Feeding Value of Western Canadian Oilseed and Biodiesel Co-products

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▪ Take Home Messages

Who can afford to feed fat(s) now-a-days? With fat prizes at record high, oilseed and biodiesel coproducts offer the only cost-effective alternative to supplementing dietary fats in monogastric animal diets. Cost per Mcal NE of residual oil content has changed our paradigm from considering canola as a traditional supplemental protein source to a novel dietary energy source. Expeller-pressed (~12% oil), extruded-pressed (~17% oil), and screw-pressed (> 20% oil) canola meal or cake, the latter two processed locally, offer opportunities to improve feed mill margins and reduce producers' feed cost.

There are also bright opportunities feeding solvent-extracted canola meal. The recent pork crisis forced us to discover its potential to reduce feed cost feeding it at unusually high inclusions. The glucosinolate content of commercially sourced canola meal is the lowest ever so high dietary inclusion rates can be sustained with confidence. *Brassica juncea* has a thinner seed coat and therefore lower fibre content and a higher energy value than *B. napus* meal. Simple, continuous vibro-sieving or air-classification of solvent-extracted canola meal produced fractions with a spread (halved) fibre content to target to ruminant and monogastric animal feeding, respectively.

Crude glycerol, camelina meal and oil are novel dietary energy sources, but safety and efficacy must to be demonstrated for Canadian Food Inspection Agency (CFIA) registration as feedstuffs. We have taken the initiative to lead the animal work. Feeding camelina, flax and canola coproduct combinations could offer the opportunity to tailor omega-3 and 6 enrichment of meat to niche market Canadian meat products.

▪ Introduction

This paper summarizes recent research conducted feeding western Canadian oilseed and biodiesel coproducts to pigs, broilers and fish. Some results are preliminary as trials are still in progress, but we want to make western Canadian nutritionists aware of what is going on and to be on the lookout for information as it is finalized. The research summarized here is not the sole effort of the authors, but that of strong collaboration among the University of Alberta, Gowans Feed Consulting, Canadian International Grains Institute, the University of Manitoba, Nova Scotia Agricultural College, Alberta Agriculture and Rural Development, Agriculture and Agri-Food Canada, and the leadership of the Canola Council of Canada.

Most of this research regards canola coproducts. Canola is Canada's most valuable crop contributing $14 billion to the economy and $5.6 billion in cash receipts to Canadian growers annually (Canola Council of Canada). The main coproduct for animal feeding is canola meal. Solvent-extracted canola meal (2 to 3% oil) has been fed to livestock in Canada for decades primarily as a supplemental protein source. But more recently we have seen an increase in the availability of canola coproducts with residual oil content. Nutritionists' interest in these coproducts has shifted from dietary protein to energy sources. In the last decade we have seen expeller-pressed canola meal (~12% residual oil) become available now from Viterra formerly Associate Proteins, Ste. Agathe MB. More recently, the development of the bio-diesel industry has led to the local production of extruder-pressed (~17% residual oil) and screw-pressed (> 20% residual oil) canola cake in smaller infrastructure plants. Residual oil content in these coproducts has made them economically attractive given the escalating cost of traditional feed fats and the opportunity cost of cereal grain starch. Distillers dried grains with solubles (DDGS) is replacing cereal grains in diets at ever greater inclusion rates, but depleted of starch, calories from residual oil from oilseed and biodiesel coproducts are a welcome addition to monogastric animal diets.

Apart from canola, there are other western Canadian oilseeds and coproducts of interest for animal feeding. Primarily due to demand for human food driving cost up, feeding flax or linseed and coproducts has been largely limited to laying hens producing omega 3-enriched eggs. Some work feeding flax to hogs to enrich pork has been conducted (Htoo et al. 2008, Jha et al. 2011, http://www.prairieswine.com/?s=flax), but will not be covered here. Camelina is the 'new' little seed that may become a giant to complement the canola and flax industries. Interest in the oil sparked as cold-weather biodiesel, but that might be a 'nutritional crime' due to its lipid profile and vitamin E content. Neither camelina coproducts nor crude glycerol should be fed to livestock in Canada as they are not listed in Schedules of the Feed Act. We describe here animal work in progress to overcome this regulatory requirement for the benefit of the livestock and feed industries.

▪ Pushing the Limits of Solvent-Extracted Canola Meal Inclusion

Solvent-extracted canola meal has been fed to livestock in Canada for ~35 years. So what's new? At first you might think little. The fact is that it has been fed to monogastric animals at conservative levels due to palatability that affects feed intake and fibre content that limits its dietary energy value. Plant breeders have helped us overcome the first of this limitation reducing total glucosinolate content over the years from ~120 – 150 in rapeseed to as low as 2 µmol/g that we have tested recently in commercially-source meal. Formulating diets on the basis of net energy has helped us overcome the second limitation. Increasing feeding levels previously resulted in reduced animal performance as we did not account for greater heat production.

More relevant perhaps has been the recent pork crisis and market availability of canola meal in western Canada. Nothing forced us to squeeze nutrient cost out of our feedstuffs more that to see our pork producers struggling to survive. Nearly in parallel, international marketing issue related to clubrot and salmonella claims, and increased crushing capacity in Saskatchewan placed downward pressure on the prize of canola meal. These factors enticed us to push the limits feeding solvent-extracted canola meal to reduce feed cost. And there is potential to sustain high dietary inclusions of solvent-extracted canola meal in diets as lower canola meal prizes are expected once soybean meal prizes weaken.

In a recent study at the University of Alberta (Landero et al. 2011), 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 using 220 weaned pigs (8 kg). Five pelleted wheat-based diets containing 0, 5, 10, 15, or 20% of canola meal were formulated to contain 2.3 Mcal/kg net energy (NE) and 5 g standardized ileal digestible (SID) lysine/Mcal NE and were fed for 4 wk starting 1 wk after weaning at 19 d of age. Canola meal replaced soybean meal and the diets were balanced for NE using canola oil and for amino acids using crystalline lysine, threonine, methionine, and tryptophan. Increasing inclusion of canola meal linearly reduced (P < 0.01) the apparent total tract digestibility of energy, dry matter, crude protein and quadratically reduced (P < 0.01) the digestible energy value of the diets. For d 0 to 28, increasing inclusion of canola meal did not affect (P > 0.05) weigh gain, feed disappearance, feed efficiency (Figure 1), and pig weight at the end of the trial. We concluded that increasing level of solvent-extracted canola meal up to 20% can replace soybean meal in diets formulated to equal NE and SID amino acid content fed to weaned pigs without detrimental effects on growth performance.

