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**EFFICACY OF CANOLA MEAL IN DIETS FOR GROWER AND FINISHER PIGS REARED IN VIETNAM**

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**Abstract**

The effect of replacing soybean meal with canola meal (CM), sourced from Canada, in the diets of grower and finisher phase pigs on final weights and average daily gain was assessed. The canola meal was deemed low in glucosinolate levels and was fed in the diet replacing soybean meal (SBM) and maize at levels of 0%, 10%, 20% and 30% of the total diet to pigs in the grower phase beginning at 20 kg and ending at 60 kg. Pigs in the finisher phase, weighing 60-100 kg, were fed levels of canola meal at 0%, 10%, 17.5% and 25% of the total diet, again displacing soybean meal and maize. In total, 360 pigs were assigned to the 4 treatments with 6 replicates and 15 pigs per replicate. Diets were formulated to contain 3,200 Kcal/kg of metabolizable energy (ME/kg) and 0.9% and 0.7% total lysine for the grower and finisher diets, respectively. From the initial stage to 60 days, there were no significant differences among the diets that included either 10% or 20% CM or SBM (*p*>0.05). However, consumption of the 30% CM diet resulted in a significant reduction in the body weight of those animals relative to the SBM control group (*p* <0.05). No differences in the feed conversion ratio (FCR) were apparent among the diets for the combined growth cycle (20-100 kg) using SBM, 10% or 20% CM (*p*>0.05), but the highest inclusion level of CM (30%) resulted in a significantly poorer FCR than the other three treatment groups. This led to the conclusion that CM in diets for growing-finishing pigs should not exceed 20%.

***Keywords:****Brassica species, canola meal, feed conversion, glucosinolates, performance*

#### Introduction

Canola, or “Canada oil low acid”, was derived from the rapeseed plant, which belongs to the Brassica (mustard) genus of crops. This genus contains the cruciferous plants, which include the well-known vegetables broccoli, kale, cabbage, turnip, radish, kale and cauliflower, and the condiment mustards (Bell, 1984). Canola seed is grown commercially first and foremost for its oil content which, at 43-44%, exceeds that of the most abundant oilseed cultivated in the world, the soybean (18-20% oil). The meal by-product derived during the processing of canola seed (i.e., canola meal = CM) is the second most widely traded protein ingredient after soybean meal (SBM), and it is generally traded at a discount to SBM based on its lower protein content (~36-38% versus 46-48% for de-hulled SBM) and energy content (variable by species). Despite a quantitative difference in protein and amino acid content relative to SBM, CM does contain a well-balanced amino acid (AA) profile. When compared directly to SBM, CM contains less lysine but more methionine and cysteine (Sauer at el 1982; Newkirk et al 2003). CM is also a rich source of most of the essential minerals (Bell, 1993). Compared to SBM, it is relatively high in calcium, phosphorus, sulphur, magnesium, manganese and selenium, but it is lower in potassium and copper. The crude fibre content of CM is three times higher than it is in de-hulled SBM, which is due to the smaller canola seed size relative to the soybean. Small seed size results in more of the total mass of the seed being located on the surface of the seed, which represents the fibre-rich hull component. The relatively low levels of digestible energy (DE) and metabolizable energy (ME) in CM are due to this high level of seed fibre (Bell, 1993). CM, like most plant-based feed ingredients, contains important anti-nutritional factors, and these must be taken into consideration when formulating finished feeds. Glucosinolates (GLS) are sulphur-containing secondary plant metabolites that are found in the plant order Capparales, sub-group Brassicales. The glucosinolates in CM are of two types - aliphatic (~85%) and indolyl (~15%) (Newkirk et al 2003). The total GLS content of Canadian CM is approximately 4.2 µmoles/g (Newkirk et al 2003). By comparison, traditional rapeseed meal (RSM) contains 120-150 µmoles/g. GLS have well-described negative effects on feed intake in swine and on liver function in laying hens (Butler et al 1982; Campbell and Slominski, 1991), but their presence in canola has been reduced consistently over time through the efforts of Canadian and other plant breeders. This, in fact, has been one of the defining measures that differentiates canola from traditional rapeseed, and this has been used to further qualify the value of various sources of CM in world markets.

Given the relative values of SBM and CM to feed livestock, and the different sources available to use in southeast Asia, the objective of this study was to evaluate the efficacy of CM in improving the growth performance of grower and finisher pigs in Vietnam.

#### Materials and methods

The location of the trial was the Thong Nhat Pig Farm at the Thai My Commune, Cu Chi District, Ho Chi Minh City, Vietnam from November 2015 to April 2016.

