Final Report

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Canola Meal Value Chain Quality Improvement

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Executive Summary

Canola meal is well recognised as a highly nutritious feedstock for animals. It contains a high concentration of protein, a well balanced amino acid profile and source of energy. Several reports, particularly from Canada where canola originated, have detailed the benefits of canola meal for poultry, pigs, dairy and beef cattle as well as aquaculture, horses, sheep and other livestock. Despite this abundance of information, Australian canola meal is not utilised to the optimum level. The reasons for undervaluing canola meal are many, with one key one being the level of variability in quality of sequential batches of canola seed and meal. Analysis of individual loads is often not feasible and as a result end-users formulate diets on the minimum likely level of proteins, and particularly individual amino acids.

Variability is a factor of environment with dry seasonal conditions creating reduced oil and increased protein content. Australia's growing conditions will always produce variable quality. However, a major reason for variability, as well as quality losses is attributed to processing. Processing involves heating seed and meal at several stages through the extraction process as well as during meal production. The level of heating, the duration and the presence or absence of moisture all contribute to degradation of canola meal components, in particular, protein digestibility and lysine values.

With the likelihood of increased amounts of canola oil being extracted in Australia, particularly in relation to the biodiesel industry, it is likely that large amounts of canola meal will become available in Australia. This gives an opportunity to replace imported soybean meal which is currently used in significant levels in animal feeds.

This project was undertaken to determine the processes which have the most influence on meal quality. Eight crushing plants within Australia, representing solvent extraction, expeller and cold pressing operations were invited to take part in the study. Samples were taken at all stages of the process from each processor and sent to laboratories to evaluate the influence of each stage of the process. All of the major chemical parameters which may be of interest to feed manufacturers were studied. All of the stages were replicated to make the study statistically sound.

Data has been provided from the analysis of 249 samples. There were many differences between meal from different types of processors, solvent or expeller but also differences in meal from processors using the same type of facilities. These differences highlight the need to fine tune the process to produce a consistent high quality feed. Some processing was advantageous, reducing antinutritional components and improving by-pass protein whereas others reduced reactive lysine and protein digestibility.

Many conclusions can be drawn from the current work regarding heat treatment, moisture content, addition of gums back to solvent extracted meal and other processes. Much of the details have strong similarities to previous studies carried out in Canada. However, Australian conditions are different to those in Canada particularly in regard to seed maturity, moisture content and ambient temperatures at the time of processing. Therefore, this study needs to be expanded to help the industry overcome known faults in the process. Information about how long and at what temperature and moisture level it is necessary to remove solvents and to dry finished meal could save processing costs and maintain or improve meal quality. The temperature and pressure utilised in expeller operations to get maximum oil extraction is also critical in improving processor profits and maintaining protein digestibility.

Education of end-users is also important to help them understand the benefits of canola meal. Feed formula are often limited to low proportions of canola based on anti-nutritional components based upon traditional views relating to rapeseed which have been virtually eliminated from current cultivars. The development of an Australian canola meal nutritional guide is to be developed and released utilising the data from this project.

Finally, the ability to determine the quality of the meal at the point of use is crucial to allow maximum utilisation of the product. Measurement of protein digestibility and reactive lysine is too expensive and time consuming with current methodology and therefore feed manufacturers will continue to be limited in their capacity to rapidly assess canola meal protein quality. NIR spectroscopy is the most likely methodology to overcome these problems. The next stage of this project needs to establish calibrations on NIR instruments to give low cost and rapid quality data on oil content, reactive lysine levels, crude protein and fibre levels. These outcomes are possible and with the co-operative support of the oilseed crushing industry has a high likelihood of success.

Contents

1 Background

Canola meal is a commonly used protein source for pig diets within Australia. Processing conditions applied in canola seed processing have been identified as having a detrimental effect upon canola meal protein quality (Newkirk and Classen 2002, van Barneveld et al. 1999). AOF canola meal end user forums have identified a need for increased meal consistency, greater nutrient information and reduction of heat damage of amino acids as being areas requiring further information.