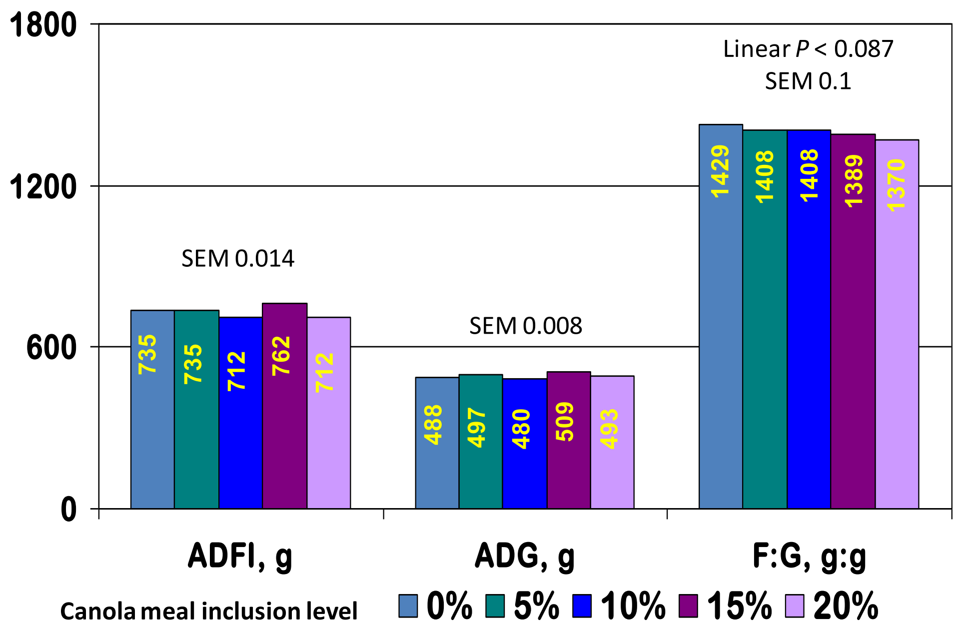

Figure 1. Growth performance of pigs (d 0 to 28) fed diets with increasing level of solvent-extracted canola meal in substitution for soybean meal (Landero et al. 2011)

We have also looked at pushing the inclusion of solvent-extracted canola meal in hog diets containing high content of DDGS (Seneviratne et al. 2011a). In a commercial-scale study, 550 barrows and 550 gilts (30 kg) housed in 50 pens (22 barrows or gilts) were fed 5 dietary regimens over 5 growth phases. Canola meal (0, 6, 12, 18 or 24%) replaced field pea and soybean meal in diets with 15% wheat DDGS formulated to equal NE (2.3 Mcal/kg) and SID lysine content (0.94, 0.84, 0.76, 0.67 and 0.62% per phase). For all phases, dietary CP and crude fibre content increased 1.5 and 0.30 %, respectively, per each 6% increase in canola meal inclusion. Increasing dietary canola meal inclusion reduced (linear P < 0.04) average daily feed disappearance (ADFI) by 19 g for every 6% increase in canola meal inclusion (Figure 2). Increasing dietary canola meal inclusion in diets reduced (linear P < 0.01) average daily weight gain (ADG) by only 7 g for every 6% increase in canola meal inclusion. Increasing the level of canola meal inclusion in diets did not affect gain:feed (G:F;P > 0.05). Pigs fed 24% canola meal attained slaughter weight only

3 d later ($P < 0.05$) than pigs fed 0% canola meal. Increasing dietary canola meal inclusion in diets containing 15% wheat DDGS did not affect carcass weight, dressing percentage, backfat thickness, loin depth, estimated lean yield, or index. In conclusion, increasing the dietary inclusion of solvent-extracted canola meal from 0 to 24% in hog diets containing 15% wheat DDGS had only a minor effect on overall growth performance and did not affect carcass traits. Therefore, these high fibre protein meals can be fed together at relatively high levels to grower-finisher pigs.

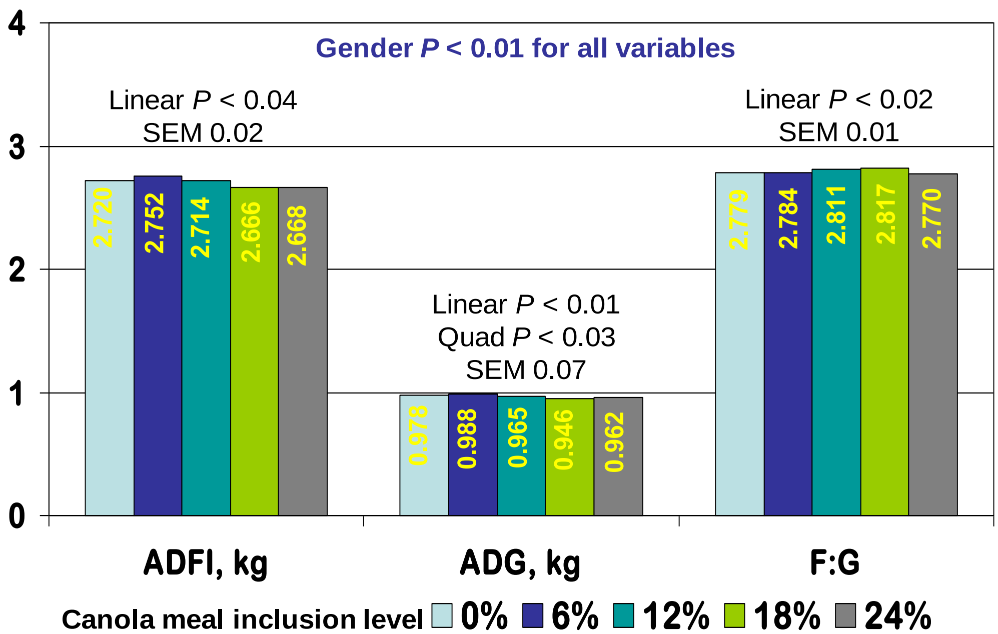

Figure 2. Growth performance of hogs (d 0 to 90) fed increasing levels of solvent-extracted canola meal in diets containing 15% DDGS (Seneviratne et al. 2011a)

▪ Yellow vs. Dark Canola Meal at High Dietary Inclusions

Reducing the fibre content of solvent-extracted canola meal has been a priority for monogastric animal feeding. Compared to dark-seeded meal (*Brassica napus*), yellow-seeded (*B. juncea*) canola meal has tested higher in protein (42% vs. 38%) and phosphorus content (1.4% vs. 1.0 %), but lower in crude fibre content (7.7% vs. 12%). Lower fibre in yellow-seeded canola meal would permit higher inclusion levels in practical diets compared to conventional canola meal and further reduce feed cost. Yellow-seeded canola meal does, however, contain higher levels of glucosinolates (> 10 vs. < 5μmol/g in dark-seeded meal) known to affect thyroid function in animals.

Table 1. Estimated dietary energy, analyzed nutrients, glucosinolate content, and particle size of solvent-extracted meals from yellow- (*B. Juncea*) and dark-seeded (*B. napus*) canola (standardized to 89% DM)

	B. juncea	*B. napus*
Net energy[1], Mcal/kg	1.71	1.55
Crude protein, %	39.09	38.98
Indispensable AA, %:		
Arginine	2.52	2.26
Histidine	1.00	0.97
Isoleucine	1.57	1.30
Leucine	2.80	2.61
Lysine	2.01	2.02
Available lysine	1.85	1.82
Methionine	0.74	0.77
Phenylalanine	1.55	1.46
Threonine	1.61	1.62
Tryptophan	0.41	0.43
Valine	1.99	1.73
Dispensable AA, %		
Alanine	1.76	1.69
Aspartic acid	2.94	2.69
Cysteine	0.83	0.93
Glutamic acid	6.13	6.10
Glycine	1.96	1.89
Proline	2.05	2.21
Serine	1.45	1.52
Tyrosine	1.07	1.04
Crude fat, %	1.72	1.93
Crude fibre, %	7.34	8.58
ADF, %	13.42	18.19
NDF, %	19.82	27.23
Starch, %	1.66	-
Ash, %	7.32	7.82
Calcium, %	0.71	0.67
Phosphorus, %	1.40	1.27
Glucosinolates, µmol/g	10.32	3.56
Particle size ± stdev, µm	640 ± 2.3	636 ± 2.2

1Calculated from analyzed chemical content (EvaPig®)

To confirm that yellow-seeded canola meal has a higher dietary energy value compared to conventional dark-seeded canola meal, we tested feeding increasing levels of each meal in growout diets and the effect on hog growth performance, dressing percentage and carcass characteristics (Seneviratne et al. 2011b). Both canolas were crushed and the oil solvent-extracted at Bunge (Altona, MB; Table 1) using similar processing parameters to minimize differences in nutritional quality of the resulting meals. The feeding trial was conducted under commercial conditions at the Drumloche test barn in Lougheed, AB. Barrows and gilts (550 of each, 33 kg) were housed in 48 single-sex pens, 22 pigs per pen. Pigs were then assigned to one of 6 dietary regimens consisting of yellow- or black-seeded canola meal at dietary inclusion levels of 10, 20 or 30% through to market weight (120 kg).

