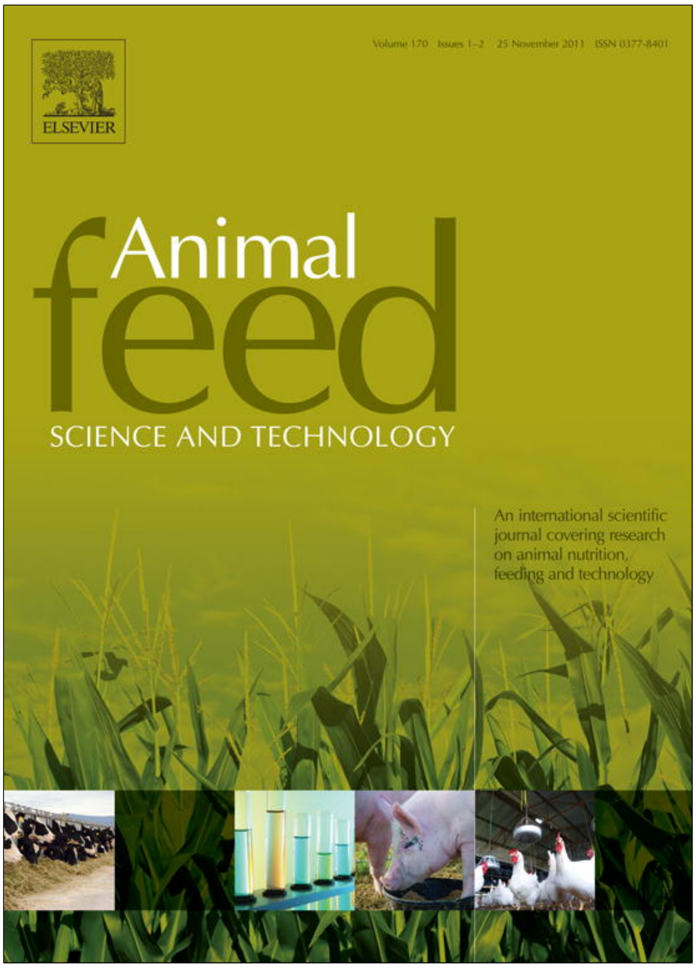
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Short communication

# The effect of feeding solvent-extracted canola meal on growth performance and diet nutrient digestibility in weaned pigs

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ABSTRACT

The effects of feeding increasing levels of solvent-extracted canola meal in substitution for soybean meal as an energy and amino acid source were evaluated in 220 weaned pigs with an initial body weight of 8.1 ± 1.8 kg. Five pelleted wheat-based diets containing 0, 50, 100, 150 or 200 g canola meal/kg were formulated to contain 9.74 MJ net energy (NE)/kg and 1.21 g standardised ileal digestible (SID) lysine/MJ NE and were fed for 4 wk starting 1 wk after weaning at 19 days of age. 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, threonine and tryptophan. Increasing inclusion of canola meal reduced linearly ($P<0.05$) the apparent total tract digestibility of energy, dry matter and crude protein and quadratically ($P<0.05$) the digestible energy content of diets. From 0 to 28 days on trial, increasing inclusion of canola meal did not affect body weight gain, feed intake and feed efficiency. In conclusion, up to 200 g solvent-extracted canola meal/kg can replace soybean meal in diets formulated to equal NE and SID amino acid content and fed to weaned pigs without detrimental effects on growth performance.



## 1. Introduction

Feed is the highest cost of pork production. Higher inclusion of protein feedstuffs other than soybean meal (SBM) into swine diets may reduce feed costs. Solvent-extracted canola meal (CM) is the main co-product of the canola seed crushing industry. Canola meal is lower in dietary energy and amino acid content than SBM and is sold at a discount relative to SBM.

In the past, feeding young pigs diets containing CM caused reduced growth performance compared with pigs fed diets containing SBM (Baidoo et al., 1986, 1987; McIntosh et al., 1986). However, in these previous experiments, diets were not formulated using modern feed formulation methods that are based on net energy (NE) and standardised ileal digestible (SID) amino acids and the CM likely contained more residual glucosinolates than meal produced currently. Indeed in a recent study (Seneviratne et al., 2011), the inclusion of 150 g CM/kg by partially removing SBM did not reduce weight gain of weaned pigs fed diets formulated to an equal NE and SID amino acid content although feed in take was reduced. The growth response of young pigs to CM was thus much better than anticipated based on historical evidence. Higher inclusion levels of CM, thus, required further investigation.