Within Australia, canola oilseed processing is undertaken by a number of companies utilising various processing equipment and conditions. The range is from cold press through to solvent extraction processing systems. There is a lack of information which is required by the pig industry to clearly define the range in nutrient levels within Australian canola meal. The majority of information in use by commercial nutritionists is derived from Canadian publications and relates to canola grown in Canada.

2 Project Objectives

This project addresses two Pork CRC outputs in providing a more reliable and consistent protein supply for the pig industry.

The project will have the following specific objectives:

- Identification of variation in nutritional quality of canola meal produced within Australian crushing plants.
- Establishment of a reactive lysine NIR calibration for finished meal with application for further research and commercial use.
- Gaining information on canola meal processing parameters and their impact upon meal quality.

This project is in part an extension of the work completed by van Barneveld (1998); this work recommended that oilseed processors should consider the adoption of the reactive lysine assay as a quality assurance tool. The data derived from this project is intended to be used within an industry canola meal nutritional guide.

Information obtained from this project will form the basis for a larger project (Stage 2) which will look at varying crushing conditions to increase amino acid digestibility. Further project work is linked to co-operative support of the commercial oilseed crushing industry. The ultimate result will be to supply higher quality and more consistent canola meal for use by the Australian pig industry.

3 Methodology

3.1 Sample Collection

Oilseed crushing plants co-operating within the project were required to take samples during 2006. Canola seed being processed was derived from the 2005/06 harvest period.

Samples were collected from eight commercial crushing plants, these being:

Crushing Plant
Cargill Australia - Newcastle NSW
Cargill Australia - Melbourne Vic
Riverland Oilseeds - Numurkah Vic
Riverland Oilseeds - Pinjarra WA
Riverland Oilseeds - Millicent SA
MSM Milling – Manildra NSW
Atlantic Pacific Foods - NSW
Cootamundra Oilseeds - NSW

Each crushing plant was required to collect samples over three different times of the day, for three different days and for three different weeks i.e. nine sampling events. Crushers were instructed to target sampling weeks within which different canola seedstock was being processed. The intent being to assess the level of variation which could occur in finished meal quality.

For each sampling event, the following samples were collected:

All plants
Canola seed – whole seed samples entering the crushing process, this being after any seed cleaning and being representative of the seed being crushed.

All plants
Expeller cake –hot seedcake after oil extraction, where the crushing plant practices double pressing, this followed the second expeller press.

Only for solvent plants
Post solvent extraction – after oil has been removed by solvent extraction but prior to desolventising and toasting (DT).

Only for solvent plants
Post DT – after toasting hot cake samples

All plants
Finished Meal – samples equivalent to product supplied to clients, cooled and ground.

Samples were delivered to NSW DPI Wagga Wagga Agricultural Institute (WWAI).

Crushing plants taking part in the project were asked to supply information relating to the processing conditions operating within their crushing plants. Commercial sensitivity limited the availability of data from a number of companies.

3.2 Sample Analyses

Chemical analyses were carried out by internationally accepted methods at WWAI.

Moisture content: Moisture content is used to adjust analytical results to common moisture levels for comparison. Moisture in canola is determined by the method of the American Oil Chemists' Association (AOCS) Ai-2-75. The method has been modified to reduce the drying time at 130^{o}C from the specified three hours to two hours as specified in AOF 4-1.5.

Oil content: The oil content was determined by the new recommended method of the AOF which is the FOSFA (Federation of Oils, Seeds and Fats Association) triple extraction method, AOF 4-1.24a.

Protein analysis: The protein analysis was carried out by Dumas combustion using a Leco analyser as described in method AOF 4-3.3.

Glucosinolates: Glucosinolates are measured as glucose following hydrolysis of the glucosinolates with myrosinase enzyme. The method is described in AOF 4-1.22.

Fatty acid profiles are determined by capillary gas chromatography after saponification and methylation of the fatty acids by method IOC 5508:1990 (International Olive Council).

Chloride: The samples were initially extracted by acetic acid extraction. Plant Chloride was then analysed at NSW DPI laboratories, Wollongbar by method SPAC 15 (Soil and Plant analysis Council 1998).

Minerals: The measurement of total minerals required digestion of the samples using nitric-perchloric block digestion (SPAC method 6). The samples were then measured using ICP-AES (inductively coupled plasma) using method USEPA 6010 (United States Environmental Protection Agency 1994). Due to some questions regarding mineral level results, the samples were again analysed using microwave digestion and ICP-AES but gave identical results.