The test diets were formulated to provide the same NE, SID lysine to NE and essential amino acid content (in ratios to lysine) within growth phase (5 phases). The cost of imported soybean meal was so high at the time that it was excluded in favour of wheat DDGS and field pea. In fact, the energy cost of wheat DDGS was lower than that of wheat grain (6.0 vs. 6.4¢/Mcal NE). Wheat DDGS was therefore included at high levels and increasing inclusions of canola meal were accommodated by adjusting the inclusions of cereal grains and field pea in the formulations. No supplemental inorganic phosphorus was required in any of the diets due to the high content and availability of phosphorus in DDGS and canola meal and the inclusion of phytase enzyme.

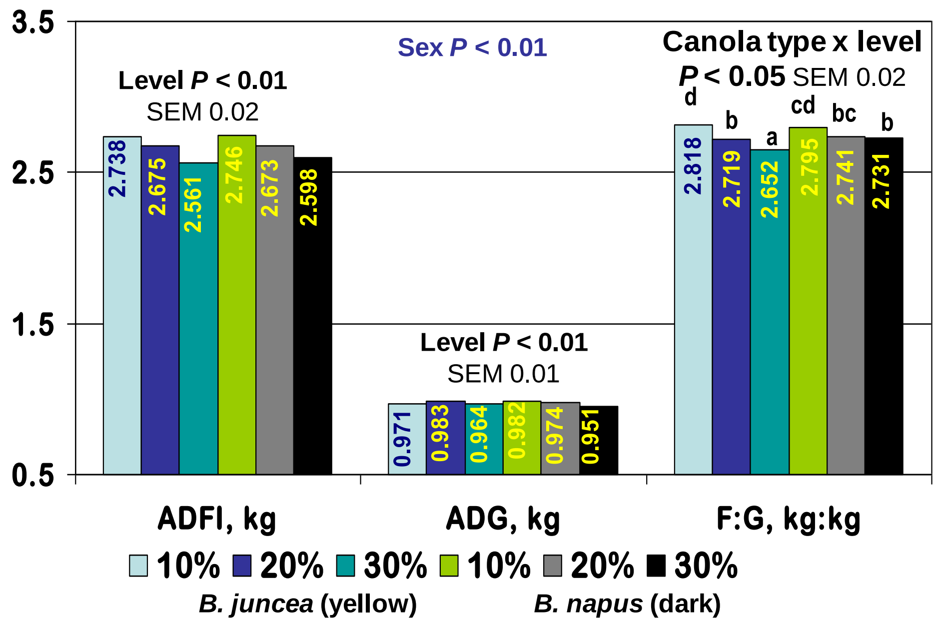

Figure 3. Growth performance of hogs (d 0 to 84) fed increasing levels of yellow- or dark-seed, solvent-extracted canola meal (Seneviratne et al. 2011b)

Feeding increasing level of both types of canola meal reduced feed disappearance by 81 g/d and weight gain by 9 g/d for each 10% increase in canola meal inclusion (Figure 3). Feeding increasing level of canola meal, however, reduced the amount of feed required per kg of weight gain. The reduction in feed to gain ratio was more pronounced for hogs fed the yellow-seeded meal compared to the dark-seeded meal (83 g vs. 32 g less feed per kg of gain for each 10% increase in canola meal inclusion). Final trial body weight was not affected either by canola type or level of dietary inclusion. The number of days on trial, however, increased by 1 for each 10% increase in canola meal inclusion. Increasing the dietary inclusion of either canola meal type reduced carcass weight by 0.46 kg, dressing percentage by 0.4 %-points and loin depth by 0.5 mm for each 10% increase in dietary inclusion. Backfat depth, lean yield and carcass index, however, were not affected by either canola meal type or inclusion level. Increasing dietary inclusion of both canola meal types increased cost per kg of weight gain. This cost increase occurred largely as a result of the lower cost wheat DDGS being displaced in formulations as canola meal inclusion level increased. The increase in cost per kg of weight gain was greater for the dark-seeded compared to the yellow-seeded canola meal. Feeding up to 30% of either yellow- or dark-seeded canola meal is therefore feasible in commercial diets with high inclusions of wheat DDGS. Hog performance and carcass traits were adequate proving evidence that canola meal and wheat DDGS together can make up 50% of hog diets. We are currently conducting a similar trial with broiler chickens feeding up to 30% of either yellow- or dark-seeded canola meal

Table 2: Apparent total tract digestibility (ATTD, %) of dietary energy, DE and calculated NE values, and standardized ileal digestibility coefficients of amino acids for solvent-extracted *B. napus* and *B. juncea* meal in growing pigs (Buchet et al. 2011)

	B. napus[1]	*B. juncea*[1]
ATTD of GE	60.31	64.60
DE, Mcal/kg DM	2.88	3.05
NE, Mcal/kg DM	1.98	2.10
CP	81.11	81.97
Indispensable AA		
Arg	94.06	95.80
His	89.26	90.31
Ile	84.44	84.79
Leu	85.22	84.78
Lys	82.87	84.68
Met	90.75	90.24
Phe	85.72	85.53
Thr	82.23	81.50
Trp	84.44	83.86
Val	82.35	82.40
Dispensable AA		
Ala	84.95	85.30
Asp	84.60	84.98
Cys	81.72	79.39
Glu	87.80	87.45
Gly	91.03	92.33
Ser	83.53	83.59
Tyr	88.15	88.84

1Mean of digestibility coefficients determined at 25 and 50% inclusion of each meal in test diets

In a more recent study (Buchet et al. 2011), the energy and amino acids digestibility of *B. juncea* and *B. napus* at two inclusion levels in diet (25% and 50%) were established. Six ileal-cannulated growing pigs (46.5 kg) were fed six diets: N-free diet based on corn starch, basal diet based on 46% wheat grain and corn starch and four diets with 46% wheat grain and canola meal from either *B. napus* or *B. juncea* included at 25% or 50%. *B. juncea* had lower fibre content than *B. napus* (12.92 vs. 20.79% ADF and 20.59 vs. 28.14% NDF, DM basis, respectively) and lower content of crude protein and amino acids (41.92 vs. 42.20% CP, 2.20 vs. 2.41% lysine, 0.45 vs. 0.55% tryptophan, 1.82 vs. 1.79% threonine, and 0.79 vs. 0.86% methionine, DM basis, respectively). The apparent ileal digestibility (AID) of GE was not different between canola species ($P = 0.939$). However, the apparent total tract digestibility (ATTD) of GE was significantly higher for B. juncea ($P < 0.05$) probably due to lower fibre content. Inclusion level did not affect the AID or ATTD of GE of canola meal. However AID and ATTD value were low compared to other study due to a higher digestibility of basal diet and the use of difference method. The SID coefficients of crude protein and amino acid were not different between canola meals or inclusion levels in the diet. Standardized ileal contents in B. juncea were significantly lower for four amino acids (lysine, methionine, tryptophan, cysteine) and higher for three (arginine, aspartic acid, serine). Consequently, B. napus in this experiment had better standardized ileal amino acid content for most limiting amino acids in swine diets. Inclusion level did not affect SID content of crude protein and amino acids. Preliminary nutrient digestibility coefficients for key nutrients in B. juncea and B. napus in broilers are listed in Table 4.

