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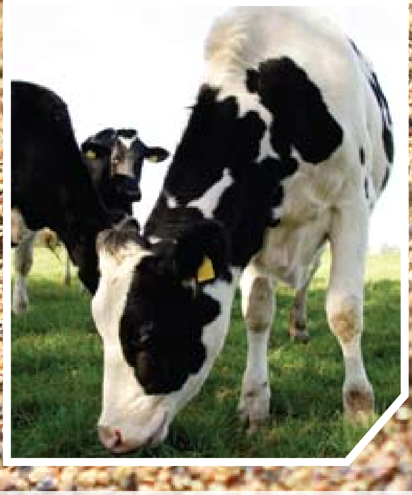
canola council

CANOLA MEAL
Feed Industry Guide
4th Edition, 2009



POULTRY

PIGS

DAIRY & BEEF CATTLE

SPECIALTY

EDITED BY:

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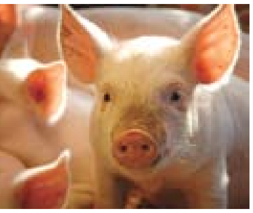
CIGI
Canadian International Grains Institute
Institut international du Canada pour le grain

INTRODUCTION

This technical guide on the use of canola meal in animal feeds is the latest in a series of canola meal publications produced by the Canola Council of Canada. Every few years, the guide is updated to incorporate new research information about canola meal and developments in feed technology. Since the previous edition in 2001, a considerable amount of new research on feeding canola meal has been conducted from around the world, especially from Canada, Europe and Asia. New information and changes in this latest version of the guide include:



- Revised information on use of canola meal in laying hen diets
- Processing factors that influence canola meal quality, especially amino acid bio-availability
- Information on expeller processed meal
- Additional information on canola meal inclusion in fish diets
- A comparison of the nutritional profile of Canadian canola meal to corn distillers dried grains

A copy of this publication can be found on the Canola Council of Canada's web site: **www.canolacouncil.org**. As well, Internet users are encouraged to visit the searchable "Pulse-Canola Feed Literature Database Record" which is partly sponsored by the Saskatchewan Canola Development Commission: www.infoharvest.ca/pcd.

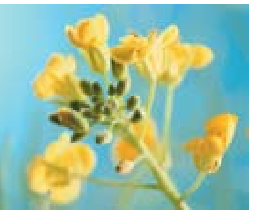


TABLE OF CONTENTS

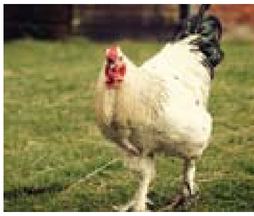
POULTRY

PIGS

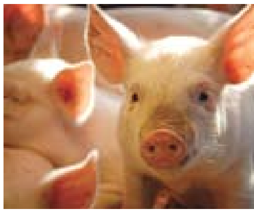
DAIRY & BEEF CATTLE

SPECIALTY

CANOLA MEAL BACKGROUND & MARKET



Canola is an offspring of rapeseed (*Brassica napus and Brassica campestris/rapa*) which was bred through standard plant breeding techniques to have low levels of erucic acid (< 2%) in the oil portion and low levels of glucosinolates (< 30 µmol/g) in the meal portion. The canola seed is small and round, 1-2 mm in diameter. It contains approximately 42-43% oil, which is extracted for use as a premium edible vegetable oil. The remaining canola meal is a widely used protein source in animal feeds. The glucosinolates in rapeseed were reduced because they are toxic and unpalatable to most animals, and therefore limit the inclusion level of rapeseed meal in animal feeds to very low levels.



The term "canola" (Canadian oil) was coined in order to differentiate it from rapeseed. Some countries, especially in Europe, use the term "double-zero rapeseed" (low erucic acid, low glucosinolate) to identify "canola quality" seed, oil and meal.

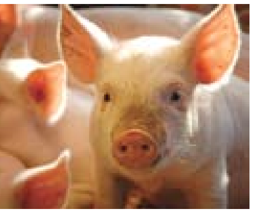
Canola and rapeseed meals are commonly used in animal feeds around the world. Together, they are the second most widely traded protein ingredients after soybean meal. The major producers and users of canola and rapeseed meal are Australia, Canada, China, European Union and India.

Canola production in Canada has been steadily increasing and currently sits at approximately 9 million tonnes of canola seed per year. The Canola Council of Canada is targeting an increase to 15 million tonnes per year by 2015. About half of the seed is exported and the other half is crushed in Canada (Table 1). Most countries that import canola seed mainly do so for the oil, which is the most valuable component. They crush the seed and then generally use the canola meal for the animal feed industry in their own countries. Canola meal is widely available and traded, usually sold in bulk form as a mash or in pellets. Canadian canola meal is traded under the rules outlined in Table 2.

Table 1. CANADIAN PRODUCTION, EXPORTS AND DOMESTIC USE OF CANOLA SEED AND CANOLA MEAL IN 000's T*

Canadian canola seed and meal production and markets	2004/2005	2005/2006	2006/2007	2007/2008
Canola seed production	7,728	9,483	9,000	9,530
Canola seed exports	3,412	5,409	5,451	5,595
United States	430	617	602	854
Japan	1,746	1,954	1,958	2,131
China	275	614	860	659
Pakistan	0	590	539	223
Mexico	944	1,274	946	1,231
United Arab Emirates	0	181	281	348
Others	17	358.7	265	149
Domestic Crush	3,031	3,423	3,579	4,144
Canola meal production	1,904	2,025	2,108	2,445
Canola meal exports	1,414	1,489	1,482	1,856
United States	1,328	1,456	1,458	1,799
Others	86	33	24	57
Canola meal Canadian use	497	534	626	589

*Statistics Canada



POULTRY

PIGS

DAIRY & BEEF CATTLE

SPECIALTY

Table 2. TRADING RULES FOR CANOLA MEAL*

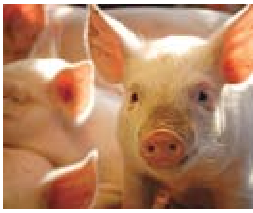
Characteristic (as fed)	Canada and US	Export
Protein, % minimum (set by COPA or industry standard at time of shipment)	36	-
Fat (oil), % typical minimum	2	-
Protein + fat, % minimum	-	37
Moisture + fat, % maximum	-	15
Moisture, % maximum	12	12
Crude fibre, % maximum	12	12
Glucosinolates, µmol/g maximum	30	30
Sand and/or silica, % maximum	-	1
Screen analysis (pellets), % retained on 2 mm screen	-	90

*COPA, 2008

CANOLA MEAL PROCESSING

Canola seed is traditionally crushed and the solvent extracted in order to separate the oil from the meal. This process, called pre-press solvent extraction, usually includes:
- seed cleaning
- seed pre-conditioning and flaking
- seed cooking
- pressing the flake to mechanically remove a portion of the oil
- solvent extraction of the press-cake to remove the remainder of the oil
- desolventizing and toasting of the meal.

Meal quality is influenced by several variables during the process, especially temperature.



SEED CLEANING

Canola seed is graded according to strict grading standards established by the Canadian Grain Commission. These include specifications for maximum moisture content, seed damage and chlorophyll level. The seed delivered to the crushing plant contains dockage materials which are removed by cleaning operations prior to processing.

SEED PRE-CONDITIONING AND FLAKING

Many crushing plants in colder climates pre-heat the seed with grain dryers to approximately 35°C to prevent shattering which may occur when cold seed from storage enters the flaking unit (Unger, 1990). The cleaned seed is first flaked by roller mills set for a narrow clearance to physically rupture the seed coat. The objective, therefore, is to rupture as many cell walls as possible without damaging the quality of the oil. The thickness of the flake is important, with an optimum of 0.3-0.38 mm. Flakes thinner than 0.2 mm are very fragile while flakes thicker than 0.4 mm result in lower oil yield.

SEED COOKING

Flakes are cooked/conditioned by passing them through a series of steam-heated drum or stack-type cookers. Cooking serves to thermally rupture oil cells which have survived flaking, reduce oil viscosity and thereby promote coalescing of oil droplets, increase the diffusion rate of prepared oil cake, and denature hydrolytic enzymes. Cooking also adjusts the moisture of the flakes, which is important in the success of subsequent prepressing operations.

At the start of cooking, the temperature is rapidly increased to 80-90°C which serves to inactivate the myrosinase enzyme present in canola. This enzyme can hydrolyze the small amounts of glucosinolates in canola and produce undesirable breakdown products which affect both oil and meal quality.

The cooking cycle usually lasts 15-20 minutes and the temperatures normally range between 80° and 105°C, with an optimum of about 88°C. In some countries, especially China, cooking temperatures of up to 120°C have been traditionally used when processing high-glucosinolate rapeseed to volatize some of the sulphur compounds which can cause odours in the oil. However, these high temperatures can negatively affect meal protein quality.

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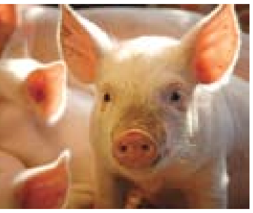
PIGS
DAIRY & BEEF CATTLE
SPECIALTY

PRESSING

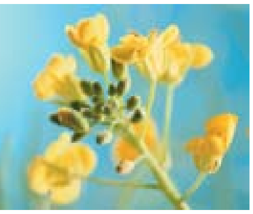
The cooked canola seed flakes are then pressed in a series of screw presses or expellers. These units consist of a rotating screw shaft within a cylindrical barrel that contains flat steel bars set edgewise around the periphery and spaced to allow the oil to flow between the bars while the cake is contained within the barrel. The rotating shaft presses the cake against an adjustable choke, which partially constricts the discharge of the cake from the end of the barrel. This action removes part of the oil while avoiding excessive pressure and temperature. The objective of pressing is to remove as much oil as possible, usually 50-60% of the seed oil content, while maximizing the output of the expellers and producing a presscake that is ideal for solvent extraction.



SOLVENT EXTRACTION

Since pressing alone cannot remove all of the oil from the canola seed, the presscake is solvent-extracted to remove the remaining oil. The cake from the expellers, containing 18-20% oil, is sometimes broken into uniform pieces prior to solvent extraction in which a solvent (hexane) is used that is specially refined for the vegetable oil industry. Various mechanical designs of solvent extractors have been developed for moving the cake and the miscella (solvent plus oil) in opposite directions to effect a continuous counter current extraction. Basket and continuous loop type extractors are commonly used for canola. The principles are the same – the cake is deposited in the extractor, which is then flooded with solvent or miscella. A series of pumps spray the miscella over the presscake with each stage using a successively "leaner" miscella, thereby containing a higher ratio of solvent in proportion to the oil. The solvent percolates by gravity through the cake bed, diffusing into, and saturating, the cake fragments. The marc (hexane-saturated meal) that leaves the solvent extractor, after a fresh solvent wash, contains less than 1% oil.

DESOLVENTIZING AND TOASTING



The solvent is removed from the marc in a desolventizer-toaster. In a series of compartments or kettles, the majority of the solvent is flashed from the meal by heating it on a series of steam-heated plates. The final stripping of the solvent is completed by injecting live steam through the meal, a process termed toasting. During the desolventization-toasting process the meal is heated to 95-115°C and moisture increases to 12-18%. The total time spent in the desolventizer-toaster is approximately 30 minutes. The meal is then cooled and dried to approximately 12% moisture by blowing air through it. The meal is next granulated to a uniform consistency using a hammer mill and is either pelleted or sent directly to storage as a mash.

POULTRY

PIGS

DAIRY &
BEEF
CATTLE

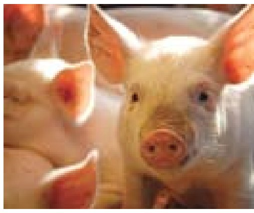
SPECIALTY

EFFECTS OF PROCESSING ON MEAL QUALITY

The quality of the meal can be both enhanced and diminished by altering the processing conditions in the crushing plant. Minimum processing temperatures are needed in order to deactivate the myrosinase enzyme which, if not destroyed, will break down glucosinolates into their toxic metabolites (aglucones) in the animal's digestive tract. The canola crushing process can also cause thermal degradation of 30-70% of glucosinolates in the meal (Daun and Adolphe, 1997). However, if temperatures are too high for too long, then the protein quality of the meal can decrease. In Canada, most crushers have very similar processing conditions and canola meal quality does not vary widely. In some countries, however, there can be considerable variation in temperatures used during canola processing. In these cases, it is important for canola meal users to routinely measure the protein quality of the meal or audit and approve suppliers.

As well, some of the by-products of canola processing are sometimes added back into the canola meal. In the case of added gums and soapstocks, these oil-rich components will increase the energy content of the meal. In the case of added screenings and foreign material, the meal quality may decrease. A good ingredient quality control program will pick up these differences in processing practices.

TEMPERATURE



Deactivation of the myrosinase enzyme is best accomplished during the canola seed cooking stage. The early research of Youngs and Wetter (1969) regarding steps to minimize glucosinolate hydrolysis by myrosinase has become the operating practice for processors around the world. Moisture content of the seed during processing should be 6-10%. Above 10% moisture, glucosinolate hydrolysis will proceed rapidly, and below 6% moisture the myrosinase enzyme is only slowly inactivated by heat. As well, during seed cooking, the temperature must be raised to 80-90°C as rapidly as possible. Myrosinase catalyzed hydrolysis of glucosinolates will proceed with increasing temperature until the enzyme is deactivated so that a slow rate of heating favours glucosinolate hydrolysis.

> **'Excessive heating during processing can result in reduced animal digestibility of some amino acids, particularly lysine.'**

Excessive heating during processing can result in reduced animal digestibility of some amino acids, particularly lysine. Processors must exercise strict process control to ensure amino acid damage is minimized by not overheating the meal in the desolventizer-toaster. Examination of meal quality at various processing stages in several Canadian crushing plants (Newkirk et al., 2003) revealed that canola meal is a uniform and high-quality product until it enters the desolventizer-toaster phase. During this stage crude protein and lysine digestibility and lysine content were significantly reduced. This research by Newkirk suggests that the commonly used temperatures in the desolventizer-toaster stage of 107°C cause some protein damage. Processing with a maximum temperature of 100°C in the desolventizer-toaster significantly increases lysine digestibility to similar levels found in soybean meal. Also, traditional toasting causes the meal to become much darker in colour. This is a quality concern for some feed manufacturers, who prefer using light-coloured ingredients due to feed customer preferences.

ADDITIVES

Crude canola oil contains a portion of phospholipid material which is removed during oil processing. This material is commonly referred to as "gums" and in Canada is added back to the meal in the desolventizer-toaster at a level of 1-2%. Also, in crushing plants with associated oil refining, the acidulated soapstocks may be added to the meal at a level of 1-2%. These additions serve to reduce the dustiness of the meal and, more importantly, increase its metabolizable energy value. In some countries the gums and soapstocks are used for other purposes and not added to the meal. This is the main reason that Canadian canola meal has higher levels of oil than meal from many other countries.