A total of 360 piglets were randomly assigned to 4 treatments, with 6 replicates per treatment and 15 pigs per replicate. The control group was fed a maize-SBM diet. The compositions of the grower (20-60 kg body weight) and finisher (60-100 kg) diets are described in Tables 1 and 3, respectively, and their calculated nutrient compositions are displayed in Tables 2 and 4, respectively. CM was added to the diet as a replacement for SBM and maize, to represent 10%, 20% or 30% of the total ration by weight in the grower phase, and at 10%, 17.5% and 25% through the finisher phase. The diets were administered in a staggered fashion to the animals, with replicates 1, 2 and 3 being provided to the animals from November 24, 2015 to March 9, 2016 and replicates 4, 5 and 6 from December 15, 2015 to April 24, 2016. This was necessitated by the number of animals involved in the study and the limited available pen space. Individual pig weights were taken at the beginning of the trial, at day 60 and on the final day of the trial. Feed intake was recorded each day by pen, and spilled feed was recorded as well. Average daily gain (ADG) was calculated as the total bodyweight gained per pen divided by the number of live pig days during the specified time period. Mortalities were recorded at the time of death, including the weight at the time of death or cull, the reason for culling or the reason for the mortality. Feed conversion ratios (FCR) were calculated as the total feed consumption divided by bodyweight gain and defined as follows: (sum of the final body weights of the surviving animals + the weight of mortalities and removals) – (sum of the initial body weights, including the initial bodyweight of the dead animals or those removed during the specified period). The feed quality of the raw material was analysed before the diets were formulated and then again after the experimental diets had been prepared.

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| **Table 1.**Experimental diets of pigs in grower stage of 20-60 kg of body weight (unit: kg) | | | | |
| **Ingredient** | **Experimental diets** | | | |
| **SBM** | **10% CM** | **20% CM** | **30% CM** |
|  | | | | |
| Soybean Meal | 218 | 146 | 72 | 12.1 |
| Canola Meal | 0 | 100 | 200 | 300 |
| Maize | 514 | 515 | 482 | 445 |
| L-Lysine | 0.50 | 0.80 | 1.10 | 1.40 |
| Other ingredients | 268 | 238 | 245 | 242 |
| Total | 1,000 | 1,000 | 1,000 | 1,000 |
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| --- | --- | --- | --- | --- |
| **Table 2.**Nutrient composition of experimental diets: 20-60 Kg | | | | |
| **Weight** | **SBM** | **10% CM** | **20% CM** | **30% CM** |
|  | | | | |
| Dry matter, % | 88.9 | 88.9 | 88.5 | 88.2 |
| ME (kcal/kg) | 3,200 | 3,200 | 3,200 | 3,200 |
| Crude protein, % | 17.0 | 17.0 | 17.0 | 17.0 |
| Crude fat, % | 3.56 | 3.45 | 3.98 | 4.64 |
| Crude fibre, % | 3.01 | 3.38 | 3.92 | 4.45 |
| Ca, % | 0.72 | 0.72 | 0.72 | 0.75 |
| Total P, % | 0.61 | 0.62 | 0.63 | 0.66 |
| Lysine, % | 0.90 | 0.90 | 0.90 | 0.90 |
| Met + Cystine, % | 0.62 | 0.63 | 0.63 | 0.64 |
| Threonine, % | 0.64 | 0.64 | 0.65 | 0.65 |
| Tryptophan, % | 0.19 | 0.19 | 0.19 | 0.19 |
| Salt, % | 0.50 | 0.50 | 0.50 | 0.50 |
| Available P, % | 0.26 | 0.26 | 0.26 | 0.26 |
| Methionine, % | 0.26 | 0.26 | 0.26 | 0.26 |
| Digestible Lysine, % | 0.60 | 0.63 | 0.66 | 0.69 |
| Digestible Methionine, % | 0.21 | 0.21 | 0.21 | 0.22 |
| Digestible Met + Cystine, % | 0.48 | 0.48 | 0.49 | 0.49 |
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| --- | --- | --- | --- | --- |
| **Table 3.** Experimental diets of pigs in grower stage of 60-100 kg of body weight (unit: kg) | | | | |
|  | **Experimental Diets** | | | |
|  | **SBM** | **10% CM** | **17.5% CM** | **25% CM** |
|  | | | | | |
| Soybean Meal | 154 | 82 | 27 | 0 |  |
| Canola Meal | 0 | 100 | 175 | 250 |  |
| Maize | 581 | 579 | 555 | 500 |  |
| L-Lysine | 0.20 | 0.50 | 0.75 | 0.92 |  |
| Other ingredients | 265 | 239 | 242 | 249 |  |
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| **Table 4.** Nutrient composition of experimental diets: 60-100 Kg | | | | |
| **Weight** | **SBM** | **10% CM** | **17.5% CM** | **25% CM** |
|  | | | | |
| Dry matter, % | 88.8 | 88.8 | 88.5 | 87.0 |
| ME (kcal/kg) | 3,200 | 3,200 | 3,200 | 3,200 |
| Crude protein, % | 14.5 | 14.5 | 14.5 | 14.5 |
| Crude fat, % | 3.61 | 3.56 | 3.96 | 3.85 |
| Crude fibre, % | 2.76 | 3.15 | 3.50 | 4.12 |
| Ca, % | 0.70 | 0.70 | 0.70 | 0.70 |
| Total P, % | 0.55 | 0.55 | 0.55 | 0.55 |
| Lysine, % | 0.70 | 0.70 | 0.70 | 0.70 |
| Met + Cystine, % | 0.60 | 0.60 | 0.61 | 0.60 |
| Threonine, % | 0.55 | 0.55 | 0.55 | 0.55 |
| Tryptophan, % | 0.15 | 0.15 | 0.15 | 0.15 |
| Salt, % | 0.50 | 0.50 | 0.50 | 0.50 |
| Available P, % | 0.21 | 0.21 | 0.21 | 0.21 |
| Methionine, % | 0.30 | 0.30 | 0.30 | 0.30 |
| Digestible Lysine, % | 0.51 | 0.52 | 0.50 | 0.52 |
| Digestible Methionine, % | 0.24 | 0.24 | 0.23 | 0.24 |
| Digesttible Met + Cys, % | 0.46 | 0.46 | 0.46 | 0.47 |
| Digestible Threonine, % | 0.38 | 0.38 | 0.40 | 0.40 |
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##### Statistical Analysis