Conventional black-seeded canola is mainly grown in the fertile Black and Grey soils of the cool central and northern Prairies. Yellow-seeded canola (*B. juncea*), however, is more heat and drought tolerant, which makes it more suitable for production in the warmer, dryer, Brown and Dark Brown soil zones of the southern Prairies. Increasing canola acreage in these regions would further increase farm cash receipts, as well as the availability of canola oil for both human food and biodiesel applications. A parallel benefit would be an increase in the local supply of lower-fibre, yellow-seeded canola meal, which could help reduce feed cost for livestock producers.

▪ Fractionation of Solvent-Extracted Canola Meal

Despite its functional role, dietary fibre not only dilutes nutrient content, but also reduces nutrient utilization in feedstuffs for monogastric animals. With the objective of reducing the fibre content of canola meal and measuring the improvement in nutrient digestibility, we have pursued pilot scale dry fractionation followed by animal digestibility work. We have conducted separation by particle size, weight and shape using sieving, gravity fractionation, and air-classification of both *B. napus* and *B. juncea* solvent-extracted meals. Due to lower success by gravity separation, the results are not presented here.

Particle size separation was carried out using a vibro-separator (SWECO Inc., Florence, KY, USAh; Model ZS30S6666EPWC) equipped with one of 2 sets of 3 circular sieves: either 20 mesh (850 µm), 30 mesh (600 µm), and 40 mesh (425 µm) or 30 mesh (600µm), 40 mesh (425µm), and 60M (250µm). Sieving of ungrounded, solvent-extracted canola meal produced 4 fractions, the finest with half the ADF and NDF content of the coarsest, but enriched protein content only by 6%-points (Table 3). The yield of fine vs. coarse fractions was reduced using to finer sieves.

Table 3. Yield, protein, ADF and NDF content of ungrounded, solvent-extracted B. juncea meal using a vibro-separator equipped with 2 sets of sieves (89% DM; Beltranena, unpublished results)

	Yield, %	Protein, %	ADF, %	NDF, %
> 850 µm	33.40 ± 1.98	41.54 ± 0.59	15.04 ± 0.42	22.77 ± 0.81
< 850 µm	20.10 ± 0.42	40.57 ± 1.09	14.90 ± 0.25	23.55 ± 1.20
< 600 µm	19.00 ± 0.28	42.85 ± 0.59	11.97 ± 0.26	18.58 ± 0.94
< 425 µm	23.90 ± 0.14	46.99 ± 0.80	7.57 ± 0.36	11.81 ± 0.41
> 600 µm	66.80 ± 1.13	41.48 ± 0.91	14.60 ± 0.58	22.26 ± 2.07
< 600 µm	10.80 ± 1.13	43.67 ± 1.51	12.77 ± 0.90	19.06 ± 2.23
< 425 µm	12.20 ± 0.28	46.65 ± 1.08	8.11 ± 0.18	13.02 ± 0.58
< 250 µm	8.20 ± 1.41	47.68 ± 0.40	7.23 ± 0.65	11.43 ± 0.54

Mean ± stdev based on 6 processing replicates

Air-classification of ungrounded canola meal (600 µm), ground (Mikro-ACM Model 15) to 98% < 300µm, or ground to 98% < 100µm was conducted using an Alpine ATP Model 200. We achieved maximum separation of fibre (ADF 12%-points, NDF 17% points) and enrichment of protein (8%-points) of solvent-extracted *B. napus* and *B. juncea* meal at 3500 and 4000 rpm, respectively, using material ground to 98% < 100µm (Figure 4). The yield of fine and coarse fractions at these setting was 65 and 35%, respectively (Figure 5). Compared to wet fractionation, air-classification does not result in a substantial enrichment of protein in canola meal, but it is a continuous rather than a batching process, there is no acid or salty slurry leftover to dispose of, and best yet …forget about the huge cost of spray-drying!

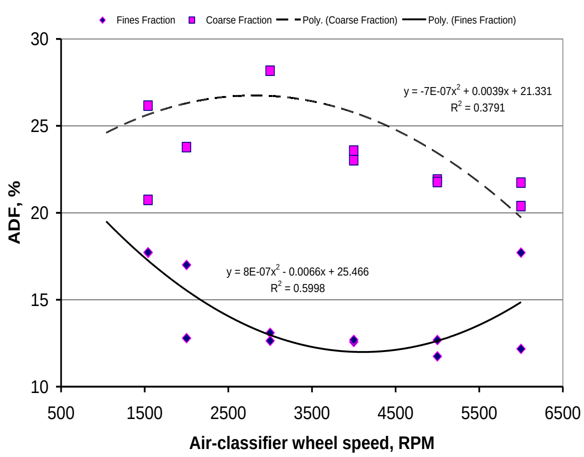

Figure 4. Shift in acid detergent fibre (ADF) content in fine- and coarse-particle fractions of solvent-extracted *B. napus* canola meal by increasing classifier wheel speed (Alpine ATP Model 200; Beltranena unpublished results)

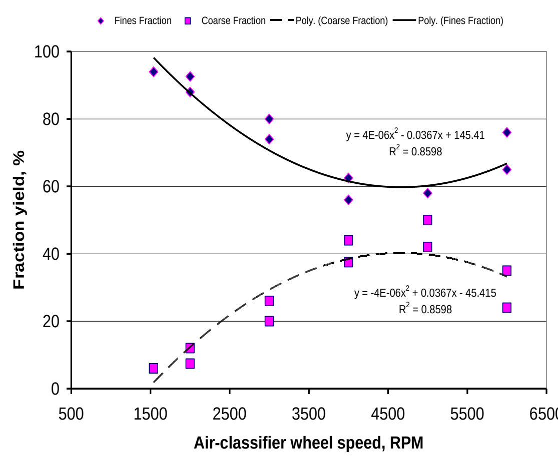

Figure 5. Yield of fine- and coarse-particle fractions of solvent-extracted B. napus canola meal by increasing classifier wheel speed of the (Alpine ATP Model 200; Beltranena unpublished results)

Preliminary results of digestibility trials with broiler chickens (Table 4) and trout fish (Table 5) indicated that the air-classified fractions have somewhat lower nutrient digestibility than the parent canola meal. However, protein enrichment in (dry) fractions was not substantial (6 to 8%-points), so growth trials will be of more value than digestibility work to validate the effect of halving fibre content in fractions on growth performance. We have not conducted a pig trial yet.