POULTRY
PIGS
DAIRY & BEEF CATTLE
SPECIALTY

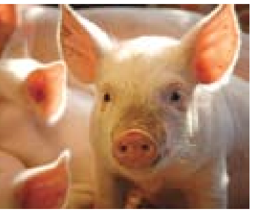
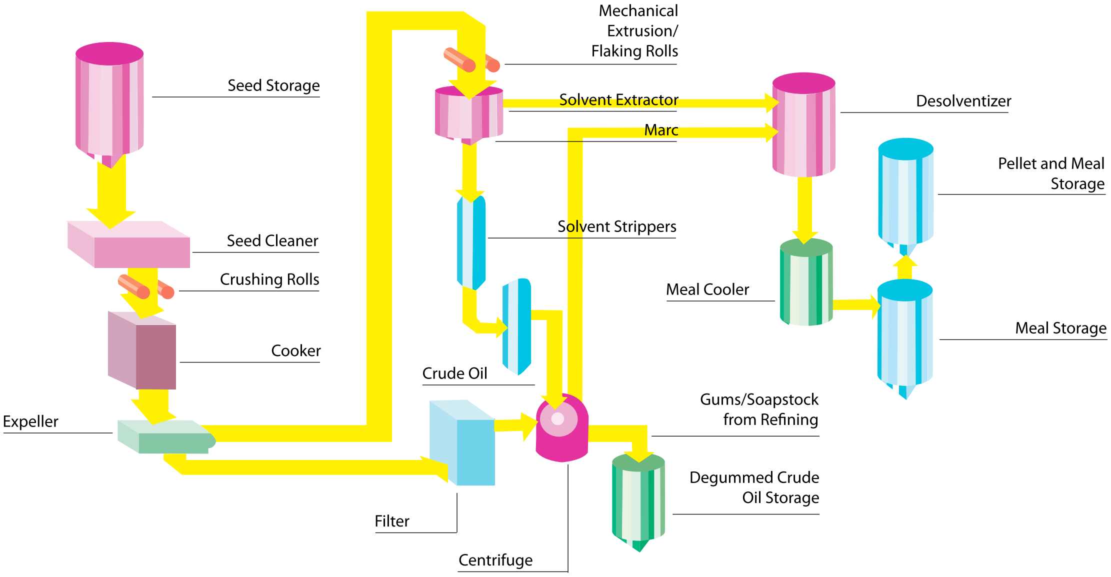


Figure 1. SCHEMATIC OF PRE-PRESS SOLVENT EXTRACTION PROCESS



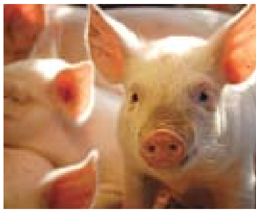
DOUBLE PRESSED CANOLA

A small proportion of Canadian canola seed, approximately 300,000 T/year, is now crushed by a process termed double pressing. The seed is expelled twice to extract oil rather than using solvent extraction to extract the residual oil. Up to the point of solvent extraction, the process is similar to the traditional pre-process solvent extraction process. However, it excludes the solvent extraction, desoventization, and drying and cooling stages. The resulting meal has higher oil content which can range from 8-11% and therefore has higher metabolisable, digestible and net energy content than traditional pre-press solvent extracted meal. The meal is not subjected to desolventization/toasting, the primary source of heat that can affect traditional solvent extracted meal, but it is still subject to the potential effects of heat due to the friction generated during the expelling process. The meal temperatures may achieve as much as 160°C but due to the low moisture content and the short duration, protein quality is generally preserved. However, in extreme cases or if the meal is not cooled quickly after extraction, protein quality can be affected.

> **‘The resulting meal has higher oil content which can range from 8-11% and therefore has higher metabolisable, digestible and net energy content than traditional pre-press solvent extracted meal.’**

CANOLA MEAL NUTRIENT COMPOSITION

Canadian canola meal is made from a blend of *Brassica napus, Brassica rapa and Brassica juncea* seed by pre-press solvent extraction. The majority (> 95%) of the seed produced in Canada, is *Brassica napus*. Canola meal nutrient composition may be influenced by environmental conditions during the growing of the crop, by harvest conditions, and to a minor extent by cultivar and processing of the seed and meal. The basic nutrient composition of canola meal is shown in Table 1.



PROTEIN AND AMINO ACIDS

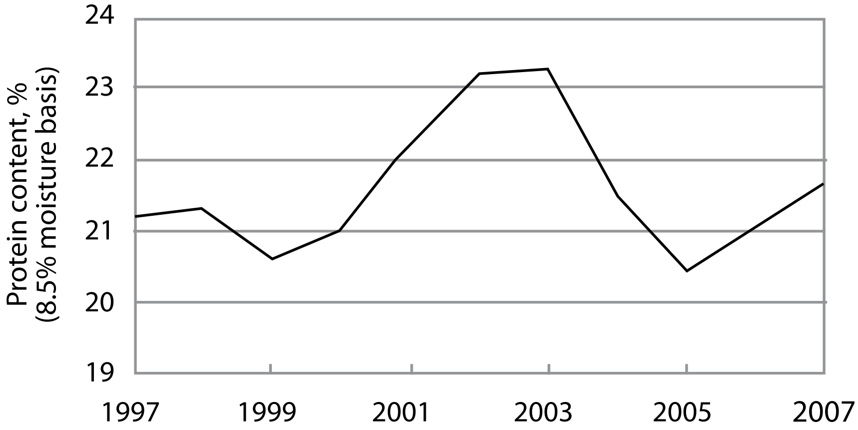
The minimum crude protein guarantee for Canadian canola meal is 36.0% (8.5% moisture basis), although the actual protein content usually is 36-39%. The minimum allows for yearly variation in canola seed composition due to growing conditions. As well, the canola crusher has some influence on the protein composition of canola meal by adjusting the level of oil and carbohydrate. The influence of weather and soil conditions on the protein content of the canola seed from 1997 to 2007 is shown in Figure 1. This publication uses a default value of 36% crude protein on an 88% dry matter basis in the nutrient composition tables.

Table 1. TYPICAL CHEMICAL COMPOSITION OF CANOLA MEAL (12% MOISTURE BASIS)

Component	Average
Crude protein (N x 6.25: %)	36
Rumen bypass protein (%)	35
Oil (%)	3.5
Linoleic acid (%)	0.6
Ash	6.1
Crude fibre (%)	12.0
Tannins (%)	1.5
Sinapine (%)	1.0
Phytic acid (%)	3.3
Glucosinolates (µmol/g)	7.2[1]

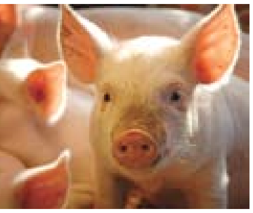
[1] Newkirk et al., 2003a

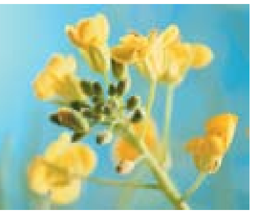
Figure 1. PROTEIN CONTENT OF CANOLA SEED 1997-2007 (8.5% MOISTURE)*



*CGC, 2007

POULTRY
PIGS
DAIRY & BEEF CATTLE
SPECIALTY





Canola meal has a good amino acid profile for animal feeding (Table 2). Like many vegetable protein sources canola meal is limiting in lysine but it is noted for having high levels of methionine and cystine. Amino acid content varies with protein content and can be calculated by multiplying the crude protein content of the meal by the proportion of amino acid as a percentage of protein shown in Table 2. The biological digestibility of the essential amino acids for absorption in the small intestine of pigs and poultry is presented in Table 3. For pigs the true ileal digestibility varies from 82-100%. These values are generally 10% lower than they are for soybean meal. A similar situation exists for poultry.

Table 2. AMINO ACID COMPOSITION OF CANOLA MEAL ON AS RECEIVED BASIS*

Amino Acid	Average % (36% CP basis)	Proportion as % of CP
Alanine	1.57	4.36
Arginine	2.08	5.78
Aspartate + asparagine	2.61	7.25
Cystine	0.86	2.39
Glutamate + glutamine	6.53	18.14
Glycine	1.77	4.92
Histidine	1.12	3.11
Isoleucine	1.56	4.33
Leucine	2.54	7.06
Lysine	2.00	5.56
Methionine	0.74	2.06
Methionine + cystine	1.60	4.44
Phenylalanine	1.38	3.83
Proline	2.15	5.97
Serine	1.44	4.00
Threonine	1.58	4.39
Tryptophan	0.48**	1.33**
Tyrosine	1.16**	3.22**
Valine	1.97	5.47

*Newkirk et al., 2003a

** Degussa, Aminodat®3.0 www.aminoacidsandmore.com

POULTRY
PIGS
DAIRY & BEEF CATTLE
SPECIALTY

Table 3. DIGESTIBILITY COEFFICIENTS OF AMINO ACIDS FOR PIGS AND POULTRY

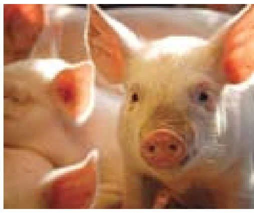
Amino Acid	Swine apparent ileal digestibility (%)[1]	Swine standardized ileal digestibility (%)[1]	Broiler chicken apparent ileal digestibility (%)[2]	Turkey apparent ileal digestibility (%)[3]	Duck apparent ileal digestibility (%)[3]
Alanine	78	80	79	75	66
Arginine	86	87	86	79	71
Aspartate + asparagine	74	76	75	72	60
Cystine	80	81	74	67	67
Glutamate + glutamine	85	87	82	86	81
Glycine	76	78	73	72	59
Histidine	83	84	84		
Isoleucine	77	78	72	75	65
Leucine	81	82	76	79	73
Lysine	74	75	78	76	66
Methionine	86	87	79	86	80
Phenylalanine	81	83	81	75	73
Proline	76	78	75	n/a	n/a
Serine	76	78	71	74	70
Threonine	72	75	69	73	64
Tryptophan	77	80	78[4]	n/a	n/a
Tyrosine	77	80	58[5]	n/a	n/a
Valine	75	77	76	72	62

[1] Sauvant et al., 2002
[2] Newkirk et al., 2003a
[3] Kluth and Rodehutscord, 2006
[4] Ravindran et al 2006
[5] Perttilä et al 2002

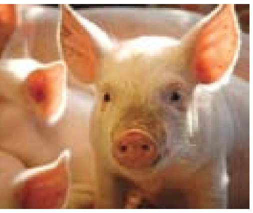
The rumen bypass protein of canola meal is 35% (Table 1) and is discussed in more detail in the section "Canola meal in cattle diets."

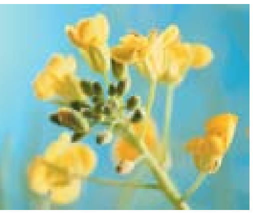
As indicated in the section "Canola meal processing," research by Newkirk et al. (2003a) and Newkirk et al. (2003b) has shown that processing temperatures are the main reason for the lower amino acid bio-availability. Although processing temperatures are relatively constant at Canadian canola crushing companies, it is prudent for canola meal users to monitor amino acid bio-availability as part of their quality control programs.

Two rapid in-vitro tests, which correlate to amino acid digestibility, are the KOH nitrogen solubility test and the neutral detergent insoluble nitrogen (NDIN) test. Anderson-Hafermann et al. (1993) made the first attempts at rapid estimation of amino acid availability in canola meal by adapting the KOH nitrogen solubility test which has been widely used on soybean meal. Daun and Kisilowsky (1999) made further methodology improvements to the KOH test. Recently, however, Newkirk et al. (2000) evaluated NDIN as a measure of canola meal protein and amino acid digestibility and found that NDIN (expressed as a percentage of total protein) values below 10% indicate a canola meal with greater than 85% lysine availability. The NDIN method appears to offer greater prediction accuracy than does the KOH solubility index ($R^2 = 0.77$ vs. 0.59). They also reported that a near-infrared reflectance spectroscopy could also be used as a rapid, precise tool for predicting lysine availability in canola meal (R^2=0.92).



POULTRY
PIGS
DAIRY & BEEF CATTLE
SPECIALTY





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PIGS
DAIRY & BEEF CATTLE
SPECIALTY

OIL

The oil content of Canadian canola meal tends to be relatively high at 3.5% (Table 1) compared to 1-2% oil in canola meals produced in most other countries, mainly because in Canada canola gums are added back to canola meal at 1-2%. The gums are obtained during the refining of canola oil and consist of glycolipids, phospholipids and variable amounts of triglycerides, sterols, fatty acids, etc. Addition of gums to canola meal increases the energy value of canola meal. The addition of up to 6% gums has been shown to have no detrimental effects on the feeding value of the canola meal for broilers or layers (Summers et al., 1978). In studies involving beef cattle (Mathison, 1978), dairy cattle (Grieve, 1978) and swine (McCuaig and Bell, 1981), the addition of gums to canola meal at levels higher than that added by Canadian canola seed processors had no adverse effects on the feeding value of the meal for these classes of animals. Likewise canola processors in Canada also add back 1-2% of the acidulated soapstocks derived from canola oil refining.

CARBOHYDRATES AND FIBRE

The carbohydrate matrix of canola meal is quite complex. The levels of starch, free sugars and soluble non-starch polysaccharides in canola meal total about 15% (Table 4) which should result in a significant contribution to digestible energy. However, it appears that these carbohydrates are protected by cell walls and that their actual contribution to digestible energy is modest (Bell, 1993; Slominski and Campbell, 1990). The 11.7% crude fibre is higher than in soybean meal because, unlike soybean meal, the canola hull stays with the meal and the hull is a relatively high proportion of the canola seed. Canola meal contains a moderate amount of acid detergent fibre (ADF) but a relatively low level of neutral detergent fibre (NDF). This relatively low NDF:ADF ratio may actually benefit the feeding of canola meal to ruminants.

MINERALS

Most references on the mineral content of canola meal use the values derived by Bell and Keith (1991) which were reconfirmed in a survey by Bell et al. (1999). The data show that canola meal is a relatively good source of essential minerals (Table 5) compared to other vegetable-origin oilseed meals.

Canola meal is an especially good source of selenium and phosphorus. Similar to other vegetable sources of phosphorus where it is present as phytate, the bio-availability is estimated to be 30-50% of the total phosphorus level. The sodium content of canola may vary somewhat depending on whether soapstocks from refining (usually sodium salt of fatty acids) are added to the meal.

Table 4. CARBOHYDRATE COMPONENTS OF CANOLA MEAL (12% MOISTURE BASIS)*

Component	Average
Starch (%)	5.1
Sugars (%)	6.7**
Sucrose (%)	6.2**
Fructose + glucose (%)	0.5**
Cellulose (%)	4.5
Oligosaccharides (%)	2.2
Non-starch polysaccharides (%)	15.7
Soluble NSP's (%)	1.4
Insoluble NSP's (%)	14.4
Crude fibre (%)	11.7
Acid detergent fibre (%)	16.8
Acid detergent lignin (%)	5.1
Neutral detergent fibre (%)	20.7
Total dietary fibre (%)	32.3

*Bell, 1993; Slominski and Campbell, 1990; **Classen, 2005, unpublished data

Table 5. MINERAL CONTENT OF CANOLA MEAL (12% MOISTURE BASIS)*

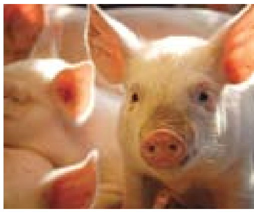
Mineral	Average
Calcium (%)	0.62
Phosphorus (%)	1.06
Available P (%)	0.3-0.5**
Sodium (%)	0.10
Chlorine (%)	0.10
Potasium (%)	1.20
Sulphur (%)	0.83
Magnesium (%)	0.53
Copper (mg/kg)	5.7
Iron (mg/kg)	162
Manganese (mg/kg)	51
Molybdenum (mg/kg)	1.4
Zinc (mg/kg)	57
Selenium (mg/kg)	1.1***
Electrolyte balance Meq/kg (K+Na-Cl)	324***
Dietary cation-anion difference mEq/kg (K+Na-Cl-S)	-193****

*Bell and Keith, 1991; Bell et al., 1999

** The higher value may be preferred for mature birds

***Sauvant, 2002

****Approximate value based on average mineral content. Calculated as described by Sauvant, 2002 using the equations: Electrolyte balance = 1000* (K/39+N/23-Cl/35.5), Dietary cation-anion difference = 1000*(k/39+N/23-Cl/35.5-S/16) where K, N, Cl and S are expressed in g/kg



VITAMINS

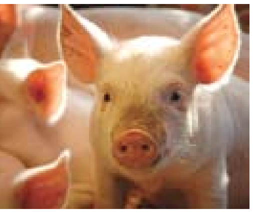
Information on the vitamin content of canola meal is very limited but it appears to be rich in choline, biotin, folic acid, niacin, riboflavin and thiamin (Table 6). As is recommended with most natural sources of vitamins in animal feeds, users should not place too much reliance on these values and use supplemental vitamin premixes instead.