Experimental results were subjected to analysis of variance (ANOVA). The Minitab statistical software version 16 was used to test for significance of treatment differences, and Tukey’s one-way multiple comparisons were used to identify differences among means in the required cases, when the analysis of variance was significant (p<0.05).

#### Results

From the initial stage to 60 days, there were no difference among the diets that included either 10% or 20% CM or SBM (p>0.05) (Table 5). However, consumption of the 30% CM diet resulted in a significant reduction in the body weight of those animals relative to the SBM control group ( p<0.05). After 60 days, the daily weight gain was the highest for the pigs fed the SBM diet (641 g/day), which was 1.41%, 3.46% and 17.48% higher than that of the diets with 10%, 20% or 30% CM, respectively. However, the daily weight gain was not significantly different among the diets with SBM and those with 10% or 20% CM (p>0.05), but the use of 30% CM did significantly reduce daily weight gain compared to the SBM diet (p<0.05). For the entire trial, feed intake was similar for all treatment groups (Table 6), ranging from 2,052 to 2,067 g/head/day. During the grower phase, the FCR of the SBM group was significantly better than that of the 20% CM and 30% CM groups (p <0.01), while the FCR of the 10% CM and 20% CM groups bettered that of the 30% CM group. The FCRs for the three CM groups were similar during the finisher phase, but the SBM FCR was significantly better than the 30% CM group during this phase (p<0.02). No differences in the feed conversion ratio (FCR) were apparent among the diets for the combined growth cycle (20-100 kg) using SBM, 10% or 20% CM (p>0.05), but the highest inclusion level of CM (30%) resulted in a significantly higher FCR than the other three treatment groups. This led to the conclusion that CM in diets for growing-finishing pigs should not exceed 20%. The higher the ratio of CM in the diet for pigs, the higher the FCR.