Table 4. Apparent ileal digestibility (%) of dry matter, protein and key amino acids of solvent-extracted canola meal and its fine- and coarse-particle size fractions produced by air-classification (Alpine ATP Model 200), expeller-pressed canola meal, extruded-pressed canola meal and solvent-extracted *B. juncea* and *B. napus* canola meals in 21d-old broiler chickens (preliminary data, Oryschak et al. 2011)

	Solvent-extracted[1]	Coarse-particle fraction[1]	Fine-particle fraction[1]	Expeller-pressed[2]	Extruded-pressed[3]	B. juncea[4]	B. napus[4]	SEM
DM	72.7	50.5	53.0	42.2	70.2	61.5	48.5	5.1
CP	101.4	96.3	91.6	68.7	79.4	76.8	72.4	1.8
Lysine	88.7	87.4	85.9	72.5	97.3	75.7	77.5	1.5
Threonine	82.7	79.1	74.4	67.4	85.8	72.1	72.7	2.2
Methionine	98.3	95.5	92.5	81.4	91.4	85.8	86.5	1.4

1Sunhaven Feed Mill, Irma, AB
2Viterra, Ste. Agathe, MB
3Cansourse Biofuels, Mayerthorpe, AB
4Bunge, Altona, MB

Both vibro-sieving and air-classification are simple, continuous processing technologies that could be implemented as back-end processing at existing crushing plants with little change in infrastructure to value-add solvent-extracted canola meal producing fractions targeted to monogastric and ruminant animal feeding.

Table 5. Apparent total tract digestibility (%) of dry matter, protein, and key amino acids of diets with 30% expeller-pressed canola meal, solvent-extracted canola meal and its fine- and coarse-particle size fractions produced by air-classification (Alpine ATP Model 200) in rainbow trout (Beltranena et al. 2011 unpublished)

	Expeller-pressed canola meal[1]	Solvent-extracted canola meal[2]	Fine-particle fraction[2]	Coarse-particle fraction[2]	SEM	Model *P* value
Dry matter	80.20d	82.80c	83.59b	80.58d	0.61	0.001
Crude protein	90.79b	93.46a	93.11a	91.61b	0.45	0.001
Lysine	93.48c	95.68a	95.33ab	94.73b	0.40	0.001
Threonine	91.20d	93.23b	93.10bc	92.32c	0.38	0.001
Methionine	93.68c	95.69ab	95.56ab	95.13b	0.40	0.001

[1]Viterra, Ste. Agathe, MB
[2]Sunhaven Feed Mill, Irma, AB

▪ Feeding Expeller-Pressed Canola Meal

Expeller-pressed canola meal contains more residual oil (~12%) than solvent-extracted canola meal (2-3%). It has become an attractive feedstuff mainly in Manitoba due to the proximity to the Ste. Agathe Viterra plant. We have fed the meal from this plant (Table 6) in five experiments:

Table 6. Nutrient content of expeller- and extruded-pressed canola meal (93.5% DM)

	Expeller-pressed[1]	Extruded-pressed[2]
Crude protein	35.27	29.86
Ether extract	12.63	17.31
Crude fibre	5.95	10.15
Ash	6.55	7.22
ADF	15.93	22.58
NDF	19.98	28.09
Calcium	0.59	0.60
Phosphorus	1.03	0.82
Indispensable AA	0.00	0.00
Arginine	2.17	1.56
Histidine	0.95	0.64
Isoleucine	1.34	0.87
Leucine	2.49	1.94
Lysine	2.09	1.21
Available Lysine	1.95	1.04
Methionine	0.68	0.55
TSAA	1.54	1.25
Phenylalanine	1.42	1.02
Threonine	1.51	1.17
Tryptophan	0.52	0.39
Valine	1.72	1.12
Dispensable AA	0.00	0.00
Alanine	1.54	1.26
Aspartic acid	2.53	1.99
Cysteine	0.85	0.71
Glutamic acid	5.67	4.43
Glycine	1.75	1.40
Proline	2.08	1.62
Serine	1.33	1.12
Tyrosine	1.00	0.74

[1]Viterra, Sta. Agathe, MB
[2]Cansource Bioproducts, Mayerthorpe, AB

In Exp. 1 (Seneviratne et al. 2010), six ileal-cannulated barrows (36 kg) were fed either a 44% expeller-pressed canola meal diet or a N-free diet in a crossover design to measure energy and AA digestibility. The expeller-pressed canola meal contained 23.2 µmol/g of glucosinolates (DM basis). Apparent total tract energy digestibility was 75.0% and the DE and predicted NE values were 3.77 and 2.55 Mcal/kg (DM basis), respectively (Table 7). The SID AA content (% of DM) was 1.77% Lys, 1.04% Thr, and 0.52% Met.

Table 7. Apparent total tract digestibility (ATTD, %) of dietary energy, DE and calculated NE values, and standardized ileal digestibility coefficients of amino acids for expeller-pressed canola meal in growing pigs (Seneviratne et al. 2010)

	Expeller-pressed canola meal[1]
ATTD of GE	75.0
DE, Mcal/kg DM	3.77
NE, Mcal/kg DM	2.55
Indispensable AA	
Arg	83.1
His	81.7
Ile	74.3
Leu	78.8
Lys	73.2
Met	83.9
Phe	78.0
Thr	67.6
Trp	83.9
Val	70.5
Dispensable AA	
Ala	72.1
Asp	72.0
Cys	72.7
Glu	84.3
Gly	63.6
Tyr	75.1

[1]Viterra, Sta. Agathe, MB

In Exp. 2 (Seneviratne et al. 2010), 1,100 pigs (25 kg) housed in 50 pens were fed 5 dietary regimens with 0, 7.5, 15, and 22.5% or decreasing amounts (22.5, 15, 7.5, and 0%, respectively) of expeller-pressed canola meal over 5 phases to market weight (120 kg). Diets were formulated to contain equal SID Lys:NE per growth phase (g/Mcal; 4.04, d 0 to 25; 3.63, d 26 to 50; 3.23, d 51 to 77; 2.83, d 78 to 90). For d 51 to 90, the 22.5% expeller-pressed canola meal regimen was reduced to 18% (22.5/18%) because of decreased ADFI for phases 1 and 2. Overall (d 0 to 90), increasing dietary expeller-pressed canola meal linearly decreased ($P < 0.001$) ADG and ADFI and linearly increased ($P < 0.01$) G:F. For 0 and 22.5/18% expeller-pressed canola meal, respectively, ADG was 978 and 931 g/d, ADFI was 2.77 and 2.58 kg/d, and G:F was 0.366 and 0.378. Increasing dietary expeller-pressed canola meal did not affect carcass backfat thickness, loin depth, or jowl fatty acid profile. Pigs fed 22.5/18% expeller-pressed canola meal reached slaughter weight 3 d after ($P < 0.05$) pigs fed no expeller-pressed canola meal. In summary, expeller-pressed canola meal provided adequate energy and AA; however, ADG was reduced by 30 g/d per each 10% expeller-pressed canola meal inclusion, likely because of increased dietary glucosinolates. We concluded that the amount of expeller-pressed canola meal included in hog diets should be targeted to an expected growth performance and carcass quality.

In a third experiment (Landero et al. 2011), the effects of feeding increasing levels of expeller-pressed canola meal in substitution for soybean meal as an energy and amino acid source were evaluated using 240 weaned pigs (7.3 kg). Five pelleted wheat-based diets containing 0, 5, 10, 15, or 20% expeller-pressed canola meal were formulated to contain 2.3 Mcal/kg NE and 5 g SID lysine/Mcal NE. The diets were fed for 4 wk starting 1 wk after weaning at 19 d of age. Expeller-pressed canola meal substituted soybean meal. Diet NE content was adjusted using canola oil, and amino acids adjusted using crystalline lysine, methionine, threonine, and tryptophan. Increasing inclusion of expeller-pressed canola meal linearly reduced ($P < 0.001$) the ATTD of energy, dry matter, crude protein and the DE value of the diets. Overall (d 0-28), increasing inclusion of expeller-pressed canola meal did not affect ($P > 0.05$) weight gain, feed efficiency and pig weight at the end of the trial. However, feed intake was quadratically reduced ($P < 0.05$). In conclusion, increasing dietary levels of expeller-pressed canola meal up to 20% can replace soybean meal in weaned pig nursery diets without affecting growth performance.