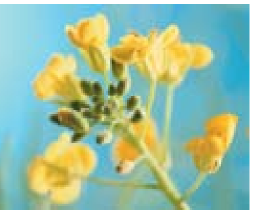
Table 6. VITAMIN CONTENT OF CANOLA MEAL (12% MOISTURE BASIS)*

Vitamin	Amount
Biotin (mg/kg)	0.96
Choline (mg/kg)	6500
Folic Acid (mg/kg)	0.8
Niacin (mg/kg)	156
Pantothenic acid (mg/kg)	9.3
Pyridoxine (mg/kg)	7.0
Riboflavin (mg/kg)	5.7
Thiamin (mg/kg)	5.1
Vitamin E (mg/kg)	13

*Values as reported by NRC, 1998

POULTRY
PIGS
DAIRY & BEEF CATTLE
SPECIALTY





ENERGY

The energy values of canola meal for various types of animals are given in Table 7. It is recognized that energy levels will vary as nutrient composition varies – especially protein, oil and fibre. The energy values in Table 7 reflect the composition of canola meal produced in Canada. For broiler chickens, the appropriate AMEn and TMEn values for canola meal are 2000 and 2070 kcal/kg (NRC, 1994), respectively. Mature laying hens are able to derive approximately 25% more energy from canola meal than young birds and therefore have an estimated AMEn value of 2390 kcal/kg (Perez-Maldonado, 2003). Reported AMEn values range from 1410 (Sauvant et al., 2002) to 2390 kcal/kg (Perez-Malonado, 2003). The values reported by NRC (1994) are 2000kcal/kg which are mid-range and therefore used in this publication.

For pigs, there is some variability in energy levels as reported in different databases. Canadian and European studies indicate that the energy fraction of meal is 68-73% digestible (Bell et al., 1991; Bell and Keith, 1989; Sauvant, 2002). For cattle, TDN, DE, ME and NE values were adopted from the 7th edition of the Nutrient Requirements of Dairy Cattle (NRC 2001). These values agree with previous editions of this guide and with those cited by Hill (1991). Lower values than shown may apply to calves with immature rumen development.

GLUCOSINOLATES

The low glucosinolate content of canola, compared to previous cultivars of rapeseed, constitutes the major improvement in meal quality achieved by plant breeders. Canola glucosinolates are composed of two main types, aliphatic and indolyl. Aliphatic glucosinolates comprise approximately 85% of the glucosinolates present in canola meal while indolyl glucosinolates account for the other 15% (Newkirk et al., 2003a). The total glucosinolate content of Canadian canola meal is approximately 7.2 µmol/g (Newkirk et al., 2003a). By comparison, traditional rapeseed meal contains 120-150 µmol/g of total glucosinolates.

Table 7. AVAILABLE ENERGY VALUES FOR CANOLA MEAL (12% MOISTURE BASIS)

Animal		Average value
Broiler Chickens*	AMEn (kcal/kg)	2000
	TMEn (kcal/kg)	2070
Laying Hens**	AMEn (kcal/kg)	2390
Pigs***	DE (kcal/kg)	3100
	ME (kcal/kg)	2900
	NE (kcal/kg)	1750
Cattle****	TDN (%)	63.0
	DE (kcal/kg)	3100
	ME (kcal/kg)	2480
	NEM (Mcal/kg)	1.690
	NEG (Mcal/kg)	1.130
	NEL Mcal/kg)	1.580

*NRC, 1994
** Perez-Maldonado, 2003
*** Bell et al., 1991; Bell and Keith, 1989; Bourdon and Aumaitre, 1990; Ajinomoto, 1996
****NRC, 2001

The problem with glucosinolates is that they break down into toxic aglucones, which have a variety of negative effects on animals. There are many different types of glucosinolates with different breakdown products – thiocyanate, isothiocyanate, oxazolidinethione (goitrin) and nitriles. Each of these products will have a unique effect on the animal – most will inhibit thyroid hormone production but others will affect the liver. The reason that glucosinolates are expressed on a molecular (µmol/g) basis rather than on a weight (mg/kg) basis is that glucosinolates have significantly different molecular weights depending on the size of their aliphatic side chain. Since the negative effect on the animal is at the molecular level, the most accurate estimate of this effect can be gauged by expressing glucosinolate concentration on a molecular basis. In addition to the toxic effect of glucosinolates, their bitter taste results in reduced feed intake for many animals. The level of glucosinolates in Canadian canola has continued to decrease in recent years due to selection pressure by canola plant breeders and is no longer a concern. The levels of glucosinolates in Canadian canola seed prior to processing can be seen in Figure 2.

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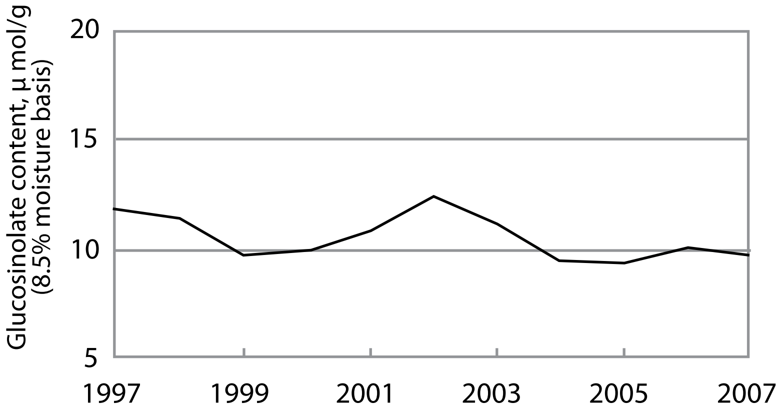
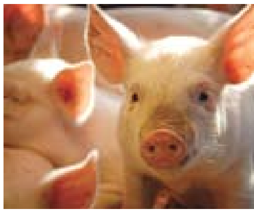
Figure 2. GLUCOSINOLATE CONTENT OF CANOLA SEED, 1997-2007 (µMOL/G, 8.5% MOISTURE)*



*CGC, 2007



OTHER MINOR COMPONENTS

There are a few minor components in canola meal which may have anti-nutrient effects (Bell, 1993). Tannins are present in canola meal at a range of 1.5-3.0%, with brown-seeded varieties having higher levels than yellow-seeded varieties. The tannins in canola meal do not appear to have the same negative effects on palatability and protein digestibility than they do in other plants.

Canola meal contains 0.6-1.8% sinapine, which can result in a fishy flavour in chicken eggs from some strains of layers. Sinapine traditionally has been thought to impart a bitter taste to canola and therefore potentially impact feed intake or broiler performance (Clandinin, 1961). Recent work by Qiao and Classen (2003) showed that while sinapine may have a bitter taste, at the levels found in canola meal it did not affect feed intake or growth rate. Interestingly, the purified sinapine extracts improved metabolisable energy diet and protein digestibility, suggesting it may not be an anti-nutrient at all but may rather have unique positive effects on nutrient utilization and gut function. Canola meal also contains approximately 0.85% phosphorus bound to phytic acid which is not very digestible by monogastics.

NUTRIENT COMPARISON OF CANOLA MEAL FROM DIFFERENT SOURCES

Most feed ingredient databases around the world have listings of nutrient values for canola and/or rapeseed meal. Not surprisingly, there are some differences in nutrient values between references, as is illustrated in Table 8. Some of these differences are caused by variations in seed nutrient composition between countries while other differences are due to processing. Canola meal produced in Canada generally has a higher level of oil and lower level of protein than European or Asian canola/rapeseed meal mainly because canola crushing companies in Canada usually add some of the gums from crushing and some soapstocks from oil refining back into the meal. This 1.0% higher oil content in Canadian canola meal increases its metabolizable energy value for swine and poultry by about 100 kcal/kg. Also, there are differences between the references in reported levels of NDF, where the Canadian values are generally lower. It is unclear why there is a discrepancy although the Canadian values are consistent between different laboratories and samples. Also, the lysine level in Chinese canola meal is lower than other references despite having a high level of crude protein. The high temperatures used in processing canola in China likely results in the lower lysine values.

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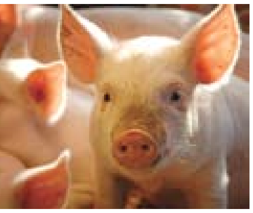
Table 8. COMPARISON OF CANOLA MEAL NUTRIENT COMPOSITION AMONG DIFFERENT LITERATURE DATABASES AND ORIGINS OF CANOLA/RAPESEED MEAL

Nutrient, as received basis (%)	Canada	Australia*	China**	Europe**	Pakistan***	Feedstuffs 2008****	NRC Poultry 1994	NRC Swine 1998	NRC Dairy 2001
Crude protein	36	37.3	37.0	34.0	40.11	38.0	36.9	35.6	33.9
Oil	3.5	3.4	2.3	2.50	2.03	3.8	3.7	3.5	3.1
Crude fibre	11.7	9.9	12.1	12.4	12.8	11.1	11.6	-	9.7
Ash	6.1	7.3	8.6	7.0	10.1	7.8	-	-	6.2
ADF	16.8	16.4	21.9	18.2	-	-	-	17.2	16.8
NDF	20.7	24.1	35.1	28.1	-	-	-	21.2	32.1
Calcium	0.62	0.56	0.71	0.76	-	0.68	0.66	0.63	0.79
Phosphorus	1.06	0.96	1.04	1.13	-	1.17	1.13	1.01	1.06
Lysine	2.00	2.02	1.64	1.86	1.86	2.02	1.71	2.08	1.85
Met + cys	1.60	1.60	1.62	1.49	1.77	1.74	1.39	1.65	1.56
Thr	1.58	1.56	1.49	1.49	1.56	1.50	1.35	1.59	1.41
Trp	0.48	5.1	0.45	0.42	-	0.46	0.39	0.45	0.35



*Spragg and Mailer, 2007
**Feedbase, 2001
***Nadeem et al., 2005
****2008 Feedstuffs Reference Issue & Buyers Guide

NUTRIENT COMPOSITION OF CANOLA OIL AND SEED

The key nutrient values for canola oil and seed are shown in Table 9. Most nutrient values for canola seed can be calculated from the nutrient values in canola meal and oil, by knowing that approximately 57% of the seed is meal and 43% is oil. The exception is energy content, where the energy value of canola seed cannot be estimated reliably from the addition of the energy values for canola oil and meal. For swine and poultry, the seed has less energy than the sum of its oil and meal components. This is likely because whole canola seed is not processed to the same degree as canola oil and meal and it is, therefore, not as well digested. Heat treatment and particle size reduction of canola seed by micronization, extrusion or expansion is often used to increase its energy digestibility.

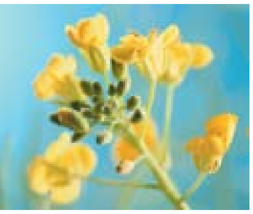


Table 9. NUTRIENT COMPOSITION OF CANOLA OIL, SEED (AS FED BASIS)

Nutrient, as is basis	Canola oil	Canola seed
Dry matter	100	93
Crude protein	0	20
Oil	100	43
Crude fibre	0	7.2
Poultry TMEn	9210*	4487**
Swine DE	8760***	5231****
Swine ME	8410***	5087****
Swine NE	5365***	3989****
Ruminant TDN*****	184	118
Ruminant NEmaint*****	5650	3050
Ruminant NEgain*****	3890	2213
Ruminant NElact*****	5650	3274
Linoleic acid (C18:2)	21.0	9.0
Linolenic acid (C18:3)	12.0	5.1

*NRC, 1994
** Barbour and Sim, 1991
***NRC, 1998
****Sauvant et al., 2004
*****NRC, 2001

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NUTRITIONAL COMPOSITION OF CANOLA EXPELLER MEAL

Smaller oilseed plants such as those associated with some biodiesel plants or in regions with limited canola seed availability use double press expeller processing rather than solvent extraction due to the lower capital cost. However, since the oil is extracted simply by mechanical means, the resulting meal contains significantly more oil than that of standard solvent-extracted canola meal. The nutritional profile of the meal is similar to that of canola meal except it contains 8-15% fat and therefore much higher energy values. Several terms are used interchangeably to differentiate solvent-extracted versus expeller-extracted meals. Terms commonly used to describe the meal include expeller meal, double press meal and presscake. The nutritional composition of expeller meal is provided in Tables 10-12. Fat content can vary widely, so it is important that the expeller cake is analyzed for fat and the energy value adjusted accordingly.

Table 10. CHEMICAL COMPOSITION OF EXPELLER MEALS (AS RECEIVED)*

Nutrient	Units
Moisture (%)	7.1
Crude protein (%)	36.3
Crude fat (ether extract) (%)	11.1
Linoleic acid (%)	2.4
Crude fibre (%)	10.6
Neutral detergent fibre (%)	24.1
Acid detergent fibre (%)	16.9
Free sugars (%)	9.8
Non-starch polysaccharides (%)	13.7
Ash (%)	6.3
Glucosinolates (umol/g)	5.3
Rumen bypass (% of protein)	30
Undegradable protein (%)	10.8

* Spragg and Mailer, 2007

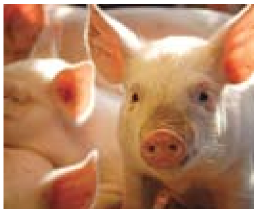

Table 11. AMINO ACID CONTENT (% AS RECEIVED AND % OF CP) AND AVAILABILITY IN CANOLA EXPELLER MEAL*

Amino Acid	%	% of CP	Poultry apparent ileal digestibility %	Pig apparent ileal digestibility (%)
Methionine	0.70	1.98	78	86
Cystine	0.86	2.44	73.5	80
Met + cys	1.56	4.43	75	83
Lysine	1.97	5.59	78	74
Threonine	1.50	4.25	68.9	72
Tryptophan	0.49	1.37	78	77
Arginine	2.15	6.09	86.2	86
Isoleucine	1.39	3.92	71.6	77
Leucine	2.43	6.88	76.2	81
Valine	1.79	5.08	75.7	75
Histidine	0.95	2.68	83.5	83
Phenylalanine	1.41	3.99	81.1	81

*Spragg and Mailer, 2007

Table 12. AVAILABLE ENERGY VALUES FOR CANOLA EXPELLER MEAL (11% FAT, 12% MOISTURE BASIS)

Animal		Average value
Chickens*	AMEn (kcal/kg)	2340
Pigs**	DE (kcal/kg)	3320
Cattle***	TDN (%)	69.0
	DE (Mcal/kg)	3.44
	ME (Mcal/kg)	2.75
	NEM (Mcal/kg)	1.76
	NEG (Mcal/kg)	1.25
	NEL (Mcal/kg)	1.76

*Perez-Maldonado, 2003
***NRC, 2001 – please note these values are for a meal containing 5.4% fat and should be adjusted based on actual fat content
** Van Barneveld, 1998

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CANOLA MEAL IN POULTRY DIETS

Canola meal is used in all types of poultry feeds. However, because of its relatively low-energy value for poultry, it tends to be economically favoured in egg layer and turkey feeds rather than in high-energy broiler feeds. Also, some feed users have expressed biases against using canola meal in poultry feeds due to health and performance problems including hemorrhagic liver in egg layers, small egg size, leg problems in broilers, reduced feed intake and reduced growth rate. This negative view of canola meal is undeserved since virtually all of these problems can be eliminated, or at least managed effectively, once a few key points in the areas of amino acid digestibility, glucosinolate effects and dietary mineral balance are understood.