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| **Table 5.**Body weight and Average Daily Weight Gain | | | | | | |
| **Item** | **Treatments** | | | | **SEM** | **p** |
| **SBM** | **10% CM** | **17.5% CM** | **25% CM** |
|  | | | | | | |
| Initial body weight (kg/head) | 25.3 | 25.3 | 25.2 | 25.8 | 1.49 | 0.877 |
| Body weight at 60 days (kg) | 63.8a | 63.0ab | 62.3ab | 61.5b | 1.27 | 0.045 |
| Final body weight (Kg) | 104a | 102a | 100ab | 96.9b | 2.57 | 0.001 |
| \*ADG 1 (g/day) | 641a | 632a | 619a | 592b | 16.51 | 0.000 |
| ADG 2 (g/day) | 880a | 857a | 829ab | 778b | 45.18 | 0.005 |
| Overall ADG (g/day) | 741a | 728a | 709a | 672b | 21.03 | 0.000 |
| SBM : soybean meal, CM: canola meal , ADG: average daily weight gain abMeans in the same row without common letter are different at p<0.05 | | | | | | |

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| --- | --- | --- | --- | --- | --- | --- |
| **Table 6.**Feed intake and feed conversion ratio | | | | | | |
| **Item** | **Treatments** | | | | **SEM** | ***p*** |
| **SBM** | **10% CM** | **17.5% CM** | **25% CM** |
|  | | | | | | |
| FI 1 (g/head/day) | 1,685 | 1,685 | 1,698 | 1,699 | 28.30 | 0.693 |
| FI 2 (g/head/day) | 2585a | 2587a | 2538ab | 2529b | 25.48 | 0.002 |
| Overall FI (g/head/day) | 2,064 | 2,067 | 2,062 | 2,052 | 19.18 | 0.555 |
| FCR 1 (kg FI/kg WG) | 2.65c | 2.67bc | 2.74b | 2.86a | 0.06 | 0.001 |
| FCR 2 (kg FI/kg WG) | 2.94b | 3.01ab | 3.06ab | 3.26a | 0.15 | 0.013 |
| Overall FCR (kg FI/kg WG) | 2.79b | 2.84b | 2.90b | 3.06a | 0.08 | 0.001 |
| SBM : soybean meal, CM: canola meal, FI: feed intake, FCR: feed conversion ratio abcMeans in the same row without common letter are different at p<0.05 | | | | | | |

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#### Discussion

Canola is now Canada’s most important cash crop, surpassing even wheat, with ~8.15 million hectares planted each growing season. It is grown primarily for its oil content (~44%), but after extraction of the oil, the remaining solids are processed into a high protein meal that is an excellent source of nutrients for livestock and aquatic species. Canola was derived from the rapeseed plant (Brassica napus and Brassica campestris/rapa) through traditional plant breeding techniques. It was designed to have low levels of erucic acid (< 2%) in the oil and low levels of GLS (<30 µmol/g) in the meal component, whereas traditional rapeseed, which is still grown in India and elsewhere, may have 35.7–51.4% erucic acid in the oil and 49.9–120.3 μmol/g GLS in the defatted meal (Chauhan et al 2007). GLS were reduced in canola due to their negative impact on palatability and their toxic effect on several livestock species. Canola meal produced from Canadian canola seed contains very low levels of anti-nutritional compounds, with an average GLS content 4.6 μmol/g (Adewole et al 2016). This low value means that when combined with proper diet formulation, CM can be included in rations at much higher levels than can RSM. Despite this, Canadian CM is often mistaken for RSM in the market place. The GLS in CM have generally been considered to have a negative influence on feed intake in pigs. Besides their anti-nutritive effects, GLS have a bitter taste to many animals. However, CM produced from low GLS seed grown in Canada has a neutral taste, meaning that reduced feed intake is no longer an issue even when high levels of Canadian CM are fed. This was evident in the present study (Table 6), as only at the highest level of CM inclusion during the finisher period (CM=25%) was there a small (2.2%) but significant decrease in feed intake. However, over the entire grower-finisher period (20-100 kg), feed intake was equivalent across all treatments. The maximum tolerable level of GLS in swine diets has yet to be determined, and Canadian plant breeders continue to focus on further reducing GLS in canola seed. The current levels of GLS in Canadian canola seed varieties do not appear limiting for CM inclusion in grower-finisher diets. As an example, Smit et al 2014a demonstrated that grower-finisher pigs perform well on diets containing up to 30% CM. Where traditional rapeseed and canola-quality meal are clearly differentiated (i.e., North America, Europe, Australia), CM is accepted in monogastric and ruminant species at relatively high inclusion levels. In contrast, in most parts of Asia, CM is considered little better than RSM as an alternative protein and energy source to SBM. Even non-nutritional factors, such as the darker color of CM than SBM, is considered a limiting factor to the inclusion of CM. This has led to restriction of CM use to the aquaculture industry, where it may be broad cast into fish ponds rather than included into feed formulations. Use of CM in swine, poultry or cattle feeds in Asia is the exception rather than the rule.