We have also established dietary energy and amino acid digestibility coefficients for expeller-pressed canola meal in broiler chickens (Oryschak et al 2011) and rainbow trout (Beltranena, unpublished results). These are summarized in Tables 3 and 4, respectively.

▪ Feeding Extruded-Pressed Canola Meal

Extruded-pressed canola meal contains even more residual oil (~17%) than expeller-pressed meal (~12%; Table 6) or solvent-extracted canola meal (2 to 3%). Even when oil presses are used in tandem, oil extraction is less effective than expeller-pressing. One must consider that the processing focus of local plants is biodiesel, not meal quality. Local plants can increase lot variability over time sourcing lower quality seed (burned, green). The seed is unlikely to be pre-heated to deactivate myrosinase, but the heat build-up during extrusion takes care of some. Extrusion also improves nutrient digestibility without causing amino acid damage (Table 3; Htoo et al. 2008).

In a commercial hog study conducted at the Drumloche test barn (Lougheed, AB; Young et al. 2011a), pigs (33.5 kg) were fed low energy diets with 7.5 or 15% extruded-pressed canola meal (Cansourse Biofuels, Mayerthorpe) with or without enzyme complex (Ronozyme VP™, DSM), and compared to pigs fed a high- or low-energy diet with the expectation that enzyme would uplift growth performance to that of the high energy diet. The diets were fed over 5 growth phases to market weight (120 kg).

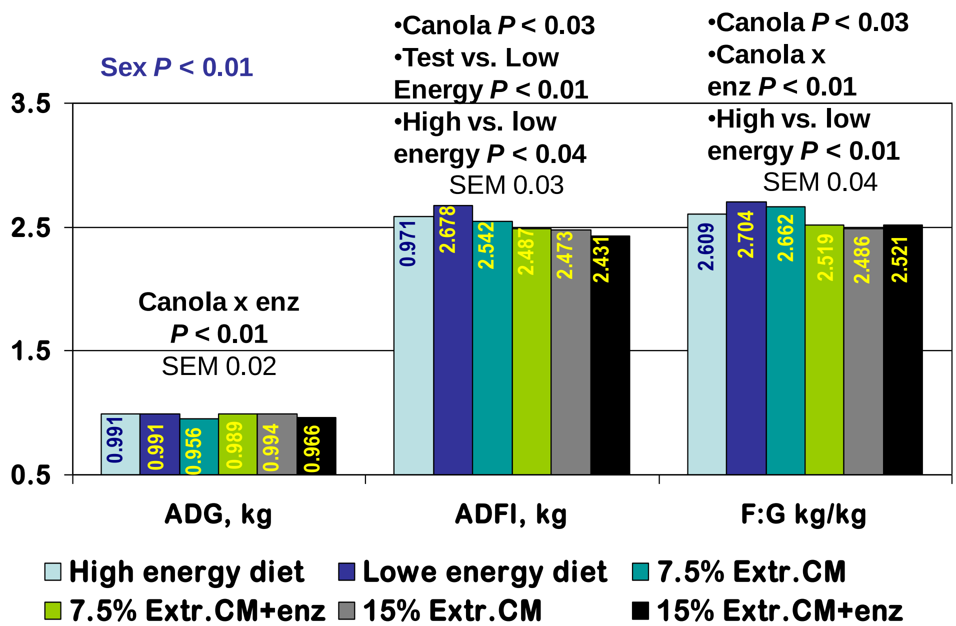

Figure 6. Growth performance (d 0 to 77) of hogs fed extruded-pressed canola meal at 7.5 or 15% inclusion with or without enzyme complex vs. a high- or a low-energy diet without enzyme

Increasing the feeding level of extruded-press canola meal and enzyme interacted on weight gain but only for the overall trial ($P < 0.05$). Enzyme increased ADG at 7.5% extruded meal (+33 g), but decreased ADG at 15% extruded meal level (-28 g). For ADFI, there was no extruded meal level x enzyme interaction for any growth period or the overall trial. Increasing dietary extruded meal level decreased ADFI, but only for the overall trial (115 g/d for each 7.5% extruded meal). Increasing level of extruded meal and enzyme interacted on G:F for the overall trial ($P < 0.05$). Enzyme complex increased G:F at 7.5% extruded-press canola meal (+22 g), but decreased G:F at 15% extruded-press canola meal level (-4 g). Increasing level of extruded-press canola meal and enzyme interacted on carcass weight and dressing percentage ($P = 0.06$): Enzyme increased carcass weight of pigs fed 7.5% extruded-press canola meal (+ 890g), but decreased carcass weight of pigs fed 15% extruded-press canola meal level (-53 g). Similarly, enzyme increased dressing percentage of pigs fed 7.5% extruded-press canola meal (+ 0.76 %-units), but decreased dressing percentage of pigs fed 15% extruded-press canola meal (- 0.41 %-units). Feeding extruded-press canola meal to pigs reduced ($P < 0.05$) dressing percentage by 0.5 %-units. Feeding the low-energy control diet to pigs reduced ($P < 0.05$) dressing percentage by 0.54 %-units compared to feeding pigs the high-energy control diet. Increasing the dietary level of extruded-press canola meal in diets from 7.5 to 15% decreased ($P < 0.05$) backfat of pigs by 0.5 mm. There was no effect of increasing level of extruded-press canola meal, enzyme inclusion or interaction on loin depth, estimated lean yield or carcass index, nor were there differences in these variables between feeding the extruded-press canola meal diets with or without enzyme and the low-energy control diet or between feeding the latter and the high-energy control diet ($P > 0.05$). In conclusion, increasing the energy content of the diets including extruded-pressed canola meal had the expected effects of reducing feed intake and dressing percentage, but improved feed conversion. It appears that enzyme inclusion was sufficient at the 7.5%, but not at 15% extruded-pressed canola meal inclusion. Income minus feed cost per hog was $2 and $1 greater feeding 7.5% extruded-pressed canola meal vs. the high- and low-energy dietary regimen, respectively.