AMINO ACID AVAILABILITY

A key to using high levels of canola meal in poultry feeds is to balance the diets to digestible amino acid minimums. The digestibility of key essential amino acids is lower in canola meal than in soybean meal as shown in Table 1.

Table 1. **POULTRY TRUE DIGESTIBILITY COEFFICIENTS OF SOME KEY ESSENTIAL AMINO ACIDS IN CANOLA MEAL AND SOYBEAN MEAL**

Amino Acid	Canola meal digestibility (%)	Soybean meal digestibility (%)
Lysine*	0.79	0.90
Methionine*	0.92	0.93
Cystine**	0.82	0.82
Threonine*	0.71	0.81
Tryptophan***	0.78	0.84

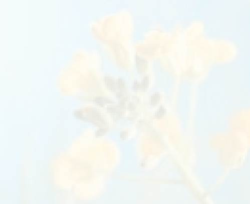
*Huang et al., 2006
**Nadeem et al., 2005
***Ravindran et al., 2006

These differences in amino acid digestibility can be significant in practical feed formulation and at high canola meal inclusion levels in feed, if not allowed for, could result in a 5-10% decrease in bird performance (growth rate). The issue of lower amino acid digestibility in canola meal compared to soybean meal is not as relevant today as it once was. Since the early 1990s most feed users around the world have been balancing diets on the basis of digestible rather than total amino acid levels.

ENZYMES

Several researchers have used dietary enzymes in attempts to increase protein, phosphorus and carbohydrate digestibility in canola meal (Kocher et al., 2000; Mandal et al., 2005; Meng et al., 2005; Meng and Slominski, 2005; Meng et al., 2006; Ravindran et al., 1999; Ramesh et al., 2006; Simbaya et al., 1996; Slominski and Campbell, 1990).

The addition of microbial phytase to diets to enhance phosphorus availability has become commonplace due to the high cost of phosphorus and environmental issues. Phytase has also been shown to enhance amino acid digestibility. Ravindran et al. (1999) observed an average 2% increase in amino acid digestibility in canola meal when supplemented with 1,200 unit/kg of phytase. Most studies examining the use of cellulase or NSP degrading enzymes to improve canola meal have failed to show significant improvements. Meng and Slominski (2005) examined the effects of adding a multi-enzyme complex (xylanase, glucanase, pectinase, cellulase, mannanase and galactonase) to broiler diets. The enzyme combination increased total tract NSP digestility of canola meal but no improvements were observed in nutrient digestibilities or animal performance. Practically, the use of dietary enzymes is very common in poultry feeds, especially those containing barley and wheat, but the benefit of using them in canola meal has not been clearly demonstrated at this point.

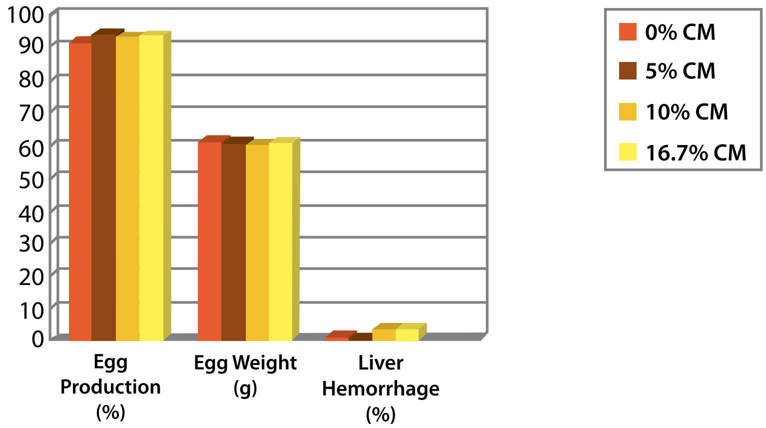


LAYERS

Canola meal is a commonly used and economically effective feed ingredient in commercial layer diets. Various studies have looked at the effects of canola meal on egg production and associated parameters (Perez-Maldonado and Barram, 2004; Kaminska, 2003; Badshah et al., 2001; Kiiskinen, 1989; Nasser et al.,1985; Robblee et al.,1986). Canola meal supports high levels of egg production and has no effect on the number of eggs produced. Feed intake and egg size also show no significant difference when canola meal is fed although in some cases there appears to be a small numerical decrease in both when canola meal is added to the diet. In particular a negative effect on egg size has been noted in some earlier studies (Summers et al., 1988a, b), but in more recent experiments this has not been the case (Perez-Maldonado and Barram, 2004; Marcu et al., 2005; Badshah et al., 2001, Classen 2008, unpublished data Figure 1).

There is one notable exception – Kaminska (2003) observed a linear decrease in egg weight but not production when canola meal was substituted for soybean meal. Closer scrutiny of this study reveals the diets were formulated on a crude protein basis and differences in amino acid content and availability were not accounted for when substituting canola meal for soybean meal. Total lysine content was 0.75% in the soybean control but only 0.72% in the canola meal treatments. It appears the reduction in egg weight in this study and the earlier studies was likely due to a marginal deficiency in essential amino acids, possibly lysine. Work by Novak et al. (2004) supports this hypothesis. They increased the lysine intake from 860 mg/d to 959 mg/d and observed a 59.0-60.2 g increase in egg weight but the added lysine had no effect on egg production rates. Based on these findings it would appear canola meal can be used effectively at elevated levels in laying diets without negatively affecting performance or egg weight as long as the diets are formulated on a digestible amino acid content. Figure 1 shows the results of a recent study conducted at the University of Saskatchewan indicating excellent performance while maintaining egg weight throughout the 40 weeks of the study.

Figure 1. **EFFECT OF FEEDING CANOLA MEAL (CM) TO LAYING HENS ON EGG PRODUCTION, EGG WEIGHT AND MORTALITY FROM LIVER HEMORRHAGE (AVERAGE OVER 40 WEEKS OF PRODUCTION- CLASSEN 2008, UNPUBLISHED DATA)**



Traditionally, including canola meal in laying hen diets was limited to a maximum of 10% due to a potential association between a low level of liver hemorrhage mortality and feeding canola meal (Butler et al., 1982; Campbell and Slominski, 1991). However, it appears this was the result of residual glucosinolates found in the initial varieties of canola (Campbell and Slominski, 1991). Plant breeding has steadily reduced the level of glucosinolates to the point where they are currently one-third of those found in the first canola varieties and used in these studies. More recent studies with current low glucosinolate varieties failed to observe statistically significant increases in liver hemorrhage even when as much as 17% canola meal is included in the diet (Classen 2008, unpublished data), although there was a small numerical increase (Figure 1).

An interesting effect of canola meal and rapeseed meal on brown-shelled layers is the incidence of fishy flavour in the eggs (Butler et al., 1982). Some brown-shelled layers apparently produce lower levels of trimethylamine oxidase than white leghorns. Therefore, trimethylamine cannot be oxidized

and instead passes into the yolk, imparting a fishy flavour. Canola and rapeseed are susceptible because they have higher levels of choline and sinapine (precursors of trimethylamine) than other ingredients. As well, goitrin and tannins inhibit the enzyme. Consequently, in North America, a limit of 3% canola meal or rapeseed meal should be used in brown-shelled layer diets. In some other countries, higher levels are used (5-10%) because high levels of fish meal have been historically used in feeds, and consumers do not find the eggs objectionable (Perez-Maldonado and Barram, 2004). Recently, researchers have made progress in identifying the genetic defect that leads to the production of tainted eggs and are striving toward elimination of this defect from the breeding population (Honkatukia et al., 2005; Classen, 2008, personal communication). It is conceivable that this may no longer be an issue within the next few years if poultry breeding programs successfully implement a process to screen out those carrying the defect.

BREEDING CHICKENS

Canola meal has no negative effect on egg fertility or hatchability for leghorn breeders (Kiiskinen, 1989; Nasser et al., 1985). The results of the first study are shown in Table 2. The average weight of the one-day-old chick decreased with increasing canola meal and the weight of the thyroid gland of one-week old chicks was higher with increasing canola meal levels. The decrease in chick weight did not result in impairment of productive function of the chicks during their subsequent egg production. A more recent study by Ahmadi et al. (2006) studied the effects of adding 0%,10%, 20% or 30% canola meal to the diet of broiler breeders. They concluded that canola meal can be used effectively in broiler breeder diets without affecting production, egg weight or chick quality. However, only the abstract is available in English so the paper was not reviewed in detail for this guide. Due to the potential effect on egg and chick weight and the lack of current studies on the use of canola meal in broiler breeder diets, many feed manufacturers do not use canola meal, or limit it to low inclusion levels in poultry breeder feeds.

Table 2. **EFFECT OF CANOLA MEAL IN BREEDER DIETS ON EGG FERTILITY AND HATCHABILITY AND CHICK QUALITY***

Measurement	Control	Canola 5%	Canola 10%
Egg production, %	79.5	79.8	80.3
Egg weight, g	58.9	58.2	57.7
Fertility, %	95.9	94.4	94.0
Hatchability, %	86.8	88.8	87.8
Live chicks/365 d	242	244	242
Chick weight, g	40.1	38.5	37.5
Thyroid wt, mg/100g BW	7.53	8.30	8.97

*Kiiskinen et al., 1989

POULTRY
PIGS
DAIRY & BEEF CATTLE
SPECIALTY

BROILER CHICKENS

The remaining low levels of glucosinolates in canola meal do not have any negative effects on broiler mortality or feed intake. Two recent studies have shown that canola meal can be effectively used in broiler diets up to 30% without negatively affecting performance as long as the diets are formulated on a digestible amino acid basis (Newkirk and Classen, 2002; Ramesh et al., 2006.). However, in Western Canada, canola meal is only used to a limited extent in broiler feeds. Normally, the lower energy in canola meal compared to other protein sources such as soybean meal economically limits its use in high-energy broiler feeds. In wheat-based and barley-based diets, canola meal is normally used at less than 10% due to its lower energy level. In corn-based feeds, the economical inclusion level of canola meal is higher.

It has been known for a long time that feeding rapeseed meal (high glucosinolate) to broilers can result in an elevated incidence of leg problems, especially tibial dischondroplasia. The leg problems have been alleviated somewhat, but not completely, by feeding canola meal. This indicates that

glucosinolates were partially, but not entirely, responsible. Summers et al. (1990, 1992) showed that the situation is related more to sulphur levels (a component of glucosinolates) rather than to the toxic effect of glucosinolates themselves. They noted that feeding organic sulphur, in the form of cystine, caused a higher incidence of leg problems. It is well known that sulphur interferes with calcium absorption. Supplementing the diet with extra calcium helps to a certain extent, but care is advised since too much dietary calcium will depress feed intake. Further work by Summers and Bedford (1994) showed that the problem is further complicated by the electrolyte balance, or more accurately the cation-anion balance in canola meal diets. Canola meal contains less potassium (1.2%) than soybean meal (1.9%), so that the electrolyte balance level is lower in a diet based on canola meal compared to soybean meal. Further, when total cation-anion balance is considered, the higher sulphur and phosphorus levels in canola meal result in an even lower positive balance of dietary cations. The authors showed that feed intake in broilers is positively correlated with cation-anion balance. This suggests that the commonly observed decrease in feed intake when including canola meal in broiler feeds is related to cation and anion levels in the diet. This further suggests that increasing levels of dietary cations will correct the problem. Attempts to do this by adding extra calcium carbonate have had marginal success, probably due to the feed intake depressing effects of calcium. Adding potassium bicarbonate to the diet likely would be preferable since this corrects the problem at its source.

'...feed intake in broilers is positively correlated with cation-anion balance.'

One final point of concern about feeding canola meal to broiler chickens is related to the processing of the chicken itself. Canola seed hulls are present in canola meal, and these concave particles have a tendency to stick to the inside of the digestive tract. If the gastro-intestinal tract is torn during processing, then the black canola hulls can stick to the carcass causing it to be downgraded. The common solution in industry is to exclude canola meal from the feed during the last five days before market. This is usually accomplished by not including canola meal in the coccidiostat withdrawal finisher feed.

TURKEYS

A study by Waibel et al. (1992) demonstrated that canola meal is an excellent protein source for growing turkeys. Indeed it is common commercial practice to feed high levels of canola meal to growing and finishing turkeys. The Waibel study illustrates the importance of balancing rations appropriately when substituting protein sources. When canola meal was added at 20% of the diet without maintaining equal energy and essential amino acid levels, growth and feed conversion efficiency was decreased. However, when extra animal fat was added and amino acid levels kept constant, performance was equal to or superior to the control diet. As with other species it is important that the diets are formulated on a digestible amino acid basis. The ileal digestibilities of the amino acids are shown in Table 3 on p.11. In some regions canola meal is often included in turkey diets at levels well beyond the 20% level. In this case it is important to ensure the dietary electrolyte balance of the final diet is in the appropriate range. The dietary electrolyte balance of canola meal (Na+K-Cl) is approximately 324 mEq/kg. However, canola meal contains a significant amount of sulfur and this should also be considered (Na+K – Cl-S = -193 mEq/kg).

DUCKS AND GEESE

Canola meal is commonly fed to ducks and geese and there are no issues in addition to feeding other types of poultry. In fact, geese have a greater digestive capability than other types of poultry and appear to digest canola meal more efficiently (Jamroz et al., 1992). The amino acid digestibility of canola meal in ducks is shown in Table 3 on p.11. Canola meal and soybean meal have similar digestibility in ducks (Kluth and Rodehutscord, 2006).

POULTRY
PIGS
DAIRY & BEEF CATTLE
SPECIALTY

CANOLA EXPELLER MEAL IN POULTRY RATIONS

Canola meal is an excellent source of protein for poultry but the energy content of solvent-extracted canola meal can limit its use in the diets of rapidly growing poultry. Due to the elevated oil content, canola expeller meal contains approximately 32% more energy than solvent-extracted meal (Table 12, p.17) and can be used as the sole source of protein in the diet without adding additional fat to the diet. Expeller meal also contains high levels of the essential fatty acid, linoleic acid, thus meeting the requirements of the bird without additional supplemental fat. Canola expeller meal can also be used as an effective protein source for turkeys. Palander et al. (2004) studied the effects of feeding canola expeller meal in growing turkeys on protein digestibility and found similar digestibility coefficients as standard pre-pressed solvent extracted meal. Fat content of the meal does vary between sources so the product should be routinely tested and the energy value adjusted accordingly. The AMEn of the meal can be estimated using the equation 1800 + (% fat * 80) = kcal/kg. For example a meal with 10% fat would have an approximate AMEn of 1800 + (10*80) = 2600 kcal/kg.

