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1. INTRODUCTION

Rapeseed (*Brassica napus*) is a bright yellow flowering member of the family Brassicaceae (mustard or cabbage family).

Brassica napus L. var. napus

Source: Wikipedia.

Industrial rapeseed is high in erucic acid or H.E.A.R, with greater than 45 per cent erucic acid, which is mildly toxic to animals especially poultry. Erucic acid at levels beyond 0.605 per cent in diet is known to cause growth depression, reduction in feed intake and efficiency in growing chicks. Natural rapeseed meal also contains glucosinolates (the 'hot' in mustard seeds, when this compound is broken down with water it reacts and provides the heat felt on the tongue, characteristic in all Brassicaceae plants). Industrial rapeseed can be high or low in glucosinolates. Large amounts of glucosinolates affect growth rate, cause swelling of the thyroid gland and make meal less palatable for livestock.

Canola is the tradename of a particular rapeseed. The term canola has been registered and adopted in Canada to describe the oil (seeds, plants) obtained from the cultivars *Brassica napus* and *Brassica campestris*. In 1986, the definition of canola was amended to refer to *B. napus* and *B. campestris* (now *Brassica rapa*) lines containing less than 2 per cent erucic acid in the oil and less than 30 µmol/g glucosinolates in the air-dried, oil-free meal. Throughout this document, the term ‘canola’ refers to low erucic acid, low glucosinolate rapeseed.

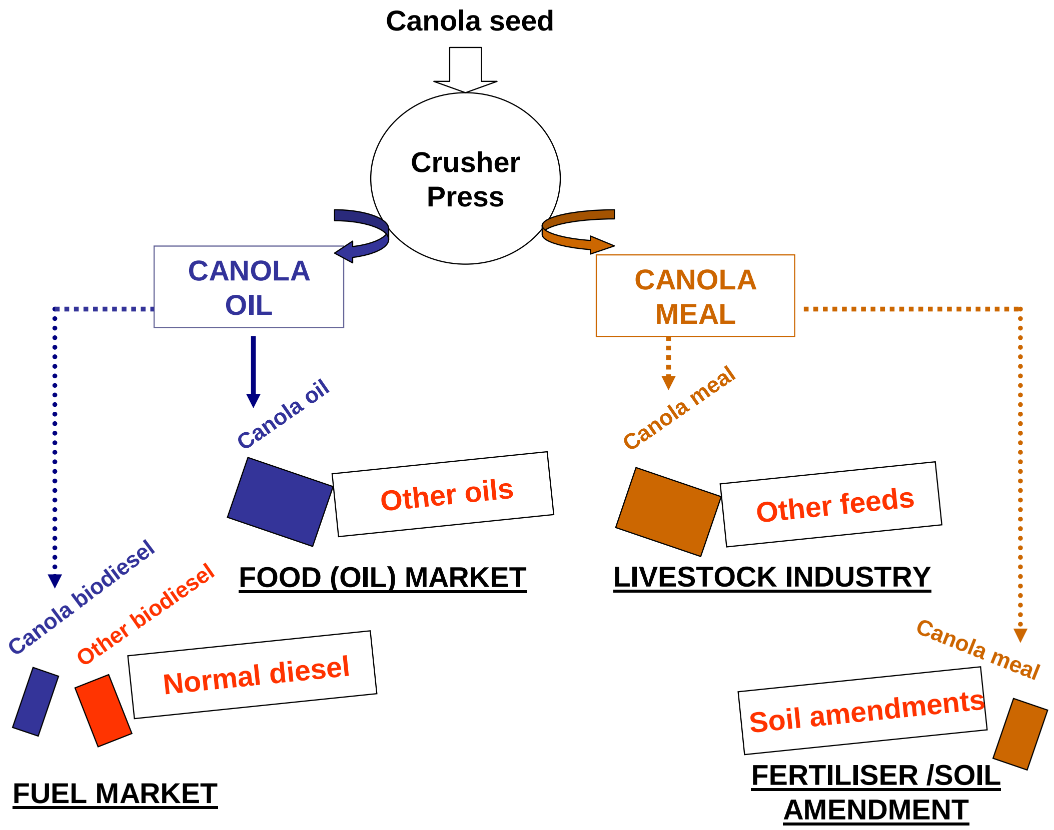

Figure 1. Canola seed flowchart.