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

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

| | Canola meal (g/kg diet) | | | | |
|---|---|---|---|---|---|
| | 0 | 50 | 100 | 150 | 200 |
| Ingredient | | | | | |
| Wheat | 578.6 | 572.8 | 567.0 | 561.0 | 555.2 |
| Soybean meal, 460 g CP/kg | 200.0 | 150.0 | 100.0 | 50.0 | – |
| Canola meal, 340 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 | 30.0 | 35.0 | 40.0 | 45.0 | 50.0 |
| 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 | 8.0 | 7.8 | 7.6 | 7.4 |
| 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 | – | 0.8 | 1.5 | 2.3 | 3.0 |
| L-Threonine, 990 g/kg | 0.4 | 0.6 | 0.8 | 1.1 | 1.3 |
| DL-Methionine, 990 g/kg | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 |
| 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 composition[e] | | | | | |
| Moisture | 123 | 121 | 119 | 118 | 122 |
| Crude protein | 225 | 224 | 221 | 217 | 207 |
| Crude fat | 45 | 53 | 59 | 64 | 67 |
| Crude fibre | 22 | 24 | 27 | 29 | 32 |
| Ash | 61 | 62 | 62 | 63 | 60 |
| Acid detergent fibre | 37 | 45 | 48 | 56 | 59 |
| Neutral detergent fibre | 102 | 128 | 122 | 128 | 129 |
| Gross energy (MJ/kg) | 17.0 | 17.1 | 17.3 | 17.3 | 17.5 |

[a] Bunge Canada, Fort Saskatchewan, AB, 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, 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): 9.74 MJ NE/kg, 11.8 g SID lysine/kg, 4.2 g SID methionine/kg, 7.8 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 CM/kg and formulated to an equal NE and SID amino acid content would have a growth performance and dietary nutrient digestibility similar to pigs fed diets without CM. The objectives were to determine whether a dose response existed for growth performance and apparent total tract digestibility (ATTD) coefficients of dietary energy and crude protein (CP) of weaned pigs fed diets containing 0 up to 200 g CM/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, 220 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 (8.1 ± 1.8 kg) and divided within gender into heavy and light BW. One heavy and one light barrow and gilt were placed randomly into one of 55 pens, for 4 pigs per pen. After weaning, pigs were fed commercial phase 1 and 2 diets for 7 days.

A wheat-based control diet and four diets containing 50, 100, 150 or 200 g CM/kg were formulated by replacing SBM with CM (Table 1). Diets without antimicrobials or growth promoters were formulated to provide 9.74 MJ NE/kg and 1.21 g SID lysine (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 CM, a content of 7.33 MJ NE/kg and 1.56 g SID Lys/kg were used for diet formulation, values based on measurements in our laboratory (data not shown). 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 55 pens in three nursery rooms with 4 blocks in two rooms and three blocks in one room. 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 of the 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 11 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 during the entire 4-wk study.

Individual pigs and 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

Canola meal, diets and lyophilized faeces were ground through a 1-mm screen in a centrifugal mill (Retsch GmbH, Haan, Germany). Canola meal was analysed for CP (method 984.13A-D), total dietary fibre (method 985.29), acid detergent fibre (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) and neutral detergent fibre (Holst, 1973). Glucosinolate profile of CM was determined by gas chromatography (Daun and McGregor, 1981). Diets and faeces were analysed for dry matter (DM) by drying at 135 °C for 2 h (method 930.15; AOAC, 2006), CP ($N \times 6.25$; 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 coefficients of ATTD 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

Growth and digestibility data were analysed using the MIXED procedure (SAS Inst. Inc., Cary, NC), 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 CM inclusion. To test the hypotheses, $P<0.05$ was considered significant.

## 3. Results

The diet with 200 g CM/kg had 10, 22 and 27 g/kg more crude fibre, acid detergent fibre and neutral detergent fibre, respectively, than the diet with 0 g CM/kg (Table 1). The CM sample contained 340 g CP/kg on as fed basis and 90% of the 20.2 g Lys/kg was chemically defined as available (Table 2).