> **'Canola meal is an excellent source of protein for poultry but the energy content of solvent-extracted canola meal can limit its use in the diets of rapidly growing poultry.'**

FEEDING CANOLA SEED AND OIL

Canola oil is routinely fed as an energy source for broiler chickens. In addition to its energy value, it is a good source of linoleic acid. Broiler starter diets that are based on barley or wheat instead of corn can be deficient in linoleic acid especially when the other dietary fat sources are saturated, such as tallow for example. In these situations, it is common to add 1.0-1.5% canola oil to the diet. Full-fat canola, after heat treatment and particle size reduction, is a mainstay protein and energy ingredient in broiler feeds in some countries like Denmark.

CANOLA MEAL MAXIMUM INCLUSION LEVELS

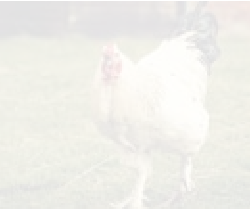
The recommended maximum inclusion levels and the reasons for limiting canola meal usage in poultry diets are listed in Table 3. These are cautious recommendations, but based on appropriate feed formulation techniques, accounting for amino acid digestibility and cation-anion balance. Higher canola meal inclusion levels may be warranted if economically attractive.

Table 3. **RECOMMENDED MAXIMUM INCLUSION LEVELS (%) OF CANOLA MEAL IN POULTRY DIETS**

Animal diet type	Maximum inclusion level	Reasons for maximum inclusion level
Chick starter	10	-
Broiler grower	20	Energy level
Turkey grower	30	-
Egg layer	10	Potential effects on mortality
Breeder	5	Smaller egg size and chick weight
Duck and goose	15	-

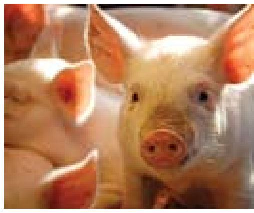
POULTRY
PIGS
DAIRY & BEEF CATTLE
SPECIALTY

CANOLA MEAL IN PIG DIETS



INTRODUCTION

The breeding of canola from rapeseed has made canola meal a conventional feedstuff for swine, especially for grower-finisher pigs. The breeding efforts in canola to reduce the concentrations of the main anti-nutritional factors glucosinolates and euricic acid were groundbreaking. These efforts produced canola meal with an enhanced nutritional value in comparison to rapeseed meal. Canola meal is better accepted by swine than rapeseed meal, but some constraints in the digestible nutrient profile of canola meal remain, especially for energy. Therefore, canola meal is currently included in swine diets mainly to provide amino acids.



The adoption of more accurate feed quality evaluation systems for energy and amino acids in North America will offset unexpected performance reduction associated with canola meal in the past. Specifically, amino acids should be characterized as standardized or true ileal digestible amino acids (Stein et al., 2007). Furthermore, the net energy system characterizes more accurately the energy value of canola meal relative to other feedstuffs. Implementation of the NE system appears critical for effective use of co-products such as canola meal in swine diets (Noblet et al., 1993), although canola meal has been introduced successfully in swine diets using the DE and ME systems for valuation of dietary energy. Restrictions for inclusion levels of canola meal will remain to ensure that reductions in voluntary feed intake do not occur.

Depending on the ratio between price and nutritional value, the inclusion of canola meal into swine diets will vary. The nutritional value of canola meal for swine is understood reasonably well, and the major limitation for value and inclusion of canola meal in swine diets is the available energy content, especially when measured as net energy.

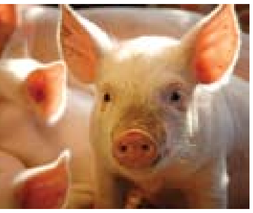
Canola meal is a cost-effective ingredient in pig diets around the world. Recent reports from Australia, Germany, and South Africa indicate that branding canola meal has been successful and that the term 'canola meal' has become common worldwide (Brand et al., 2001; Mullan et al., 2000; Roth-Maier, 2004). In some countries, however, restrictions on the use of canola meal remain due to a lack of understanding of the differences between rapeseed meal and canola meal. Rapeseed meal continues to have a high glucosinolate content and has valid toxicity and palatability concerns, whereas canola meal has a low glucosinolate content and is not toxic. Improper feed quality evaluation information for digestible nutrient for canola meal has resulted in some problems with poorer pig performance in the past. Current data clearly show that diets containing canola meal, when properly formulated, will support high levels of efficient growth performance.

AMINO ACID DIGESTIBILITY

A key to using high levels of canola meal in swine diets is to balance the diets correctly for digestible amino acids. Furthermore, crude protein and moisture content of canola meal should be monitored. Recent experiments have suggested clearly that amino acids in swine diets should be formulated on the basis of true or standardized amino acid digestibility (Nyachoti et al., 1997). The digestibility of key essential amino acids is lower in canola meal than in soybean meal [National Research Council (NRC), 1998].

Swine diets must be formulated for digestible amino acids. When canola meal replaces soybean meal in the diet, the overall levels of digestible amino acids, especially lysine and threonine, will decrease if the diet is balanced to total amino acid levels. Presently swine diets are routinely formulated to levels of digestible amino acids rather than total amino acids. Diets in earlier feeding trials with canola meal were balanced to the same levels of crude protein, total essential amino acids and energy. However, a lower pig growth rate compared to soybean meal-fed pigs was observed (Baidoo et al., 1987; Bell et al., 1988; Bell et al., 1991; McIntosh et al., 1986), because levels of digestible lysine decreased as canola meal inclusion level in the diets increased. Since then, feeding trials with canola meal in grower-finisher pigs, where the diets were balanced to the same levels of digestible lysine, (Hickling, 1994; Hickling, 1996; King et al., 2001; Mateo et al., 1998; Mullan et al., 2000; Patience et al., 1996; Raj et al., 2000; Robertson et al., 2000; Roth-Maier, 2004; Siljander-Rasi et al., 1996) resulted in a growth rate equivalent to soybean meal, even at very high inclusion levels of canola meal.

GLUCOSINOLATE TOLERANCE



Glucosinolates are a main anti-nutritional factor for swine. During the development of canola meal, the maximum level of glucosinolates that pigs can tolerate in the diet was defined by several researchers. In a review of earlier research on canola meal, a maximum level in pig diets of 2.5 µmol/g of glucosinolates was suggested (Bell, 1993). Two subsequent studies generally supported this recommendation (Schone et al., 1997a, 1997b). In the first study, growing pigs weighing approximately 20-50 kg were fed a variety of diets containing the same levels of canola meal, but varying in total glucosinolate content from 0-19 µmol/g (Schone et al., 1997a). A greater level than 2.4 µmol/g of glucosinolates in the diet had negative effects on feed intake, growth rate and thyroid function. In the second study, the maximum safe glucosinolate level was determined at 2.0 µmol/g of diet (Schone et al., 1997b). Given that Canadian canola meal contains on average 6 µmol/g of glucosinolates, this would correspond to a maximum canola meal inclusion level of 33% in growing pig diets. Recent studies have demonstrated grower-finisher pigs will perform well on diets containing up to 25% canola meal (Brand et al., 2001), which would result in a dietary glucosinolate content of approximately 1.5-2 µmol/g. The glucosinolate of canola meal and thus diets containing canola meal varies. A recent study with diets containing 26% canola meal measured 2.2 µmol/g of glucosinolates. The maximum tolerable level of glucosinolate in swine diets remains of interest, and breeding efforts in canola should remain focused on a further reduction ensuring that glucosinolates are not a limiting factor to achieve inclusion levels of canola meal higher than 25%.

'Recent studies have demonstrated grower-finisher pigs will perform well on diets containing up to 25% canola meal...'

FEED INTAKE

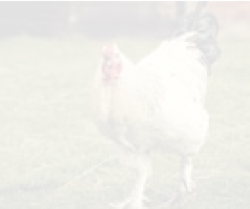
The effect of a feed ingredient on feed intake of pigs is difficult to objectively evaluate given the many factors involved (Nyachoti et al., 2004). Variables such as basic palatability of the ingredient, dietary inclusion level, other ingredients in the feed mix, feed energy and fibre content (bulk density), and feed mineral balance will influence feed intake. For canola meal, several factors with the potential to negatively influence feed intake exist such as glucosinolates, tannins, sinapine, fibre, and mineral balance. Certainly the major negative influence of high glucosinolate rapeseed meal on feed intake is glucosinolates. Aside from their anti-nutritive effects, glucosinolates have a bitter taste to many animals. Canola meal, with its very low levels of glucosinolates, has a more neutral taste. Other causes than glucosinolates likely play a role in situations (baby pigs, for example) where reduced feed intake of canola meal diets is observed.

STARTING PIGS (6-20 KG)

For starting pigs, limit dietary levels of canola meal. Live weight performance of young pigs tends to decrease as dietary levels of canola meal increase. The reduced performance of young pigs is likely due to fibre levels and the presence of tannins, sinapine and (perhaps) glucosinolates in the meal (Bourdon and Aumaître, 1990; Lee and Hill, 1983). Generally, producers resist the extensive use of canola meal in pig starter diets up to 20 kg bodyweight, but like to introduce canola meal at levels up to 5% in the later stages of the starter period to facilitate transition to diets containing higher levels of canola meal.

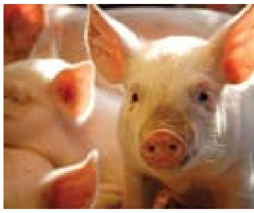
GROWING AND FINISHING PIGS (20-100 KG)

In the growing and finishing phases of pig growth, canola meal can be used at high dietary levels and will support excellent pig performance. An array of studies have shown that when diets are balanced for digestible amino acid levels, performance is the same as with soybean meal with dietary inclusion levels of canola meal up to 25% (Brand et al., 2001; Hickling, 1994; Hickling, 1996; King et al., 2001; Mateo et al., 1998; Patience et al., 1996; Raj et al., 2000; Robertson et al., 2000; Siljander-Rasi et al., 1996;



Roth-Maier, 2004). Two of these studies are presented in detail. The Canola Council of Canada sponsored a series of feeding trials with growing and finishing pigs in Canada, Mexico, and the Philippines to demonstrate that balancing the diets to digestible amino acids will improve pig performance results.

CANADIAN FEEDING TRIALS



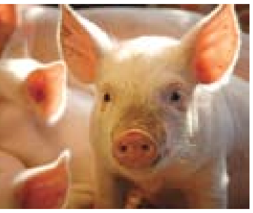
Three feeding trials were conducted in Western Canada – one each in Manitoba, Saskatchewan and Alberta. The trials were conducted at different times of the year and with different genetics of pigs. The overall diet compositions were similar among the three locations. The diets were balanced to digestible lysine and threonine minimums, which were considered to be the first and second limiting amino acids (the diets were balanced to ideal protein amino acid composition). Supplemental lysine HCl was used to meet digestible lysine minimums. The digestible threonine minimums were met from higher natural sources in the diet – the level of crude protein increased in the canola meal treatment diets. The diets were isocaloric, achieved by increasing the amount of wheat relative to barley in the canola meal treatment diets. The diet composition and combined results of the feed trials are shown in Table 1 (Hickling, 1994). Pig performance was equivalent, both numerically and statistically, for all three diets. Contrary to popular belief, there was no decrease in feed intake with increasing canola meal levels in the diet. There was no difference in the quality of the pig carcasses as measured by dressing percentage and backfat index.

Table 1. **CANADIAN FEEDING TRIAL RESULTS – AVERAGE PERFORMANCE OF GROWING PIGS (20-60 KG) AND FINISHING PIGS (60-100 KG) FED DIETS SUPPLEMENTED WITH SOYBEAN MEAL (SBM) AND CANOLA MEAL (CM) (HICKLING, 1994)**

		Grower			Finisher	
Ingredients	SBM	MED CM	Hi CM	SBM	MED CM	Hi CM
Barley	62	53	48	60	48	40
Wheat	13	20	24	19	29	35
Soybean meal	20	16	13	16	10	5
Canola meal	-	6	10	-	8	15
Canola oil	1	1	1	1	1	1
L-lysine	.04	.07	.10	.06	.12	.15
Other	4	4	4	4	4	4
Nutrients						
Crude protein (%)	17.6	17.8	17.9	16.4	16.5	16.6
DE (kcal/kg)	3200	3200	3200	3200	3200	3200
Total lysine (%)	.94	.94	.95	.81	.82	.83
Digest. lysine (%)	.75	.75	.75	.65	.65	.65
Total met + cys (%)	.61	.64	.66	.54	.59	.63
Digest. met + cys (%)	.49	.52	.54	.43	.48	.51
Total thr (%)	.66	.66	.67	.56	.58	.59
Digest. thr (%)	.47	.47	.47	.40	.40	.40
Performance						
Avg daily feed, kg	1.905	1.928	1.887	3.061	3.113	3.083
Avg daily gain, kg	.456	.765	.767	.841	.830	.822
Feed/gain ratio	2.52	2.52	2.46	3.64	3.75	3.75

Total Period (20-100 KG)	SBM	Med CM	Hi CM
Avg daily feed, kg	2.461	2.498	2.465
Avg daily gain, kg	.799	.798	.795
Feed/gain ratio	3.08	3.13	3.10
Dressing (%)	78	78	78
Carcass backfat index	107	107	107

POULTRY
PIGS
DAIRY & BEEF CATTLE
SPECIALTY



MEXICAN FEEDING TRIALS

Three feeding trials were conducted in three Mexican states – Nuevo Leon, Sonora and Michoacan (Hickling, 1996). The objective was to duplicate the performance found in the Canadian feeding trials, but using Mexican ingredients (two of the feed trials used sorghum as the grain base in the diet and one trial used corn) and Mexican conditions (environment, pig genetics and management). Also, the canola meal used in the trials was produced from Canadian canola seed by Mexican oilseed crushers. The design was very similar to the Canadian trials. Three dietary treatments were used – a control, a medium canola meal diet and a high canola meal diet. The diets were balanced for minimum digestible amino acids, ideal protein and equal energy levels. The diets and results are shown in Table 2. As with the Canadian results, equivalent growth, feed efficiency and carcass quality performance was observed on all three dietary treatments. Performance between locations varied due mainly to pig genetics and seasonal effects.