The crushing of canola produces canola oil that can be sold to the food market and/or sold to the biofuel market where it is converted into biodiesel (Figure 1). The meal remaining after the oil has been extracted can be sold to the livestock industry as feedstuff (canola meal) and/or can be used as a soil amendment or fertiliser (Figure 1).

The expansion of the biofuels industry will result in a significant increase in volume of canola meal. This is because canola meal is a by-product of biodiesel production. Traditionally, the canola meal (Figure 2) was absorbed by the feedlot industry. However, there is a limit to how much vegetable protein, i.e. canola meal can be utilised in the livestock industry. Therefore as the biodiesel industry expands and the availability of canola meal increases, further research and development is required for market diversification.

Source: Agriculture and Food Canada.

Figure 2. Canola meal.

This report investigates the current research that is being conducted on canola meal and commercial uses of canola meal. It will cover the current and potential new uses of canola meal in both the livestock, agricultural and industrial sectors.

2. USES OF CANOLA MEAL

Internationally, opportunities for canola meal are increasing particularly in the livestock sector due to changes in government policy and market access issues. Although animal feed markets have lower regulatory, commercial and technical requirements than human markets, the Mad Cow disease problem in Europe has resulted in bans on meat and bone meal as protein sources in animal feeds. Import bans on meat and bone meal have also been imposed in Japan. In addition, there is increased scrutiny on feed additives such as antibiotics and their impact on animal and human health. All of this has producers are seeking safe, natural, high quality feed sources such as canola meal to sustain and safeguard their assets and their markets.

2.1 Animal nutrition

The Australian livestock feeding industry utilises a broad range of feedstuffs (Table 1).

Table 1. The range of Feedstuffs utilised in livestock diets in Australia

Cereal	Milling offals and byproducts	Animal proteins	Vegetable proteins	Legumes	Others
Wheat	Wheat bran	Meatmeal	Soyabean meal	Lupins	Molasses
Barley	Wheat pollard	Bloodmeal	Canola meal	Peas	Salt
Oats	Rice pollard	Fishmeal	Sunflower meal	Faba beans	Limestone
Sorghum	Pea pollard	Poultrymeal	Cottonseed meal	Chickpeas	Phosphates
Triticale	Oat pollard	Feathermeal	Whole cottonseeds	Mung beans	Bentonite
Rye	Whey		Safflower meal	Lentils	Bicarbonate of Soda
Rice	Milk/cheese		Linseed meal	Vetch	Mg salt
Maize	Vegetable pomace		Yeast	Cowpeas	Amino acids
	Confectionery			Lablab	Fats/oils
	Almond shells			Culinary beans	Organic acids
	Citrus pulp			Azuki beans	
	Brewers grains				
	Potato wastes				
	Malt combings				

Source: ACE Livestock Consulting Pty Ltd.

Ingredients used by the stockfeed manufacturing sector can be easily substituted, and thus feed processors tend to purchase competitively priced ingredients. Energy values are a function of protein level, residual oil content and available carbohydrates. Australia typically produces mid protein meals (36-38 per cent) which have a lower energy value. As a result, rations that substitute imported soybean meal with canola, sunflower or cottonseed meal must be compensated with a high-energy feedstuff such as stabilised tallow (Table 2).

Table 2. Nutrient composition of canola meal relative to soybean meal

Component	Canola meal*		Soybean meal
	Canada[a]	Australia[bc]	USA[de]
Moisture	10.0	11.0	12.0
Crude protein % (N x 6.25)	35.0	37.0	47.0
Rumen bypass (% of prot)	35.0	-	(14.0)
Oil %	3.5	2.9	(3.0)
Linoleic acid %	0.6	0.58	(0.6)
Ash %	6.1		6.02
Sugar %	8.0		9.17
Starch %	5.2		5.46
Cellulose %	4.6		
Oligosaccharides	2.3		
Non-starch polygosaccharides %	16.1		
Soluble NSP %	1.4		
Insoluble NSP %	14.7		
Crude fibre %	12.0	11.9	5.40
Acid detergent fibre %	17.2	16.9	7.05
Neutral detergent fibre %	21.2	26.6	11.79
Total dietary fibre %	33.0		
Tannins %	1.5		
Sinapine %	1.0	1.5	Nil
Phytic acid %	4.0	(2.0)	(1.55)
Glucosinolates (u mol/g)	16.0	11.0	Nil

Source: ACE Livestock Consulting Pty Ltd.