All pigs remained on test for the entire study and signs of disease were not observed. Increasing dietary inclusion of CM reduced linearly ($P<0.05$) the ATTD of CP, gross energy and DM and quadratically ($P<0.05$) the digestible energy (DE) content of the diet (Table 3).

For the entire experiment (days 0–28) or for individual weeks, increasing the inclusion of CM did not affect ADG, ADFI and G:F (Table 4). Final BW of weaned pigs was 21.7, 22.0, 21.5, 22.3 and 21.9 kg for 0–200 g CM/kg, respectively, and was not affected by increasing CM inclusion.

## 4. Discussion

Although canola, *i.e.*, low erucic acid, low glucosinolate rapeseed, is a major oilseed crop, and CM has been a feedstuff for more than 30 years, knowledge about the feed value of recently produced CM for weaned pigs is limited. Growth performance data from the present study indicate that CM is presently a better feedstuff for young pigs than suggested by studies conducted 25 years ago, although digestibility data indicate that room for improvement remains.

The linear reductions in diet nutrient digestibility values with increasing inclusion of CM are likely attributed to increasing fibre content. Indeed, CM contains three times more fibre than SBM (Bell, 1993). Therefore, even though the increasing fibre content did not affect feed intake in the present study, the decreased nutrient digestibility was consistent with previous research (Fernandez and Jorgensen, 1986). These results indicate that nutrient utilisation in CM could be improved further by reducing its fibre content or increasing fibre digestibility.

In early studies, young pigs fed diets containing CM had a lower growth rate than pigs fed diets containing SBM (McIntosh et al., 1986; Baidoo et al., 1986, 1987). However, recent findings with weaned pigs contradicted these studies, because 150 g CM/kg replaced half of the dietary SBM without affecting growth performance (Seneviratne et al., 2011). In the present study, the inclusion was pushed up further by replacing up to 200 g SBM/kg entirely with CM. The Lys in the CM was chemically defined as 90% available, indicating limited heat damage during CM processing. Canola meal did not reduce growth performance of weaned pigs in the present study, indicating that the used batch of CM had a better feed value than 25 years ago.

**Table 2**
Analysed nutrient content (g/kg diet as fed) of canola meal included in the experimental diets.

| Item | Canola meal |
|---|---|
| Moisture | 111 |
| Crude protein | 340 |
| Crude fat | 35 |
| Crude fibre | 93 |
| Acid detergent fibre | 172 |
| Neutral detergent fibre | 260 |
| Total dietary fibre | 320 |
| Starch | 17 |
| Ash | 68 |
| Calcium | 8.8 |
| Phosphorus | 9.8 |
| Indispensable amino acid | |
| Arginine | 21.8 |
| Histidine | 9.6 |
| Isoleucine | 13.9 |
| Leucine | 25.5 |
| Lysine | 20.2 |
| Methionine | 7.1 |
| Phenylalanine | 14.6 |
| Threonine | 15.6 |
| Tryptophan | 3.9 |
| Valine | 18.0 |
| Total amino acids[a] | 331.4 |
| Available lysine | 18.1 |
| Total glucosinolates[b], μmol/g | 3.84 |

[a] Dispensable amino acid (g/kg of canola meal): alanine, 16.0; aspartic acid, 25.0; cysteine, 8.6; glutamic acid, 59.8; glycine, 18.2; proline, 22.2; serine, 15.2; tyrosine, 10.4.
[b] Contained the following glucosinolates (μmol/g of canola meal): 3-butenyl, 0.93; 4-pentenyl, 0.10; 2-OH-3-butenyl, 1.99; CH3-thiobutenyl, 0.07; phenylethyl, 0.05; 3-CH3-indolyl, 0.10; 4-OH-3-CH3-indolyl, 0.60.