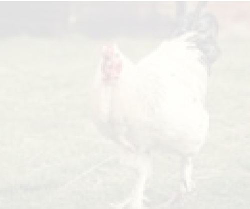
Table 2. **MEXICAN FEEDING TRIAL RESULTS: AVERAGE PERFORMANCE OF GROWING PIGS (20- 60 KG) AND FINISHING PIGS (60-100 KG) FED DIETS SUPPLEMENTED WITH SOYBEAN MEAL (SBM) AND CANOLA MEAL (CM) (HICKLING, 1996)**

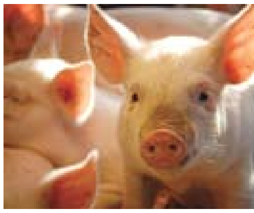
	Grower						Finisher					
Ingredients	SBM		MED CM		Hi CM		SBM		MED CM		Hi CM	
Sorghum	72	-	68	-	667	-	76	-	72	-	70	-
Corn	-	72	-	67	-	66	-	76	-	72	-	70
Soybean meal	24	24	19	20	16	17	20	19	13	12	10	9
Canola meal	-	-	8	8	12	12	-	-	10	10	15	15
Tallow	-	-	1	1	2	1	-	-	1	1	2	1
L-lysine	-	-	.33	-	.47	-	-	-	.50	.50	.70	.70
Other	4	4	4	4	4	4	4	5	4	5	3	5

Nutrients						
Crude protein (%)	17.6	17.7	17.9	16.0	16.2	16.4
DE (kcal/kg)	3150	3150	3150	3160	3160	3160
Total lysine (%)	.92	.93	.94	.81	.82	.83
Digest. lysine (%)	.75	.75	.75	.65	.65	.65
Total met + cys (%)	.58	.63	.65	.55	.58	.61
Digest. met + cys (%)	.45	.47	.49	.41	.44	.46
Total thr (%)	.71	.71	.72	.63	.63	.64
Digest. thr (%)	.53	.53	.53	.47	.47	.47

Performance						
Avg daily feed, kg	2.17	2.23	2.18	3.22	3.21	3.12
Avg daily gain, kg	.778	.773	.764	.851	.833	.824
Feed/gain ratio	2.78	2.87	2.86	3.79	3.85	3.79

Tot. Period (20-100 KG)	SBM	Med CM	Hi CM
Avg daily feed, kg	2.72	2.74	2.67
Avg daily gain, kg	.818	.807	.797
Feed/gain ratio	3.32	3.39	3.35
Meat yield, %	48.6	48.8	49.3
Carcass backfat, cm	2.38	2.33	2.15





BREEDING SWINE

Canola meal has been readily accepted in diets for sows and gilts both in gestating and lactating periods. Flipot and Dufour (1977) found no difference in reproductive performance between sows fed diets with or without 10% added canola meal. Lee et al. (1985) found no significant difference in reproductive performance of gilts through one litter. Studies at the University of Alberta (Lewis et al., 1978) have shown no difference in reproductive performance of gilts through two reproductive cycles when fed diets containing up to 12% canola meal. Recently, levels of 20% canola meal did not affect performance of lactating sows (King et al., 2001). The results suggest that canola meal may represent the main supplemental protein source in gilt and sow diets for all phases of reproduction. Canola meal may be restricted in sow diets that are formulated to maximum fibre levels in order to limit hind gut fermentation. For the most part, producers are now accepting canola meal as an appropriate alternative supplemental dietary protein source for sows. There is, however, still some unfounded concern over daily feed intake of nursing sows fed canola meal-based diets. These concerns are not supported by research.

FEEDING CANOLA EXPELLER MEAL

Canola expeller meal is an excellent source of energy and protein in swine rations. Brand et al. (2001) studied the effects of adding canola expeller cake in the grower finisher rations. The diets were comprised of as much as 29.2% expeller meal and found no effects on feed intake, feed conversion or live weight gain, indicating the meal is an effective ingredient. In Manitoba, Canada, a double press plant processes approximately 1000 T/day of canola and the resulting meal is used widely as a protein source for all species of animals but is very commonly used in the swine rations in the region, in many cases completely replacing soybean in the diet. As is the case with other species it is important to have the fat content of the meal analyzed prior to formulation and the energy content assigned accordingly.

Fat content of expeller meal varies between and within sources so the product should be routinely tested and the energy value adjusted accordingly. The energy content of the meal in kcal/kg can be calculated as DE= 2464 + (% fat * 63), ME = 2237 + (% fat * 62) and NE= be calculated using the following equation 1800 + (% fat * 70) = kcal/kg. For example, a meal with 10% fat would have an NE of 1800 + (10*70) = 2500 kcal/kg.

FEEDING CANOLA SEED AND OIL

Canola oil is routinely fed to all types of pigs. Crude canola oil is often an economical energy source as well as a dust suppressant in the feed. Canola seed is also fed as a protein and energy source although it is usually limited to 10% dietary inclusion since higher levels will result in softer fat in the carcass (Kracht et al., 1996). Canola seed should be ground before feeding. It can effectively be fed raw, although heat treatment may prove beneficial as long as excessive heat is not used during processing, which will reduce amino acid digestibility.

CANOLA MEAL MAXIMUM INCLUSION LEVELS

The recommended maximum inclusion levels for canola meal in pig diets, together with the reasons, are given in Table 3.

Table 3. **RECOMMENDED MAXIMUM INCLUSION LEVELS (%) OF CANOLA MEAL IN PIG DIETS**

Animal diet type	Max inclusion level	Reasons for maximum inclusion level
Pig starter	5	Palatability
Hog grower/finisher	No Limit	-
Sow lactation	15	Reduce hind gut fermentation
Sow gestation	No limit	-

POULTRY
PIGS
DAIRY & BEEF CATTLE
SPECIALTY

CANOLA MEAL IN CATTLE DIETS

Canola meal is widely used in feeds for beef and dairy cattle, and is considered to be a premium ingredient due to its high palatability and the high quality of its protein for milk production.

PALATABILITY

Canola meal is a highly palatable source of protein for ruminant animals. Spörndly and Åsberg, (2006) examined the relative palatability of common protein sources by comparing eating rate and preference in heifers. When fed a mash diet, heifers consumed 221g of canola meal in the first three minutes while those fed soybean meal only consumed 96 g, demonstrating the highly palatable nature of canola meal. The reasons for the high degree of palatability are not known but may be related to the high sucrose content.

> **'Canola meal is a highly palatable source of protein for ruminant animals.'**

When feeding canola meal it is important to ensure the meal is derived from modern low glucosinolate varieties. Some regions such as China and India still produce rapeseed and mustard with relatively high levels of glucosinolates which can reduce feed intake. Ravichandiran et al. (2008) examined the impact of feeding rapeseed or mustard meals with varying levels of residual glucosinolates to five-month-old calves. Calves receiving a concentrate containing low glucosinolate canola meal (<20 umol/g) consumed the same quantity as the control without canola meal (1.10 vs 1.08 kg, respectively). However, calves fed a concentrate containing high glucosinolate mustard meal (>100 umol/g) only consumed 0.76 kg.

RUMEN DEGRADABILITY

The rumen degradability of canola meal protein has been studied extensively. Table 1 provides a summary of the effective degradability of the dry matter and crude protein fractions of canola meal assuming a rumen turn-over rate of 5% per hour. Ha and Kennelly (1984) reported that the effective degradability of canola meal protein was 65.8%. Effective degradabilities of soybean meal and dehydrated alfalfa were 53.6% and 41.4%, respectively. Kendall et al. (1991) found that the effective degradability of canola meal averaged 51.5%, compared to 59.1% for soybean meal. Woods et al. (2003) reported that the effective degradability of canola meal protein was 66.8% while cottonseed meal was 73.7%, soybean meal, 73.8%; and corn gluten, 73.4%. Piepenbrink and Schingoethe (1998) reported a rumen degradability of canola meal of 53.1%. Cheng et al. (1993) reported that the effective degradability of canola meal was 62.5% with concentrate diets and 72-74% with hay or straw diets. Increasing the ruminal turnover rate from 2-5% and 10%/hour reduced effective degradability from 79.3-65.2% and 56.9% (Sadeghi and Shawrang, 2006). Therefore, it is important when evaluating such results for ration formulation purposes to consider the type of diet into which the protein supplement is to be incorporated.

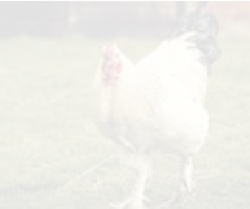
Research at the University of Manitoba has focused on the digestibility of the amino acids present in canola meal. Kendall et al. (1991) noted that following 12 hours of rumen incubation, total tract digestibilities of amino acids present in canola meal approached 85% or greater. Considerable variation was noted between samples and between amino acids in the proportion degraded ruminally or absorbed postruminally. Boila and Ingalls (1992) reported that the amino acid profile of canola meal protein that bypasses the rumen was superior in valine, isoleucine, threonine, phenylalanine, serine, aspartate and alanine, relative to unincubated meal. The magnitude of the enrichment in the bypass fraction ranged from 14-33%. The results, in combination with the data presented in Table 1, suggest that a sizable but variable fraction of the protein of canola meal bypasses the rumen. In light of the enriched amino acid content of the bypass fraction observed by Boila and Ingalls (1992), it would appear that canola meal provides an important contribution to both rumen microbial protein needs and to the digestible amino acids required for animal growth and lactation.

Table 1. SUMMARY OF THE EFFECTIVE RUMEN DEGRADABILITY OF CANOLA MEAL DRY MATTER AND PROTEIN FRACTIONS (RUMEN OUTFLOW RATE 5% PER HOUR)

	Effective rumen degradability (%)	
	Dry matter	Crude protein
Ha and Kennelly (1984)		
Trial 1	57.1	68.5
Trial 2	57.7	65.5
Kirkpatrick and Kennelly (1987)		
Trial 1	63.0	63.2
Trial 2	64.2	72.0
Kendall et al. (1991)	53.5	51.5
Cheng et al. (1993)		
Trial 1 (Hay diet)	-	74.9
Trial 2 (Straw diet)	-	72.3
Trial 3 (Grain diet)	-	62.5
Piepenbrink and Schingoethe (1998)	65.1	53.1
Woods et al. (2003)	60.5	66.7
Sadeghi and Shawrang (2006)		
2%/hr passage rate	78.1	79.3
5%/hr passage rate	66.5	65.2
10%/hr passage rate	59.5	56.9

USING CANOLA MEAL IN DAIRY RATIONS

Canola meal is an excellent protein supplement for lactating dairy cows. In a summary of 24 research trials with canola meal (Table 2), the mean milk production response was +1.0 kg/d when compared to diets containing cottonseed meal or soybean meal. Recent research with cows producing ≥40 kg/d (Brito and Broderick, 2007) clearly indicates that, even at high levels of production, canola meal is still a superior protein supplement when compared with soybean meal or cottonseed meal.



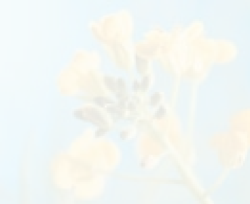


Table 2. **MILK PRODUCTION OF COWS FED CANOLA MEAL COMPARED TO SOYBEAN MEAL OR COTTONSEED MEAL**

	Milk yield (kg/day)	
	Control	Canola
Ingalls and Sharma (1975)	23.0	23.7
Fisher and Walsh (1976)	24.4	23.0
Laarveld and Christensen (1976)	24.9	26.4
Sharma et al. (1977)	20.7	20.9
Sharma et al. (1977)	21.5	21.8
Papas et al. (1978)	24.3	25.2
Papas et al. (1978)	23.9	24.6
Papas et al. (1979)	21.8	22.2
Laarveld et al. (1981)	26.4	27.7
Sanchez and Claypool (1983)	33.4	37.7
DePeters and Bath (1986)	39.8	41.4
Vincent and Hill (1988)	28.5	28.6
Vincent et al. (1990)	25.1	26.7
McLean and Laarveld (1991)	28.9	30.7
MacLeod (1991)	17.2	16.9
Emmanuelson et al. (1993)	21.0	21.9
Dewhurst et al. (1999)	24.0	24.5
Dewhurst et al. (1999)	23.7	25.5
Whales et al. (2000)	21.8	22.3
White et al. (2004)*	21.7	22.7
Maesoomi et al. (2006)	27.0	28.0
Johansson and Nadeau (2006)**	35.4	38.4
Brito and Broderick (2007)	40.0	41.1
Mulrooney et al. (2008)***	34.3	35.2
Average milk yield	**26.4**[a]	**27.4**[b]

*Ruminal protected canola meal vs lupin
**Canola expeller meal vs commercial concentrate
***Canola meal vs DDGS
[a,b] Students T test P<0.0001

AMINO ACID PROFILE OF CANOLA MEAL FOR MILK PRODUCTION

The amino acid content of rumen microbes, canola meal, soybean meal, corn gluten meal, cottonseed meal and sunflower meal expressed as a percentage of the amino acid composition of milk protein are shown in Table 3. Canola meal is an excellent source of histidine, methionine, cystine and threonine. The abundance of these amino acids and the extent to which they supplement amino acids from other protein sources may, in part, explain the consistent milk yield response found when canola meal is included in dairy cow rations. Of all the protein sources listed in Table 3, canola meal has the best amino acid balance, as indicated by the relatively high level of its first limiting amino acid.

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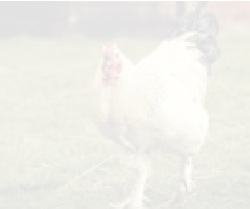


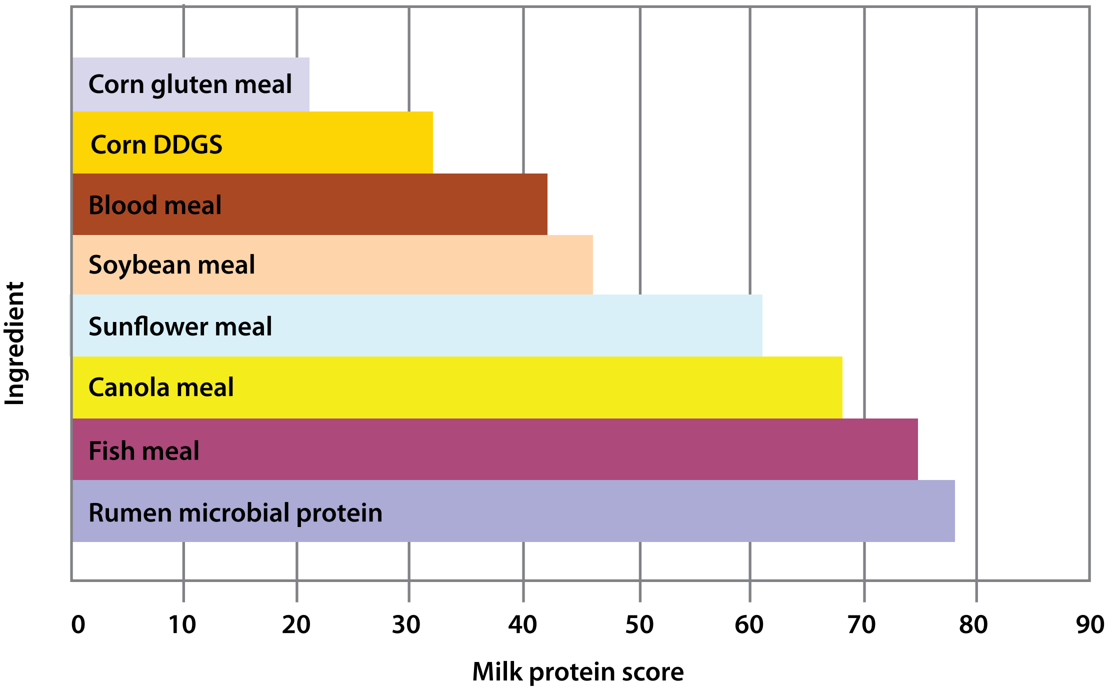
Table 3. **INGREDIENT AND RUMEN MICROBE AMINO ACID COMPOSITION COMPARED TO MILK PROTEIN* (THE FIRST LIMITING AMINO ACID IN EACH PROTEIN SOURCE IS HIGHLIGHTED)**

	Amino acid as percent of milk protein							
	Milk % EAA	Rumen microbe	Canola meal	Soybean meal	Corn gluten meal	Cottenseed meal	Sunflower meal	Corn DDGS
Arg	7.2	139	197	225	99	361	288	149
His	5.5	**73**	138	111	85	120	113	120
Ile	11.4	107	83	89	80	64	87	86
Leu	19.5	81	**82**	88	190	71	133	130
Lys	16.0	119	84	87	**23**	**61**	**50**	37
Met	5.5	84	95	**58**	95	67	102	87
Phe	10.0	104	103	116	141	125	110	**34**
Thr	8.9	121	113	98	84	85	98	102
Trp	3.0	90	115	93	40	93	97	77
Valine	13.0	85	88	78	79	77	90	96

*NRC, 2001

Another commonly used measure of protein quality for dairy cattle is "milk protein score" which relates the amino acid composition of protein sources compared to the amino acid composition of milk protein. The milk protein score of common ingredients – as calculated by Schingoethe (1991) for a corn, corn silage and alfalfa based diet – is shown in Figure 1. Canola meal has the highest score of all the supplemental protein sources (except fish meal).

