533	538	555	528	541	19	0.916	0.676
Days 22–28	650	654	639	661	666	19	0.471	0.543
Days 0–28	454	446	446	442	455	9	0.933	0.250
Feed efficiency								
Days 0–7	0.84	0.79	0.84	0.77	0.79	0.04	0.174	0.941
Days 8–14	0.70	0.70	0.71	0.71	0.73	0.01	0.075	0.382
Days 15–21	0.68	0.70	0.71	0.70	0.69	0.01	0.374	0.075
Days 22–28	0.64	0.66	0.64	0.65	0.67	0.01	0.053	0.687
Days 0–28	0.71	0.71	0.73	0.71	0.72	0.02	0.757	0.939

[a] Least-squares means based on 12 pen observations of 4 pigs each per diet, except 10 observations for 100 g expeller-pressed canola meal/kg.
[b] ADFI = average daily feed intake; ADG = average daily gain; SEM = standard error of the mean.

present study contained 10.9 μmol/g glucosinolates, 3-fold the 3.8 μmol/g in solvent-extracted canola meal (Landero et al., 2011). The calculated glucosinolate content for the diet with 200 g/kg of EP canola meal was thus 2.2 μmol/g diet, which is within the generally accepted glucosinolate tolerance level (2.0–2.4 μmol/g) for growing pigs (Roth-Maier et al., 2004; Schöne et al., 1997a,b). The maximum tolerable level of dietary glucosinolates for weaned pigs has not been established to date. Some authors indicate that young pigs are more affected by glucosinolates (Corino et al., 1991) whereas others suggest that finishing pigs are more sensitive (Roth-Maier et al., 2004). Finally, the higher glucosinolate content in EP than solvent-extracted canola meal is likely due to differences in canola processing. Expeller-pressed canola is not always heat-conditioned to reduce myrosinase activity that influences glucosinolate metabolism. The solvent extraction process includes a desolventization-toasting step that applies additional heat to the meal, reducing glucosinolate content by 50% (Newkirk et al., 2003).

Expeller pressing, especially double-pressing, can generate temperatures up to 160 °C (Canola Council of Canada, 2009) that may impact protein quality, particularly available lysine (Mailer, 2004). However, oil pressing is fast compared to desolventization-toasting. Nonetheless, in the present study, expeller pressing reduced chemically defined lysine availability by 15%, indicating that protein contained in EP canola meal had limited heat damage.

Including EP canola meal in late nursery diets has two advantages. First, EP canola meal is a high energy protein feedstuff that provides additional flexibility in the feedstuff matrix for pigs during the energy-dependent phase of growth. Second, the cost per MJ NE of residual oil in EP canola meal is less than supplementing such energy from feed grade canola oil, tallow, or vegetable-animal fat blends (Beltranena and Zijlstra, 2011).

5. Conclusion

Weaned pigs can be fed up to 200 g EP canola meal by replacing soybean meal in diets formulated to equal NE and SID amino acid content without reducing growth performance, starting 1 wk post weaning. Increasing EP canola meal reduced the ATTD of energy, DM and CP and energy content of diets.

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