* Refers to solvent extracted meal. Expeller and cold press meals have higher oil content with concurrent dilution of their other components.

a = Canola Council of Canada – Feed Industry guide.
b = Perez-Maldonado 2003.
c = Department of Primary Industry.
d = American Soybean Association.
e = National Research Council (NRC).

Canola meal is sold as a protein source for a variety of animal species with markedly different digestive capacities and nutrient requirements. Canola meal can be mixed into a full ration at 10 to 15 per cent for cattle and sheep. Pigs and poultry rations typically consist of 15 per cent canola meal.

Protein content is important in poultry and pig diets. However, protein content is not as important for ruminants because the majority of proteins are easily degraded in the rumen. In both monogastrics and ruminants, protein quality can be improved by altering the sulphur amino acid composition of the seed. This can also be achieved by adding synthetic amino acids to the ration. However, input costs and other economic factors must be considered.

Based on the high methionine and cystine amino acid content of canola meal, it can be a valuable supplement for sheep feed. Lupin seeds which are often fed to sheep in Western Australia, have lower methionine and cystine levels in comparison.

Canola meal is partially protected from degradation in the rumen, particularly if it has been processed to decrease solubility. Feeding canola meal to sheep has resulted in increased wool growth by between 27 and 133 per cent (Milton and Masters, 1998).

Crude fibre is present in larger amounts in the hulls of oilseeds and limits their use in diets for poultry and young pigs. Removal of hulls and indigestible fibres enhances the digestible and metabolisable energy of the meal. The easiest way to address this problem is through plant breeding to make the seed coat thinner.

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A major factor influencing the energy value of canola meal is the amount of residual oil. The Eastern States processing plants use a solvent extraction method, which leaves only 2 per cent oil in the meal. The crushing plants in Western Australia use an expeller, which leaves 7-8 per cent oil in the meal. The higher oil content increases the available energy value in the canola meal which means the Western Australian livestock industry has a comparative advantage over the Eastern States.

In addition, the pig and poultry industries are not receptive to using canola meal for full protein supplementation because of some anti-nutritional factors (ANF) in canola meal. One of the ANF includes phenolics. Phenolics are unwanted and undesirable in animal feed material. They are considered to hinder animal nutrition in at least two ways: they are associated with poor palatability due to bitterness or astringency, thus affecting feed intake; secondly, they interfere with nutrient uptake in the digestive system.

In canola, sinapine is the most abundant of all small phenolics (Table 2). Sinapine caused issues with chickens when hens started to produce eggs that smelled 'fishy' or 'crabby'. The problem was traced back to canola meal that contained sinapine. These hens could not metabolise sinapine fully and trimethylamine, an intermediate, was leached into the eggs thus giving them the objectionable fishy odour. Consequently, even though there are low sinapine canola varieties; the poultry industry generally only uses canola meal for protein supplementation at low levels.

Another ANF found in canola meal is phytate, a form of phosphorus generally not bioavailable to non-ruminant animals and fish, because they lack the digestive enzyme, phytase, required to separate phosphorus from the phytate molecule. The unabsorbed phytate increases the amount of phosphorus in the manure. Excess phosphorus excretion is known to lead to environmental problems. In freshwater hatcheries, where cultured salmon spend a portion of their lives, excess phosphorus can promote the proliferation of algae and phytoplankton that consume oxygen, leading to oxygen-starving of fish and other aquatic organisms in the system.

In contrast, ruminants can utilise more of the fibre and phytate phosphorus. Canola meal is used in dairy diets because it possesses an excellent nitrogen profile for rumen microbes. Studies demonstrated that daily feeding of 3.4 kg of canola meal instead of 5.6 kg of cottonseed meal enhances milk percentage of protein and solids-not-fat, improves nutrient digestibility, and maintains productivity of midlactation cows. However, the high quality amino acids are considered an expensive source of nitrogen for rumen bacteria.

The aquaculture market is a potential new market opportunity for canola meal. Aquaculture is experiencing tremendous growth and is expected to outstrip sufficient feed sources, such as fish meal. During the past decade aquaculture has maintained a four per cent average annual growth Today aquaculture contributes to about a third of Australia's total fisheries production, with a value of A$611 million in 2004-05, Western Australia's aquaculture industry was A$128 million in 2004-05 or a quarter of the total Western fisheries production (A$539 million).