Figure 1. **MILK PROTEIN SCORE OF COMMON FEED INGREDIENTS FOR DAIRY CATTLE (SCHINGOETHE, 1991)**



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CANOLA MEAL CONTRIBUTION TO MICROBIAL PROTEIN PRODUCTION

Canola meal optimizes the amount of absorbable amino acids for lactating dairy cows by providing adequate amounts of rumen-degradable protein (RDP) that stimulates microbial protein production in the rumen. Microbial protein is a high-quality protein that accounts for as much as 60% of a dairy cow's metabolizable protein requirements for milk synthesis. The high rumen protein degradability of canola meal efficiently provides ammonia, amino acids and peptides, which are essential growth factors for rumen bacteria that can be readily incorporated into microbial protein. A comparative study investigating canola meal, cottonseed meal and soybean meal as protein supplements for high-producing dairy cows demonstrated numerically higher post-rumen flow of microbial protein in cows fed canola meal compared to those fed cottonseed meal and soybean meal (Brito et al., 2007).

CANOLA RUMEN UNDEGRADABLE PROTEIN

The rumen-undegradable protein (RUP; bypass protein) fraction in canola meal contains a profile of essential amino acids that closely matches that of milk protein. Recent trials with lactating dairy cows demonstrated that cottonseed meal > canola meal > soybean meal in post-rumen flow of RUP and total protein and canola meal > soybean meal > cottonseed meal in milk and milk protein yields (Brito and Broderick, 2007; Brito et al., 2007). Improved milk production that is observed with canola meal is attributed to the amino acid profile in the bypass fraction of canola meal being complementary to microbial protein (Brito et al., 2007). The post-rumen supply of total amino acids, essential amino acids, branched-chain amino acids, and limiting amino acids (methionine, lysine, histidine, and threonine) when canola meal is used as a protein supplement is numerically higher or at least comparable to that when diets are supplemented with soybean meal or cottonseed meal (Brito et al., 2007). Unequivocal research data indicates that when it is used to supplement dairy cow diets, canola meal can meet the RDP and RUP requirements of dairy cows, which is reflected by the increase in milk production.

> **'Unequivocal research data indicates that when it is used to supplement dairy cow diets, canola meal can meet the RDP and RUP requirements of dairy cows, which is reflected by the increase in milk production.'**

USING CANOLA MEAL IN COMBINATION WITH DISTILLERS DRIED GRAINS

The recent surge in production of ethanol has resulted in large quantities of distillers dried grains with solubles (DDGS) becoming widely available to the feed industry. Used as both a source of energy and protein, it typically replaces part of the corn and soybean meal in the diet. Amino acid composition of DDGS (Table 4) is very similar to that of the grain from which the product was derived, usually corn, wheat or sorghum, and is therefore deficient in key amino acids such as lysine. Studies have shown that canola meal can be effectively used in combination with DDGS to restore amino acid balance and maximize animal performance. Mulrooney et al. (2008) examined the potential to use canola meal in combination with distillers dried grains in the rations of lactating dairy cows. Diets containing 3.24% DDGS and 4.6% canola meal tended to produce the highest level of milk production (Table 5).

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PIGS
DAIRY & BEEF CATTLE
SPECIALTY

Table 4. **NUTRITIONAL COMPOSITION OF CANOLA MEAL AND DISTILLERS DRIED GRAINS**

Amino Acid	Canola meal	Corn distillers dried grains with solubles[1]	Wheat distillers dried grains with solubles[2]
CP (% as fed)	36	28.5	34
Ether extract (%)[2]	3.5	9.5	2.7
Acid detergent fibre (%)	16.8	17.5	13.5
Neutral detergent fibre (%)	20.7	44.0	39.5
Amino acid (% of CP)			
Methionine	2.06	2.1	1.9
Cystine	2.39	1.1	2.4
Met + cys	4.45	3.2	4.2
Lysine	5.56	2.5	3.1
Threonine	4.39	3.3	3.4
Tryptophan	1.33	0.7	1.5
Arginine	5.78	3.7	4.5
Isoleucine	4.33	5.3	3.3
Leucine	7.06	7.8	4.7
Valine	5.47	5.7	3.6
Histidine	3.11	2.5	2.0
Phenylalanine	3.83	5.29	4.7

[1] Distillers Grains Technology Council www.distillersgrains.org
[2] Zijlstra et al., 2003

Table 5. **EFFECT OF USING CANOLA MEAL IN COMBINATION WITH DDGS ON MILK PRODUCTION**

Diet	DDGS (% of DM)	Canola meal (% of DM)	Milk production (kg/d)	Dry matter intake(kg/d)
1	10.41	0	34.31	25.10
2	6.69	2.35	34.51	25.94
3	3.24	4.60	35.84	25.41
4	0	6.63	35.18	25.24

BEEF CATTLE

Canola meal has gained widespread acceptance as a protein supplement for beef cattle. This acceptance is based in part on increasing producer experience with the product and from a number of research trials that demonstrate the value of canola meal for promoting the growth of young calves, and growing and finishing cattle.

CANOLA MEAL FOR BEEF COWS

Canola meal can be used to supplement protein in gestating or lactating cows. Patterson et al. (1999) examined the potential to use sunflower meal or canola meal as a protein supplement for beef cows being grazed on low protein winter native pasture. Canola meal resulted in similar body condition score, calf birth weight and calf weaning weights as the sunflower meal supplemented control.




CANOLA MEAL FOR CALVES

Weaned calves have been shown to perform very effectively when canola meal is used as the protein supplement. Claypool et al. (1985) found that 45-day-old Holstein calves gained at rates of 0.6-0.9 kg per day when offered a canola meal-based starter ration during a seven-week pre-weaning and eight-week post-weaning period, respectively. Performance of calves fed canola meal was similar to those fed cottonseed or soybean meal based starter rations. In British studies, no adverse influence of canola meal was observed on feed intake of 160-kg calves relative to soybean meal supplemented animals (Hill et al., 1990).

CANOLA MEAL FOR GROWING AND FINISHING CATTLE

Most studies that have looked at canola meal supplementation of feedlot diets for cattle have not been iso-nitrogenous. The usual performance response observed with canola meal supplementation can often be attributed to the extra protein rather than the source of protein. Petit and Veira (1994) did show that canola meal resulted in increased average daily weight gain in crossbred steers (approx. 225 kg body weight) when protein levels were constant. Koenig and Beauchemin (2005) examined the efficacy of canola meal in corn-based feedlot rations. Canola meal resulted in similar weight gain as the iso-nitrogenous control (1.48kg/d vs 1.40kg/d, respectively). However, canola meal supplementation of the low protein diet increased weight gain from 1.29-1.48kg/d as would be expected. Generally, there are no issues with regard to feeding canola meal to beef cattle.

> **'Generally, there are no issues with regard to feeding canola meal to beef cattle.'**

FEEDING CANOLA EXPELLER MEAL

There is limited research available regarding the use of canola expeller meal in ruminant diets. The nutritional value is similar to that of solvent-extracted meal except for the higher energy values and potentially lower effective rumen degradability. Table 6 compares the effects on milk production of feeding canola meal, canola expeller meal or heated canola expeller meal in research that was conducted at the University of Saskatchewan. Results indicate that the inclusion of canola expeller meal in diets for lactating dairy cows results in similar levels of milk production (Beaulieu et al., 1990), or an additional 0.9-2.3 kg/d of milk (Jones et al., 2001), when compared to feeding canola meal.

Heating canola expeller meal to reduce its rumen degradability increased milk production in primiparous cows. Johansson and Nadeau (2006) examined the effects of replacing a commercial protein supplement with canola expeller meal in organic diets and observed an increase in milk production from 35.4 kg/d to38.4 kg/d. In this study and others, the feeding of canola expeller meal tends to reduce the saturated fat content of the milk and increases the level of oleic acid. Johansson and Nadeau (2006) observed a reduction in the palmitic acid content (C16:0) from 30.3% to 21.9% of the fat and an increase in Oleic acid from 15.7% to 20.9%. Similarily Jones et al. (2001) observed a shift in fatty acid profile when canola expeller meal was fed. This would suggest the fat remaining in the expeller meal is somewhat resistant to the degradation in the rumen and therefore a portion is absorbed directly from the small intestine.

Table 6. **MILK PRODUCTION OF DAIRY COWS FED CANOLA MEAL, CANOLA EXPELLER MEAL OR HEATED CANOLA EXPELLER MEAL**

Reference	Parity	Sampling period	Treatment	Milk yield, kg/d
Beaulieu et al., 1990	Mixed[1]	Unknown	Canola meal	28.9
			Canola expeller meal	28.8
Jones et al., 2001	Multiparous	70 ± 17 DIM at beginning of trial	Canola meal	28.6
			Canola expeller meal	30.9
			Heated canola expeller meal	30.0
Jones et al., 2001	Primiparous	73 ± 17 DIM at beginning of trial	Canola meal	23.6
			Canola expeller meal	24.5
			Heated canola expeller meal	25.2

[1] Primiparous and multiparous cows.

FEEDING CANOLA SEED AND OIL

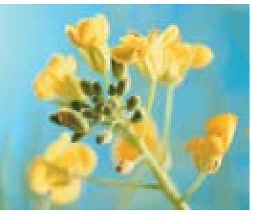
There is considerable interest in feeding canola seed and canola oil to dairy cattle. The objectives are to increase the energy content of the diet and also, in the case of the seed, to provide a high-quality dietary protein. Also, there is interest in increasing the level of unsaturated fatty acids and conjugated linoleic acid (CLA) in milk to make it "healthier" for humans. Heat and/or chemical treatment of the seed and oil are used to help both the protein and oil bypass the rumen (the oil is subject to bio-hydrogenation in the rumen). A recent study by Chicholowski et al. (2005) demonstrated the benefits of feeding ground canola seed as compared to canola expeller meal to ruminants. Supplementation with ground canola seed resulted in a reduced omega 6 to omega 3 ratio and a higher proportion of CLA and vaccenic acid (precursor to CLA) in the milk, suggesting a healthier product can be produced in this manner while having no impact on milk production. Johnson et al. (2002) also observed increased CLA and oleic acid in the milk when the diets were supplemented with whole canola and cottonseed. Bayourthe et al. (2000) observed significant reductions in saturated fat in the milk when fed whole, ground or extruded canola seed. They also observed similar reductions in saturated fatty acid content of milk when calcium salts of canola fatty acids were added to the diet. With the exception of whole canola seed, supplementation with high-fat canola products also improved milk production, indicating that adding processed canola seed or protected canola oil are effective methods of altering the fatty acid profile of milk products.

CANOLA MEAL MAXIMUM INCLUSION LEVELS

The recommended maximum inclusion levels for canola meal in cattle diets are listed in Table 7.

Table 7. **RECOMMENDED MAXIMUM INCLUSION LEVELS (%) OF CANOLA MEAL IN CATTLE DIETS**

Animal diet type	Maximum inclusion level
Calf	No limit
Dairy	No limit
Beef feedlot	No limit



CANOLA MEAL IN SPECIALTY DIETS

Since canola meal is so widely available, feed manufacturers have used it in many specialty feeds. Given that research in some of these specialty areas is very limited, the commercial application of canola meal has sometimes been demonstrated and accepted without the benefit of formal research. There are very few, if any, specialty feed areas where canola meal has not found acceptance. Canola meal is increasingly used in aquaculture feeds for salmon, trout, catfish, carp, tilapia, shrimp and minor species. It is routinely used in diets for horses, sheep, rabbits and other specialty animals.

AQUACULTURE DIETS

Canola meal is commonly used in aquaculture diets for species such as catfish, carp, tilapia, bass, perch, seabream, turbot, and shrimp. Lim et al. (1997) found that canola meal can be included in channel catfish diets at up to 31% with no negative effects on performance. Canola meal and rapeseed meal are also commonly included in carp diets, which are normally vegetable protein based. Higgs et al. (1989) determined that canola meal could be effectively used at a 10% inclusion level in juvenile tilapia diets without significantly depressing growth rate or feed conversion efficiency. Abdul-Aziz et al. (1999), on the other hand, fed up to 25% canola meal in tilapia diets with no effects on performance. Glencross (2003) found that canola meal could comprise up to 60% of the diet for Red Seabream without detrimental effects on performance. In the case of shrimp, Lim et al. (1998) found that 15% canola meal in shrimp diets resulted in no significant performance differences but that 30% and 45% inclusion levels resulted in growth rate and feed intake depression. A non-nutritional concern about using canola meal in shrimp feeds is the negative effect that the fibre has on feed pellet water stability.

> **‘Canola meal is commonly used in aquaculture diets for species such as catfish, carp, tilapia, bass, perch, seabream, turbot, and shrimp.’**

USE OF CANOLA MEAL IN SALMON AND TROUT FEEDS

Canola meal is well-established as a feed ingredient in salmon and trout diets where it has been routinely fed for over 20 years (Higgs et al., 1996). Canola meal is used at up to 20% inclusion levels in salmonid diets but it is desirable to further displace fish meal in the diet due to limited world supplies and the growing demand for these highly valued species.

NUTRITIONAL AND ANTI-NUTRITIONAL PROPERTIES OF CANOLA MEAL

The digestible energy content of canola meal ranges from 2300-2750 kcal/kg for salmonid fish (NRC, 1993). The amino acid balance of canola protein is the best of the commercial vegetable protein sources currently available (Friedman, 1996). Using protein efficiency ratio (PER; weight gain per gram of protein fed) as a measure, canola protein has a PER of 3.29 compared to 1.60 for soybean meal and 3.36 for beef (Sarwar et al., 1984). Furthermore, canola meal protein is approximately half the cost of fish meal on a per kg of protein basis. Canola meal contains small amounts of heat labile (glucosinolates) and heat stable (phytic acid, phenolic compounds, tannins, and fibre) anti-nutritional factors (Table 1). These factors can diminish the nutritional value of canola meal in finfish.