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

| Variable | Canola meal, g/kg diet | | | | | SEM | P-value | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 50 | 100 | 150 | 200 | | Linear | Quadratic |
| CATTD | | | | | | | | |
| Crude protein | 0.824 | 0.814 | 0.814 | 0.813 | 0.791 | 0.004 | <0.001 | 0.058 |
| Gross energy | 0.855 | 0.846 | 0.843 | 0.843 | 0.824 | 0.003 | <0.001 | 0.087 |
| Dry matter | 0.842 | 0.831 | 0.828 | 0.826 | 0.805 | 0.002 | <0.001 | 0.059 |
| DE, MJ/kg | 14.6 | 14.5 | 14.6 | 14.6 | 14.4 | 0.050 | 0.090 | 0.044 |

[a] Least-squares means based on 11 pen observations of 4 pigs each per diet.

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

| Variable | Canola meal (g/kg diet) | | | | | SEM | P-value | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 50 | 100 | 150 | 200 | | Linear | Quadratic |
| ADFI[b] (g/day) | | | | | | | | |
| Days 0–7 | 298 | 297 | 301 | 305 | 288 | 12 | 0.771 | 0.462 |
| Days 8–14 | 615 | 594 | 593 | 642 | 588 | 21 | 0.920 | 0.850 |
| Days 15–21 | 888 | 887 | 835 | 941 | 851 | 23 | 0.775 | 0.803 |
| Days 22–28 | 1141 | 1160 | 1118 | 1160 | 1121 | 30 | 0.602 | 0.735 |
| Days 0–28 | 735 | 735 | 712 | 762 | 712 | 14 | 0.592 | 0.543 |
| ADG (g/day) | | | | | | | | |
| Days 0–7 | 248 | 254 | 249 | 268 | 253 | 11 | 0.475 | 0.617 |
| Days 8–14 | 419 | 406 | 413 | 437 | 407 | 16 | 0.916 | 0.776 |
| Days 15–21 | 592 | 605 | 547 | 599 | 586 | 16 | 0.724 | 0.307 |
| Days 22–28 | 692 | 723 | 712 | 733 | 724 | 18 | 0.163 | 0.456 |
| Days 0–28 | 488 | 497 | 480 | 509 | 493 | 8 | 0.419 | 0.836 |
| Feed efficiency | | | | | | | | |
| Days 0–7 | 0.83 | 0.86 | 0.83 | 0.91 | 0.87 | 0.04 | 0.224 | 0.874 |
| Days 8–14 | 0.68 | 0.68 | 0.70 | 0.69 | 0.69 | 0.02 | 0.690 | 0.859 |
| Days 15–21 | 0.67 | 0.68 | 0.65 | 0.64 | 0.69 | 0.02 | 0.942 | 0.103 |
| Days 22–28 | 0.61 | 0.62 | 0.64 | 0.64 | 0.65 | 0.01 | 0.057 | 0.574 |
| Days 0–28 | 0.70 | 0.71 | 0.71 | 0.72 | 0.73 | 0.01 | 0.087 | 0.872 |

[a] Least-squares means based on 11 pen observations of 4 pigs each per diet.
[b] ADFI = average daily feed intake; ADG = average daily gain.

Current canola cultivars contain less glucosinolates compared to cultivars of rapeseed (Canola Council of Canada, 2009) but residual glucosinolates in CM may decrease further over time by advances in crop breeding and processing. The CM meal sample used in the present study contained as fed 3.84 μmol glucosinolates/g (Table 2), which is 47% lower than the 7.2 μmol/g reported almost ten years ago (Newkirk et al., 2003). Using the measured glucosinolate value, the calculated glucosinolate content for the diet with 200 g CM/kg was 0.77 μmol/g diet, which is below the generally accepted tolerance level of 2.0 μmol/g (Schöne et al., 1997a,b). The low glucosinolate content may partially explain the lack of detrimental effects of CM on growth performance of weaned pigs in the present study. Additionally, the reduced growth performance of pigs fed CM observed in previous studies could be explained by the nutrient content in diets formulated for total essential amino acids and digestible energy rather than digestible amino acids and NE. Formulating swine diets using the NE and SID amino acid systems reduces risks associated with including co-products. The advantage of the NE vs. ME or DE system is that the former accounts for the increased energetic losses as heat due to high fibre and protein of co-products such as CM.

## 5. Conclusion

Weaned pigs can be fed up to 200 g CM/kg by replacing soybean meal in diets formulated to equal NE and SID amino acid without reducing growth performance, starting 1 wk post weaning. Increasing CM reduced the ATTD of energy and CP of diets, but the reductions were of small magnitude.

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