The demand for high-quality fishmeal; a major component of aquaculture diet is currently worth approximately $1100 per tonne; is expected to rise dramatically over the next five years. The Asian prawn industry alone currently requires one million tonnes of fishmeal annually. However, world supplies of fishmeal, composed of whole caught fish or fisheries waste, are static and vulnerable to fluctuations; 50 per cent of fishmeal is produced by a single fishery in Peru whose output is heavily influenced by the El Niño effect. Therefore, there is great potential for feed grain production and supply to the aquaculture industry as fishmeal sources continue to become scarce.

Canola meal was first identified in the 1980s as having some potential as a useful feed ingredient in the diets of fish. More recently it was identified that protein concentrates made from these meals had more value to fish than the raw canola meals. Despite this progression, surprisingly little is known about the differences in nutritional value of the raw meals produced from different oil extraction methods, such as expeller and solvent extraction.

Canola meal has the potential to be a good ingredient for use in aquaculture diets. The amount of digestible protein and energy in the meal are the two components for inclusion rates in the diet. The composition of canola meals produced by different methods has different amounts of protein and energy (Table 3). The different processes influence the nutritional value of these meals to animals.

Table 3. Composition of fishmeal, canola meals and the protein concentrate used in the study

	Fishmeal	Expeller extracted	Solvent extracted	Protein concentrate
Dry matter content (g/kg)	925	898	962	483
Crude protein (g/kg DM)	703	381	431	483
Crude fat (g/kg DM)	73	136	22	33
Ash (g/kg DM)	216	66	86	59
Carbohydrates (g/kg DM)	8	418	461	425
Phosphorus (g/kg DM)	40	24	23	36
Gross energy (MJ/kg DM)	19.6	23.1	19.6	22.1
Phytate (g/kg DM)	0	25.6	36.6	n/a
Glucosinolates (mmol/kg DM)	0	3620	1100	n/a

Source: B. Glencross, Department of Fisheries.

n/a – Not assessed; DM – Dry matter.

Canola meal could have an important and increased use in the pet food industry. For example, canola meal is already utilised in the manufacture of some dog biscuits. There is potential for further utilisation in the pet food industry.

Research is being conducted to investigate the economic fractionation of canola meal into value added products that more closely match the requirements of target animal species. The fractionation procedures are proprietary, but in general the process involves liquid fractionation. Although it is possible to obtain a number of different product lines, the three of most interest are: insoluble, soluble and fibre protein fractions.

The insoluble and soluble products maintain the excellent amino acid balance and low antigenicity characteristics of canola meal but concentrate the protein (650 to 800 g/kg) and eliminate or reduce the levels of phytate and other anti-nutritional factors. These products are designed to compete with fish meal and high protein plant concentrates in non-ruminant and aquaculture diets.

A fourth stream from the fractionation processing system is sugar rich and contains high levels of available minerals. It is envisaged that this product may be combined with the fibre protein as a ruminant feedstuff.

The use of this fractionation technology will give canola meal very good prospects in the animal nutrition market. This particular fractionation technology has been pioneered by researchers David Maenz, Henry Classen and Rex Newkirk from the University of Saskatchewan. The Canadian company, MCN BioProducts, and a Western Australian university, Curtin University, are in the process of refining the technology. Although it is a proven technology, it is still at the very early stage of commercialisation and it is anticipated that another five to eight years are required to make it a commercially reality.

The European Union also funded a project to improve the market prospects of canola meal. The project 'Green Chemicals and Biopolymers from Rapeseed Meal with Enhanced End-uses Performance': was called ENHANCE and started in 2000, The overall objective of the ENHANCE-project was to develop and design production systems to extract protein products, from the canola meal, tailored to meet functional requirements within products such as animal feeds as well as paper coating, binders in thermal isolating materials, adhesives and cosmetics.

Prototype proteins have been produced in pilot scale. They have been evaluated and their functional properties have been enhanced during the project. The ENHANCE proteins consist of two different protein product simply named Protein I and II. Protein I can be regarded as a substitute for fish meal, while Protein II could be considered as a substitute for casein (milk protein). The quality of the end-products and the final market possibilities are still being assessed.