Table 8. Nutrient content of screw-pressed canola cake and expeller-pressed canola meal (93% DM; Seneviratne et al. 2011c)

	Screw-pressed[1]	Expeller-pressed[2]
GE, Mcal/kg	4.87	4.84
Crude protein	39.43	35.71
Ether extract	13.30	12.83
Crude fibre	6.20	7.34
ADF	16.09	17.21
NDF	33.85	20.46
Ash	7.13	6.44
Calcium	0.84	0.54
Phosphorus	1.37	1.04
Indispensable AA	0.00	0.00
Arginine	1.70	1.67
Histidine	0.61	0.56
Isoleucine	2.30	2.37
Leucine	1.73	1.80
Lysine	1.24	1.53
Avail. lysine	1.00	1.40
Methionine	0.54	0.52
Phenylalanine	1.37	1.42
Threonine	1.27	1.16
Valine	0.98	2.11
Dispensable AA	0.00	0.00
Alanine	1.37	1.40
Aspartic acid	2.66	2.21
Cysteine	1.01	1.00
Glutamic acid	7.50	6.05
Glycine	2.01	1.81
Serine	1.08	0.74
Tyrosine	0.73	0.77

[1]Heated barrel, fast speed (Seneviratne et al. 2011c)
[2]Viterra, Ste. Agathe, MB

▪ Feeding Screw-Pressed Canola Cake

Screw-pressed canola cake is a coproduct of local biodiesel production. It contains even more residual oil content (> 20%) than extruded-pressed (~17%), expeller-pressed (~12%), or solvent-extracted canola meal (2 to 3%). Screw-pressed canola cake can be an attractive, but very variable feedstuff for livestock feeding due to local availability from small plants. Low quality canola seed that would not meet human food oil grade can be locally pressed for biodiesel and the meal fed to livestock. However, the nutritional quality and content of anti-nutritional factors of screw-pressed canola cake can vary widely and be affected even more than other types of commercially available canola meal by diverse pressing conditions and equipment.

This experiment (Seneviratne et al. 2011c) evaluated screw-pressed canola cake processed using 4 different conditions: nonheated and heated barrel at slow and fast screw speed in a 2 × 2 factorial arrangement. Seven ileal cannulated barrows (26 kg BW) were recruited to measure the energy and AA digestibility and to calculate SID AA and NE values. Both AID and ATTD of gross energy in screw-pressed canola cake were 36% greater (P < 0.05) in heated (Table 9) vs. nonheated conditions and 8% greater (P < 0.05) in fast vs. slow screw speed without interaction, indicating that barrel heating at screw-pressing increased energy digestibility. The AID of energy of screw-pressed canola cake was 13 and 118% greater (P < 0.01) than expeller-pressed canola meal and canola seed, respectively. Barrel heat application and screw speed interacted (P < 0.05) for SID of AA of test ingredients, but effects were not consistent among AA. The DE and calculated NE content of screw-pressed canola cake were 0.73 and 0.52 Mcal/kg greater (P < 0.01; DM basis), respectively, than expeller-pressed canola meal and did not differ from canola seed. Screw-pressed canola cake averaged 4.17 Mcal of DE/kg, 2.84 Mcal of NE/kg, 0.87% SID Lys, 0.46% SID Met, and 0.79% SID Thr (DM basis). In conclusion, heat applied during screw-pressing greatly affected the digestible nutrient content of canola cake. Content of residual oil was an important determinant of the energy value of screw-pressed canola cake, whereas residual glucosinolates did not hamper nutrient digestibility.

Table 9. Apparent total tract digestibility (ATTD, %) of dietary energy, DE and calculated NE values, and standardized ileal digestibility coefficients of amino acids for heated barrel, fast speed screw-pressed canola cake in growing pigs (Seneviratne et al. 2011c)

	Heated barrel, fast speed, screw-pressed canola cake
ATTD of GE	89.6
DE, Mcal/kg DM	4.68
NE, Mcal/kg DM	3.19
Indispensable AA	
Arg	52.7
His	85.3
Ile	90.1
Leu	88.9
Lys	83.0
Met	91.9
Phe	90.8
Thr	82.0
Val	89.1
Dispensable AA	
Ala	72.1
Asp	72.0
Cys	72.7
Glu	84.3
Gly	63.6
Tyr	75.1

▪ Feeding Green Canola Seed

Green canola is the immature seed that contains high levels of chlorophyll. Seed crushing removes the chlorophyll with the oil, but it imparts a greenly, darker colour to the oil that is costly to remove. Green seed is therefore a major discounting factor for canola grading and finding alternative markets is a challenge. Recently, there has been renewed interest in feeding green canola seed to livestock as it may help to reduce feed cost.

Gowans Feed Consulting recently finished a commercial scale trial (Young et al. 2011b). Eleven hundred hogs (33 kg) were fed 0, 5, 10, 15% green canola seed (~90% green) or declining green seed level by growth phase to market weight (122 kg). For the overall trial (0 to 83 days), there were no effects ($P < 0.05$) of feeding green seed level on weight gain, feed disappearance, and feed:gain. However, there was a trend ($P < 0.07$) for feed conversion to be better for the pigs fed the control diet compared to green canola seed levels. Pigs fed 5% green canola seed weight were heavier ($P < 0.05$) on day 83 than controls or those fed declining seed inclusions by phase. Days from first to last pig marketed averaged 23.5 days and were greater ($P < 0.01$) only for the hogs fed the 15% green canola seed. Dressing percent was also lower ($P < 0.01$) for hogs fed 15% green canola seed, compared to controls, those fed 5% throughout, or fed declining green seed inclusions by phase. Dressing percent was also lower ($P < 0.01$) for hogs fed 10% green seed throughout to market weight compared to those fed declining seed levels. Backfat thickness, loin depth, calculated lean yield and index were similar among dietary regimens. Feed cost was higher ($P < 0.01$) for the control regimen and decreased as green canola seed level increased being lowest at 15% green canola seed inclusion. Nonetheless, feed cost per kg gained, gross revenue minus feed cost per hog were no different ($P > 0.05$) across dietary seed regimen inclusions. These results indicated that other than a correctable drop in dressing percentage at high inclusions ($\geq$ 10%), feeding up to 15% green canola seed resulted in reasonable hog performance and carcass traits and can be an alternative channel for marketing green seed that otherwise would be discounted for food oil.

▪ Feeding Crude Glycerol

Crude glycerol is the main coproduct of biodiesel production. It can be readily fed as a dietary energy source to livestock and substantially reduces (40%) pelleting power requirements. We have carried some animal work feeding crude glycerol produced in western Canada derived from canola, but it has not been as extensive as research work conducted in the US. Because several chemicals are used in the esterification process and recovery is not complete, residual chemical content in crude glycerol must be monitored to protect the health of animals and humans consuming their animal products. Therefore, the CFIA requires that companies pursuing marketing of crude glycerol for feed use register their product(s) despite the fact the pure glycerol is listed in Schedule IV of the Feed Act.

The effects of substituting wheat grain with crude glycerol as a dietary energy source were evaluated. Seventy-two weaned pigs were fed for 4 wk one of three pelleted wheat-based diets containing 0, 4, or 8% glycerol and formulated to 2.3 Mcal/kg NE and 5 g lysine/Mcal NE. For day 0 to 28, body weight increased linearly ($P < 0.04$); pigs fed 8% glycerol were 1.11 kg heavier at the end of the trial than pigs fed no glycerol. Glycerol inclusion tended to increase weight gain linearly ($P < 0.07$) and increased feed disappearance quadratically ($P < 0.04$) without affecting feed efficiency ($P > 0.10$). In conclusion, feeding up to 8% dietary crude glycerol by substituting wheat grain improved growth performance of weaned pigs.

In a second study, partially substituting soybean meal and wheat grain with canola coproducts was evaluated using 240 weaned pigs (6.3 kg). Pigs were fed for 4 weeks pelleted diets containing 15% solvent-extracted or expeller-pressed canola meal either with 0 or 5% crude glycerol (Table 10) or a soybean meal control diet to measure growth performance and diet nutrient digestibility. The wheat-based diets were formulated to contain 2.25 Mcal/kg NE and 4.7 g SID lys/Mcal NE. Glycerol increased (P < 0.05) DE value by 0.14 and 0.05 Mcal/kg of DM for solvent-extracted and expeller-pressed canola meal diets, respectively. Canola coproduct diets had a lower (P < 0.05) nutrient digestibility than the control diet, while DE values did not differ. For d 0 to 28, weight gain and feed efficiency did not differ between the 2 types of canola meal, the 2 levels of glycerol, and the canola coproduct diets and control diet, although feed intake was 6% higher (P < 0.05) for the control than canola coproduct diets. In conclusion, 15% of solvent-extracted or expeller-pressed canola meal with 5% glycerol can partially replace soybean meal and wheat grain in diets formulated to equal NE and SID amino acid content fed to weaned pigs without affecting nursery growth performance.