Nevertheless, CM is well accepted by swine, and with proper diet formulation to account for the diminished digestibility of energy and amino acids (AA) compared to SBM, it can be included in diets at increasingly high levels during all growth phases. Due to the higher crude fiber content of CM than in either non-dehulled or dehulled SBM, it is necessary to balance swine rations for digestible amino acids, rather than total amino acids, and for metabolizable energy (ME) or net energy (NE) rather than digestible energy (DE). The digestibility of key AA in CM is lower than in SBM. As a result, when CM replaces SBM in the diet, the overall levels of digestible AA, especially lysine and threonine, will decrease if the diet is balanced to total rather than digestible AA. In developed markets, swine diets are formulated to levels of digestible AA. A number of recent swine feeding trials demonstrated equivalent growth rates compared to SBM control diets, even at quite high CM levels, when the diets were balanced for digestible lysine (Sanjayan et al 2014, Landero et al 2012, Landero et al 2011, Smit et al 2014a, Smit et al 2014b).

In Vietnam, it is not common practice to balance swine rations for digestible AA or for NE. Larger feed mills and integrated swine farms do formulate to ME, and the leading integrators and feed mills (usually multi-national companies) will adjust their formulas for differences in AA digestibility. However, the domestic swine sector is still dominated by small back-yard farms that are serviced by smaller feed mills, which do not adjust for differences in nutrient digestibility in the feed ingredients that it utilizes. Therefore, in this study, no attempt was made to adjust the experimental rations for AA digestibility. CM is considered to be an inferior source of energy for swine diets compared to SBM due to its higher crude fiber content, which limits nutrient digestibility. However, in a NE system, the lower protein content of CM than in SBM improves its acceptance level in feed formulations. In this trial, the control and experimental diets were balanced to equivalent ME levels, which is the standard practice in Vietnam. DE, ME and NE Energy values published by NRC 2012 are 3,273; 3,013 and 1,890Kcal/kg, respectively and are based on historical information. Recently, Maison et al 2015 determined DE values of 3,378 Mcal/kg of dry matter and 3,127 Mcal/kg of dry matter for the ME for CM. In this study, despite a borderline deficiency of lysine as the inclusion level of CM increased from 0 to 30% (lysine is the limiting amino acid in maize-soybean meal diets, and lysine is both lower on a total basis in CM than in SBM and more poorly digested (Canola Council of Canada, 2015), the CM fed animals in the grower group exhibited comparable performance to the SBM fed animals up to 20% CM inclusion. This is a considerably higher level of CM than would normally be fed in Vietnam to grower pigs, if at all. Only at a 30% inclusion rate did performance suffer relative to the SBM fed animals. This study and others clearly demonstrate that diets containing CM at relatively high levels will support excellent growth performance in swine. Several studies have shown that when grower and finisher diets are balanced for NE and standard ileal digestible AA levels, performance is the same as with SBM, up to 25% CM inclusion (Brand et al 2001; Raj et al 2000; Siljander-Rasi et al 1996; Roth-Maier 2004). Smit et al 2014b fed grower-finisher pigs (initial weight of 29.9 kg) five-phase diets containing varying levels of CM up to 24%, while also including 15% dried distillers’ grains with solubles in all diets. The pigs fed the 24% CM reached market weight three days later than did those fed the 6% CM, but there were no differences in carcass traits. Smit et al 2014a then fed grower-finisher pigs up to 30% CM and found a slight reduction in performance and carcass traits between the 20% CM group and the 30% CM group, but feed efficiency was improved in the latter group.

The relationship between cost and nutrient content of a feed ingredient (plus any pre-determined restrictions or mandated levels) will determine the level of inclusion of the ingredient in a well formulated, least-cost ration. Therefore, it is critical to have the most accurate information possible on the digestibility of the AA in CM in the species being fed, as well as the digestibility of AA in other ingredients that are normally fed.

#### Conclusion

* Using 10-30% CM in swine diets did not adversely affect feed intake during the grower or finisher phases.
* Growing and finishing pigs fed diets containing up to 20% and 17.5% CM, respectively, had weight gain and feed conversion ratios that were equivalent to pigs fed a diet containing SBM.
* CM can successfully replace significant quantities of SBM in swine rations that are typically fed to pigs in southern Vietnam.
* These levels may be increased further if the rations are formulated on the basis of digestible AA, to account for the lower digestibility of the essential AA in CM than in SBM. Further value can be obtained from CM if the diets are formulated to the NE values rather than to the ME values of feed ingredients.