While dietary fibre is usually not considered to be an anti-nutritional factor, most finfish reared in aquaculture do not naturally consume high levels of fibre in their diets. Canola meal contains relatively high levels of fibre including approximately 14.5% cellulose, 5.0% hemicellulose and 8.3% lignin. This results in a crude fibre content of 10.6% for commercial canola meal (Mwachireya et al., 1999). These fibre fractions cannot be used by finfish and may diminish the nutritional value of other dietary ingredients (Poston, 1986). However, levels of dietary fibre less than 8% generally do not impact fish growth performance indicating that any feasible inclusion rate of canola meal (< 50%) should not have a negative effect on fish growth performance (Hilton et al., 1986; Poston, 1986). Nevertheless,

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the fibre component of canola meal does dilute the amount of protein and energy in the meal. Thus, removal of the fibre fraction of canola meal could enhance its value in nutrient dense aquafeeds by increasing the nutrient density of the meal. The heat stable anti-nutritional factors vary widely in structure and their nutritional effects. They prevent the use of canola meal in salmonid diets at inclusion levels over approximately 10% of the diet (Higgs et al., 1983). The solution to improving the nutrient utilization of canola meal is to remove them by fractionating canola meal by various means. Fractionation will also increase the level of digestible protein and energy in the resulting products, resulting in a much more desirable ingredient for finfish diets.

While the presence of anti-nutritional factors in canola is a negative for its use in some aquaculture diets, the use of canola protein and oil also has significant advantages over the use of fish meal and oil in that they are lower in polychlorinated dibenzodioxins and polychlorinated dibenzofurans (PCDD/F) and dioxin-like polychlorinated biphenyls (DL-PCB). When fish meal and oil was completely replaced with canola protein concentrate and canola oil the levels of PCDD/F and PCBs were significantly reduced in prepared diets (4.06 vs 0.73 pg/g as is basis) and in the fillets (1.10 vs 0.12 pg/g as is basis) of fish fed these diets during a six-month growth trial (Drew et al., 2007). The human tolerable daily intake of organochlorine contaminants is 14 pg/kg body weight/week according to the European Commission's Scientific Committee on Food. Based on these levels, a 50-kg person could safely consume 640 g per week of trout fed the fish meal and oil diet compared to 5,880 g per week of the trout fed the canola protein and oil diet. This suggests that decreasing the level of fish meal and oil present in aquafeeds by the use of canola oil and protein could significantly impact the safety of farmed fish and increase consumer acceptance of these products.

CANOLA PROTEIN CONCENTRATE FOR SALMONID SPECIES

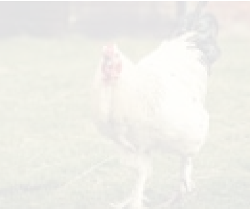
Canola meal may be converted into canola protein concentrate (CPC) by aqueous extraction of protein (Mwachireya et al., 1999; Thiessen et al., 2004). Recently, CPC has become available from CanPro Ingredients. CPC contains approximately the same crude protein level as fish meal (South American super prime) and high levels of lysine and methionine relative to corn gluten and soybean meal. The process used to concentrate the protein results in a CPC is completely devoid of phytate and contains extremely low levels of glucosinolates. The crude protein digestibility was reported to be up to 97% in rainbow trout and the digestibilities of key amino acids (lysine, methionine and arginine) were greater than 90%. Apparent digestible energy of CPC was 4310 kcal/kg compared to 3360 kcal/kg for soybean meal.

Replacement of 50% or 75% of fishmeal in diets fed to rainbow trout resulted in no significant differences in any of the performance measures (Thiessen et al., 2004). Feed efficiency and PER values of the control and the 75% CPC diet were essentially identical over the 63-day period of the experiment. These results confirm that CPC can replace up to 75% of fish meal protein with no significant decrease in growth or feed efficiency.

In an experiment in Nile tilapia, fish were fed diets containing 24.7% CPC, replacing fish meal, soybean meal and corn gluten meal (Borgeson et al., 2006). The fish receiving the CPC diets grew significantly faster than those receiving the control diets (2.29 vs 1.79 g/d). This suggests that CPC might allow a higher level of fish meal replacement in aquafeeds without affecting fish growth performance.

FUTURE USE OF CANOLA IN AQUACULTURE DIETS

The aquaculture feed industry must find alternatives to fish meal to meet the high rate of industry growth. While canola meal is probably too low in energy and protein content to be widely used as a primary feed ingredient in finfish diets, the fractionation of canola meal into new nutrient dense products including canola protein concentrate could play an important role in replacing fish meal in these aquaculture feeds.

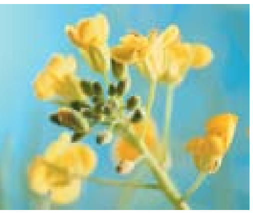


HORSE DIETS

Even though there are only a handful of research studies (Cymbaluk, 1990; Sutton, 1988) using canola meal in horse feeds, it is commonly used at relatively high inclusion levels. Sutton (1988) investigated potential concerns about canola meal palatability for horses. He determined that up to 15% canola meal, the highest level tested, in recreational horse diets had no effect on feed intake.

SHEEP DIETS

Canola meal is widely fed to all types of sheep and there are no effects on feed intake or other performance parameters (Hill, 1991). In fact, sheep can apparently tolerate high glucosinolate rapeseed meal quite well. Vincent et al. (1990) fed diets containing 21% rapeseed meal (18 µmoles/g of glucosinolates in the concentrate) to lambs with no negative effects on feed consumption or growth rate. Vincent et al. (1988) fed ewes a diet containing 20% high glucosinolate rapeseed meal (17 µmoles/g of glucosinolates in the concentrate) with no negative effects on feed intake, milk production, number of lambs per ewe or lamb birth weight. In fact milk production was numerically higher on the rapeseed meal diet (3.25 kg/day) compared to the soybean meal control diet (3.14 kg/day). Recently, Mandiki et al. (1999) fed lambs diets containing up to 30% canola quality rapeseed meal (6.3 µmoles/g of glucosinolates in the concentrate). There were no effects on weight gain or feed intake, despite the fact that thyroid weight was marginally higher and thyroid hormone production was marginally lower at the high dietary inclusion levels of rapeseed meal. The processing temperature of canola meal may be important in feeding sheep. Konishi et al. (1999) recently demonstrated that excessive heat processing of canola meal suppressed phytate degradation in the rumen and led to lower availability of dietary phosphorus. The extent to which phytate degradation decreased was greater in canola meal than in soybean meal. Petit et al. (1997) observed a somewhat different effect of heat treatment. They compared dietary nutrient degradability in the rumen of raw and extruded whole soybeans and canola seed in growing lambs. They found that extrusion of canola seed increased dry matter and nitrogen degradability but decreased soybean nitrogen degradability.



MISCELLANEOUS DIETS

For other "miscellaneous" animals there is very little published research on feeding canola meal. Commercially, it is quite common to feed canola meal to rabbits as the main dietary protein supplement. This is supported by the early research of Lebas and Colin (1977) and Throckmorton et al. (1980). Likewise, in early work with mink, Belzile et al. (1974) showed that rapeseed meal is a suitable dietary protein source. In the case of ratites, Brand et al. (2000) have shown that canola meal has a high metabolizable energy value for ostriches.

CANOLA MEAL MAXIMUM INCLUSION LEVELS

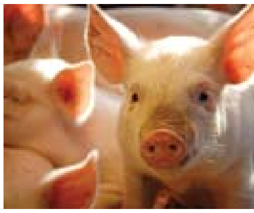
The recommended maximum inclusion levels, together with the reasons for canola meal usage in aquaculture and specialty diets, is given in Table 1.

Table 1. **RECOMMENDED MAXIMUM INCLUSION LEVELS (%) OF CANOLA MEAL IN AQUACULTURE AND SPECIALTY DIETS**

Animal diet type	Max inclusion level	Reasons for maximum inclusion level
Salmon, trout	20	Glucosinolates, fibre, phytate
Catfish	30	-
Tilapia	25	-
Red Seabream	60	-
Prawns	15	Fibre
Horses	15	-
Sheep	30	-

ECONOMICS OF FEEDING CANOLA MEAL

The value of canola meal relative to other protein ingredients, such as soybean meal, varies with the type of animal fed and with animal performance level. Canola meal has several strong nutritional characteristics that add to its value – a good amino acid balance with especially high levels of methionine, cystine and histidine. It also has high levels of phosphorus. On the other hand, canola meal is limited by its relatively low levels of lysine and energy. Therefore, animals which require intermediate levels of energy and high levels of methionine, cystine and histidine, such as dairy cattle and laying chickens, place a higher value on canola meal.



Animals with high energy and lysine requirements, such as broiler chickens, place a lower value on canola meal. Canola meal is often called a complementary protein in that its amino acid balance, notably the high levels of methionine and cystine, can complement other protein sources, such as soybean meal and feed peas, which are low in these amino acids. As well, cattle and pigs are able to extract more energy from canola meal than poultry. This results in a relatively high value for canola meal in cattle and pig feeds. Subjective and non-nutritional factors can sometimes influence the value of canola meal. For example, vegetable protein sources may be preferred over animal protein sources due to disease concerns. This favours canola meal. Likewise preference for a non-GMO ingredient or a light-coloured ingredient penalizes canola meal. The relative value of canola meal to high-protein soybean meal in some typical least cost animal feeds is shown in Table 1.

Table 1. RELATIVE ECONOMIC VALUE OF CANOLA MEAL TO HIGH PROTEIN (47%) SOYBEAN MEAL IN LEAST-COST ANIMAL FEEDS

Animal feed type	Relative value of canola meal to soybean meal (%)
Layer	65-75
Broiler starter	60-70
Broiler grower/finisher	55-65
Pig starter	60-65
Hog grower	65-75
Hog finisher	65-75
Gestating sow	65-75
Lactating sow	60-70
Dairy	75-85

POULTRY

PIGS

DAIRY & BEEF CATTLE

SPECIALTY

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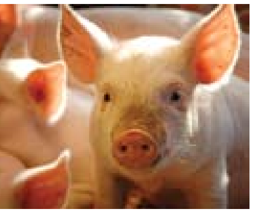

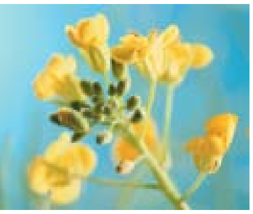

POULTRY

PIGS

DAIRY & BEEF CATTLE

SPECIALTY

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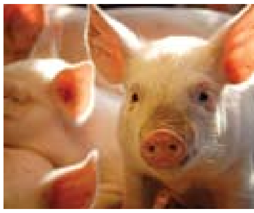

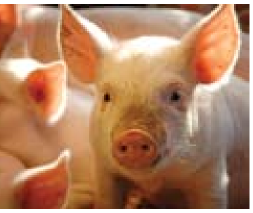

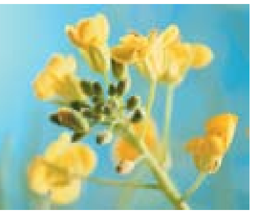

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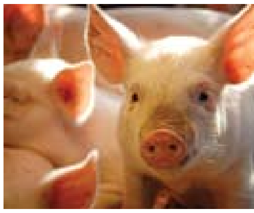
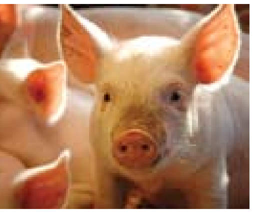


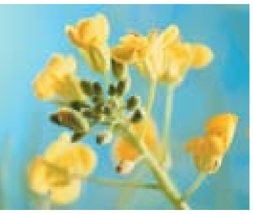
POULTRY

PIGS

DAIRY & BEEF CATTLE

SPECIALTY





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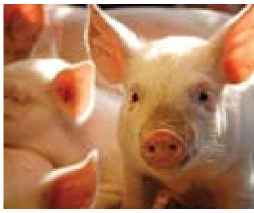
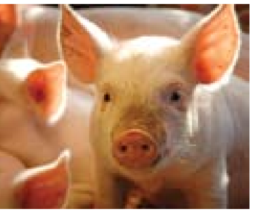


CANOLA MEAL NUTRIENT COMPOSITION TABLES



Component	Average
Crude Protein (N x 6.25: %)	36
Rumen bypass protein (%)	35
Oil (%)	3.5
Linoleic acid (%)	0.6
Ash	6.1
Sugars (%)	7.8
Starch (%)	0.6
Sucrose (%)	6.2
Fructose + glucose (%)	0.6
Cellulose (%)	4.5
Oligosaccharides (%)	2.2
Non-starch polysaccharides (%)	15.7
Soluble NSP's (%)	1.4
Insoluble NSP's (%)	14.4
Crude fibre (%)	11.7
Acid detergent fibre (%)	16.8
Acid detergent lignin (%)	5.1
Neutral detergent fibre (%)	20.7
Total dietary fibre (%)	32.3
Tannins (%)	1.5
Sinapine (%)	1.0
Phytic acid (%)	3.3
Glucosinolates (µmol/g)	7.2

Amino Acid	Total (%)*	Swine standardized ileal digestibility (%)	Broiler chicken apparent ileal digestibility (%)
Alanine	1.57	80	79
Arginine	2.08	87	86
Aspartate + asparagine	2.61	76	75
Cystine	0.86	81	74
Glutamate + glutamine	6.53	87	82
Glycine	1.77	78	73
Histidine	1.12	84	84
Isoleucine	1.56	78	72
Leucine	2.54	82	76
Lysine	2.00	75	78
Methionine	0.74	87	79
Methionine + cystine	1.60	85	77
Phenylalanine	1.38	83	81
Proline	2.15	78	75
Serine	1.44	78	71
Threonine	1.58	75	69
Tryptophan	0.48	80	78
Tyrosine	1.16	80	58
Valine	1.97	77	76

*Based on 36% crude protein

POULTRY
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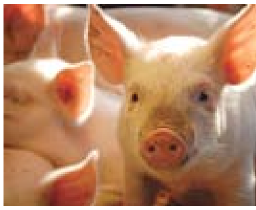
SPECIALTY

Mineral	Average
Calcium (%)	0.62
Phosphorus (%)	1.06
Available p (%)	0.3-0.5
Sodium (%)	0.10
Chlorine (%)	0.10
Potassium (%)	1.20
Sulphur (%)	0.83
Magnesium (%)	0.53
Copper (mg/kg)	5.7
Iron (mg/kg)	162
Manganese (mg/kg)	51
Molybdenum (mg/kg)	1.4
Zinc (mg/kg)	57
Selenium (mg/kg)	1.1
Electrolyte balance Meq/kg (K+Na-Cl)	324
Dietary cation-anion difference Meq/kg (K+Na-Cl-S)	-193



Vitamin	Amount
Biotin (mg/kg)	0.96
Choline (mg/kg)	6500
Folic acid (mg/kg)	0.8
Niacin (mg/kg)	156
Pantothenic acid (mg/kg)	9.3
Pyridoxine (mg/kg)	7.0
Riboflavin (mg/kg)	5.7
Thiamin (mg/kg)	5.1
Vitamin E (mg/kg)	13

Animal		Average value
Broiler chickens	AMEn (kcal/kg)	2000
	TMEn (kcal/kg)	2070
Laying hens	AMEn (kcal/kg)	2390
Pigs	DE (kcal/kg)	3100
	ME (kcal/kg)	2900
	NE (kcal/kg)	1750
Cattle	TDN (%)	63.0
	DE (kcal/kg)	3100
	ME (kcal/kg)	2480
	NEM (kcal/kg)	1690
	NEG (kcal/kg)	1130
	NEL (kcal/kg)	1580

ALL VALUES ARE BASED ON 88% DRY MATTER

POULTRY
PIGS
DAIRY & BEEF CATTLE
SPECIALTY

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