Table 10. Analyzed chemical content (%) of crude glycerol (Seneviratne et al. 2011d)

	Crude glycerol[1]
Crude protein	0.9
Ether extract	49.6
Ash	10.8
Sodium	0.02
Potassium	3.36
Methanol	<0.01

[1]Milligan Bio-Tech, Foam Lake, SK

▪ Safety and Efficacy of Camelina Meal and Oil

Camelina is a hardy oilseed related to flax and canola. Only a small number of farmers in western Canada currently grow camelina for use as cold-weather biodiesel stock and less market the oil for human consumption. This oilseed (Table 11) has a high content of vitamin E, a naturally occurring antioxidant. Current camelina acreage is not indicative of its oil potential. Camelina oil has 3x more linolenic acid (33% ω18:3) and greater content (20%) of long-chain (20+ carbons) fatty acids that canola oil (60% oleic, 20% linoleic, 10% linolenic). Camelina oil therefore complements canola oil, not competes with it. Consequently, there is huge potential for economic growth of the camelina industry and coexistence with canola. Feeding camelina meal or oil to livestock could enrich animal products with omega-3 fatty acids and possibly extend shelf live due to its high vitamin E content. However, camelina meal and oil are not registered feedstuffs in Schedule IV of the Feed Act. We have taken the initiative to generate safety and efficacy animal data required by CFIA to list camelina coproducts as feedstuffs. Not being able to market the meal and oil as feed is the main current deterrent to growing the camelina industry.

At writing, we have 2 camelina trials in progress. We are feeding 0, 8, 16 and 24% camelina meal (20% residual oil) to broilers from 0 to 42 days of age. Birds have been taken for post-mortem examination and histopathology, if required, at 14, 28 and will be at 42d. No organ abnormalities have been detected and thyroid glands that could be enlarged by meal glucosinolates still appeared normal on day 28. Preliminary growth performance results (Table 12) to day 28 show no detrimental effect of feeding up to 24% screw-pressed camelina meal to broiler chickens and a linear increase in breast yield. Brain, liver, thigh and breast muscle are being assayed for fatty acid content.

Table 11. Nutrient profile of screw-pressed camelina meal, oil, and seedstock (93.5% DM)

	Meal	Oil	Seed
Crude protein	32.46		21.11
Crude Fat	19.06	90.12	43.68
Crude Fiber	8.39		6.28
ADF	15.28		
NDF	36.97		
Ash	5.15		3.41
Calcium	0.30		
Phosphorus	1.03		
Meal amino acids, %			
Arginine	2.56	Valine	1.61
Histidine	0.76	Alanine	1.44
Isoleucine	1.17	Aspartic acid	2.51
Leucine	2.09	Cysteine	0.70
Lysine	1.59	Glutamic acid	4.89
Avail. lysine	1.46	Glycine	1.65
Methionine	0.55	Proline	1.46
Phenylalanine	1.33	Serine	1.28
Threonine	1.31	Tyrosine	0.91
Tryptophan	0.47		
Oil fatty acid, %			
Palmitic (16:0)	5.25	Arachidic (20:0)	1.44
Stearic (18:0)	2.72	(20:1n9)	16.19
Oleic (18:1n9)	15.5	(20:3 ω3)	1.44
Linoleic (18:2)	17.57	Docosanoic (22:0)	0.3
Linolenic (ω18:3)	33.06	Erucic (22:1n9)	2.6

To determine the minimum amount of time needed to swing enrichment of broiler meat from omega-6 to omega-3, we are currently feeding 6% camelina oil for 1, 2, or 3 weeks prior to 42 d slaughter in replacement for 6% canola oil. As per the camelina meal trial, post-mortem gross examination and organ weights will be conducted in addition to profiling brain, liver, thigh and breast muscle fatty acid content to confirm safety and efficacy of feeding camelina oil. No results from this study were available yet at the time of writing.

Table 12. Effect of feeding increasing levels of camelina meal to broilers 0 - 28d of age

	Camelina meal dietary level			
	0%	8%	16%	24%
d 0 to 14				
Wt d14, g	396	424	417	399
ADG, g	27.9	30.6	29.6	28.3
ADFI, g	47.6	50.1	50.4	49.9
Gain:feed	0.59	0.61	0.59	0.57
d 14 to 28				
Wt d28, g	1134	1324	1332	1240
ADG, g	51.0	59.7	61.3	56.2
ADFI, g	108.7	110.1	111.7	112.2
Gain:feed	0.47	0.55	0.55	0.50

▪ Conclusions and Implications

Differential cost per Mcal NE of residual oil content (Table 13) can be used as a guideline to decide what is the "best buy" among canola coproducts to reduce feed cost. The more costly feed oil and tallow become, the greater the buying opportunities. But coproduct variability due to antinutritional factors, local processing, and seed quality (green, burned) can become issues that their lack of we take for granted feeding conventional solvent-extracted canola meal.

Table 13. Differential cost[1] per Mcal NE[2] of residual oil content of canola coproducts and animal tallow

	Solv.-ext. meal	Expl.-press meal	Extr.-press meal	Scr.-press cake	Green seed	Canola oil	Tallow
Solv.-ext. meal	1.00						
Expl.-press meal	0.82	1.00					
Extr.-press meal	0.72	0.88	1.00				
Scr.-press cake	1.05	1.28	1.46	1.00			
Green seed	0.87	1.07	1.22	0.83	1.00		
Canola oil	1.45	1.77	2.03	1.38	1.66	1.00	
Tallow	1.26	1.55	1.77	1.21	1.45	0.87	1.00

[1]Solvent-extracted canola meal $225, expeller-pressed canola meal $250, extruded-pressed canola meal $230, screw-pressed canola cake $400, green (20%) canola seed $400, canola oil $1000, tallow $800 per 1000 kg
[2]Solvent-extracted canola meal 1.75, expeller-pressed canola meal 2.38, extruded-pressed canola meal 2.50, screw-pressed canola cake 2.97, green (20%) canola seed 3.57, canola oil 5.36, tallow 4.92 Mcal NE/kg

We have shown more opportunities feeding canola meal. We have pushed dietary inclusions (up to 30%) in combination with wheat DDGS (making up 50% of the diet). *B. juncea* meal offers lower fibre content and a higher energy value, but glucosinolate content should be tested prior to feeding at high inclusions. We have also demonstrated that simple, continuous vibro-sieving or air-classification of solvent-extracted canola meal produced fractions with a spread (halved) in fibre content to target to ruminant and monogastric animal feeding, respectively.

To facilitate registration of new feedstuffs, we have endeavoured to conduct safety and efficacy studies. Crude glycerol can be included in pig nursery diets up to 8%. Screw-pressed camelina meal can be safely included up to 24% in broiler chicken diets. We are currently confirming tissue enrichment with omega-3 fatty acids and hope to determine the amount of time required to swing from omega-6 to -3 enrichment prior to market weight.

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