#### References

**Adewole D I, Rogiewicz A, Dyck B and Slominski B A 2016** Chemical and nutritive characteristics of canola meal from Canadian processing-facilities. Animal Feed Science and Technology 222: 17-30.

**Bell J M 1984** Nutrients and toxicants in rapeseed meal: a review. Journal of Animal Science 58: 996–1010.

**Bell J M 1993** Factors affecting the nutritional value of canola meal: a review. Canada Journal of Animal Science 73: 689–697. https://doi: 10.4141/cjas93-075.

**Brand T S, Brandt D A and Cruywagen C W 2001** Utilisation of growing-finishing pig diets containing high levels of solvent or expeller oil–extracted canola meal. New Zealand Journal of Agricultural Research 44: 31–35.

**Butler E J, Pearson A W and Fenwick G R 1982** Problems which limit the use of rapeseed meal as a protein source in poultry diets. Journal of the Science of Food Agriculture 33: 866-875.

**Campbell L D and Slominski B A 1991** Feeding quality of very low glucosinolate canola. Twelfth Western Nutrition Conference in Winnipeg, Manitoba, September 11-12, 1991: 245-252.

**Canola Council of Canada 2015**Canola Meal Feeding Guide 2015, from <https://www.canolacouncil.org/media/516716/2015_canola_meal_feed_industry_guide.pdf>

**Chauhan J S, Bhadauria V P S, Singh M, Singh K H and Kumar A 2007** Quality characteristics and their interrelationship in Indian rapeseed-mustard (Brassica sp) varieties. Indian Journal of Agricultural Sciences 77, 616–620.

**Landero J L, Beltranena E and Zijlstra R T 2012**Growth performance and preference studies to evaluate solvent-extracted Brassica napus or Brassica juncea canola meal fed to weaned pigs. Journal of Animal Science 90, 406–408.

**Landero J L, Beltranena E, Cervantes M, Morales A and Zijlstra R T 2011** The effect of feeding solvent-extracted canola meal on growth performance and diet nutrient digestibility in weaned pigs. Animal Feed Science and Technology 170: 136–140.

**Maison T, Liu Y and Stein H H 2015** Digestibility of energy and detergent fiber and digestible and metabolisable energy values in canola meal, 00-rapeseed meal and 00-rapeseed expellers fed to growing pigs. Journal of Animal Science 93:652–660.

**National Research Council 2012**Nutrient Requirements of Swine, 11th Edition, The National Academies Press, 500 Fifth St. NW, Washington, D.C. 20001.

**Newkirk R W, Classen H L, Scott T A and Edney M J 2003**The digestibility and content of amino acids in toasted and non-toasted canola meals. Canada Journal of Animal Science 83:131-139.

**Raj S T, Fandrejewski H, Weremko D, Skiba G, Buraczewska L, Zebrowska T and Han I K 2000** Growth performance, body composition, and protein and energy utilisation of pigs fed ad libitum diets formulated according to digestible amino acid content. Asian-Australasian Journal of Animal Sciences 13: 817–823.

**Roth-Maier D A, Böhmer B M and Roth F X 2004**Effects of feeding canola meal and sweet lupin (L. uteus, L. angustifolius) in amino acid balanced diets on growth performance and carcass characteristics of growing-finishing pigs. Animal Research 53: 21–34.

**Sanjayan N, Heo J M and Nyachoti C M 2014**Nutrient digestibility and growth performance of pigs fed diets with different levels of canola meal from Brassica napus black and Brassica juncea yellow. Journal of Animal Science 92: 3895–3905.

**Sauer W C, Cichon R and Misir R 1982**Amino acid availability and protein quality of canola and rapeseed meal for pigs and rats. Journal of Animal Science 54: 292–301.

**Siljander-Rasi H, Valaja J, Alaviuhkola T, Rantamäki P and Tupasela T 1996** Replacing soybean meal with heat-treated low-glucosinolate rapeseed meal does not affect the performance of growing-finishing pigs. Animal Feed Science and Technology 60: 1–12.

**Smit M N, Seneviratne R W, Young M G, Lanz G, Zijlstra R T and Beltranena E 2014a**Feeding Brassica juncea or Brassica napus canola meal at increasing dietary inclusions to growing-finishing gilts and barrows. Animal Feed Science and Technology 198: 176–185.

**Smit M N, Seneviratne R W, Young M G, Lanz G, Zijlstra R T and Beltranena E 2014b**Feeding increasing inclusion of canola meal and distillers’ dried grains and solubles to growing-finishing barrows and gilts. Animal Feed Science and Technology 189: 107–116.