2.2 Non-feed uses for canola meal

2.2.1 Use of canola and rapeseed meals as a soil amendment/fertiliser

Industrial rapeseed meal and canola meal could be used as a fertiliser and soil amendment.

Canola meal is a good organic fertiliser with responsible amounts of nitrogen, phosphorus and sulphur (6.4-0.8-1.3). The value of these nutrients currently equates to $100 per tonne for the canola meal. This would be a suitable fertiliser for farmers who are interested in producing their own biodiesel and have the canola meal as a co-product on-farm. There are several advantages with this system as it lowers the cost of purchasing and transporting the fossil fertilisers to the farm, recycles all the nutrients back into the soil and is an effective fertiliser resource.

High glucosinolate meal from industrial rapeseed has the potential for use as a bio-fumigant, replacing expensive soil fumigants such as methyl bromide. Non-chemical, economically viable strategies for the control of soil-borne disease are needed, particularly for organic producers.

Rapeseed meal was shown to be effective in suppressing apple root infection by Rhizoctonia solani, an important soil-borne disease pathogen. Others field studies have indicated that rapeseed meal has pesticidal properties against *Cylindrocladium parasiticum*, casual agent of Cylindrocladium black rot (CBR) of peanuts.

A major obstacle to using rapeseed meal amendments to control fungal and bacterial pathogens in soil is that beneficial organisms can be eliminated too in the process. Formulation technologies or amendment strategies must be developed to ensure that pathogen populations are not stimulated. The glucosinolate degradation products can also alter seed germination and plant growth. Lifetimes of glucosinolate products in the environment are generally short, an advantage when considering environmental impact.

Rapeseed meal has been used as a soil amendment in an attempt to control nematodes. The results were ambiguous, and acceptable control was not achieved.

Other compounds besides products of glucosinolate degradation may be biologically active and thus contribute to pest inhibition. Although phenolics are often suggested to participate in plant defences against infection, little work appears to have been done on the potential pesticidal activity of specific phenolics in rapeseed meals.

The use of rapeseed meal as fumigant will always be limited because of the large amounts that are necessary to obtain a biocidal activity equivalent to that obtained with standard chemical biocides.

2.2.2 Industrial uses for canola meal

The use of soy protein as plastics can be traced back to the 1930s and 1940s. Proteins are polymers of amino-acids and plastics are three-dimensional networks of polymer chains. Table 2 show the relatively high content in crude protein found in canola meal and soybean meal.

In Europe, the previously mentioned ENHANCE-project investigated ways to develop non-feed uses from canola meal components such as green chemicals and biopolymers with enhanced end use performances in diverse and versatile markets.

The researchers found that the most interesting and promising markets for canola proteins are in the surfactants and adhesive applications. Protein extraction, separation and modification processes, for producing value-added components from canola meal are still being developed.

Adhesives

According to a preliminary evaluation, the ENHANCE formulations are competitive with currently available natural adhesives but not with synthetic adhesives. The ENHANCE formulations includes Protein II, a protein extracted from the canola meal and can be used in adhesives.

Surfactants

Researchers from the ENHANCE project at the Institut National de Recherches Agronomiques (INRA) of Nantes, in France, have developed a process to produce biodegradable surfactants from the canola meal. Surfactants are used in the productions of foams, emulsions and detergents, and represent a market of 2.5 million tonnes in Europe, of which still 70 per cent are derived from the petro-chemical industries.

The biodegradable surfactants recently developed by INRA researchers have already proved their effectiveness in the degreasing of the metal parts in the mechanical precision industries. They are currently being tested for the production of non adherent films, used for example to protect certain surfaces.

Limitations

Canola meal has a future as a source of specific proteins that could be the raw material for the production of several products with industrial and pharmaceutical applications. The limiting factors include low concentrations of the raw ingredient; canola meal, development of economical extraction techniques, cost-competitiveness with compounds already being used, market volumes and production-to-market mechanisms.

3. CONCLUSION

The expansion of the biofuels industry will result in a significant increase in volume of canola meal.

The livestock industry will remain the main market for canola meal until researchers find an economical way to isolate and extract the proteins of the meal. Canola meal also has a future as a source of protein to substitute fishmeal in the aquaculture industry.

In the longer term, canola meal could be used as a source of specific proteins that could be the raw material for the production of several products with industrial applications. These include soil amendments, soil fertilisers, bio-polymers, surfactants and adhesives.

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