Water soluble carbohydrates: Australian Fodder Association (AFIA) method 11A

Fibre analysis: Fibre was analysed using an Ankom fibre analyser. The individual methods include:

Crude fibre: AOCS Ba 6a-05 (Ankom 10-21-05)

Neutral detergent fibre (NDF): Ankom NDF method 8/98

Acid detergent fibre (ADF): Ankom NDF method 9/99

Neutral detergent insoluble nitrogen (NDIN): Ankom NDF method 8/98 + AFIA method 4R

Ash: AFIA method 10R

Amino acid analyses: completed by Degussa AG, Germany using protein hydrolysis.

Phytate, the mixed salt of phytic acid, is predominately found as inositol hexaphosphate esters (IP_6) and pentaphosphate (IP_5).

Phytate phosphorus: the HPLC separation of inositol phosphates completed by Sydney University was achieved using an HPLC anion exchanger and an isocratic mobile phase of sodium nitrate solution. The method is able to distinguish IP6 (phytate) from IP5 and lower inositol phosphates.

Reactive lysine: were determined by Massey University New Zealand according to the procedure of Moughan and Rutherfurd (1996).

4 Results

4.1 Samples and Processing Conditions

A total of 249 samples were collected from eight crushing plants. Samples comprised 63 canola seedstock samples, 118 in-process samples and 68 finished meal samples.

It is recognised that considerable variation exists within the processing conditions applied by expeller extraction plant operations, this ranging from “cold press” production through to high temperatures. The three solvent-extraction plants operate with similar processing conditions.

The key steps in production of canola meal involve:

- Seed handling and cleaning
- Conditioning and flaking
- Expelling → Expeller Plant Finished Meal
- Solvent extraction
- Desolventising and toasting → Solvent Plant Finished Meal

Cold press oil extraction - canola seed is not pre-conditioned prior to oil extraction, with temperatures up to 65°C being generated within the expeller due to frictional forces.

Expeller oil extraction – seed is heat conditioned and the expeller press operated to optimise oil extraction, this can generate meal temperatures up to 135°C for the brief period seed cake is passing through the press. Some plants operate double pass systems where seed cake is reprocessed to increase oil recovery.

Solvent extraction – involves a two stage oil extraction process, utilising an initial expeller extraction operating at 100 - 120°C, resulting in the production of a seed cake with approximately 20% oil (equivalent whole soybean cake). This then undergoes solvent oil extraction using hexane, and then a final desolventising and toasting process at temperatures of 100 - 115°C.

Both expeller and solvent oil extraction processes apply significant levels of heat to canola seed as it is being processed. The level of heat damage is influenced by the temperatures in operation, whether meal is double processed if from expeller plant operation and the degree of heat and time applied during desolventising and toasting.

4.2 Analysis Results

Chemical analysis results for canola seed used within this project are shown in Table 1. Crushing plant results have been grouped (Tables 2-9) into either expeller or solvent extraction results based upon the processing method employed to remove oil from the seedstock.

Moisture: levels for solvent extracted meals are higher than that found within expeller meals. The desolventising and toasting process is achieved through steam addition which increases meal moisture. There is additionally moisture contained within the gums added back to the finished meal.

Oil extraction: from canola seed is shown in Figure 1. This identifies the removal of oil through cold press, expeller or solvent extraction processing. Solvent processing plants remove 96%+ of the oil, with approximately half being extracted within the expeller and half in the solvent processing stages. In contrast, expeller plants are being operated to remove 75% of the canola seed oil content through the expeller processing stage.

The increase in oil content from post expeller or post solvent extraction to finished meal reflects the addition of gums back to the meal stream. Although processors vary in their level of oil refining and method of adding gums back to the finished meal, the addition rate is in the range 0 - 2%.

Fatty acids profiles: (Table 3) vary between expeller and solvent extracted meals. The changes in the major fatty acids from seed, through in-process sampling to finished meal is shown in Table 4. Palmitic acid and linoleic acid were consistently higher in solvent extracted meal than in expeller meal. Conversely, oleic acid and linolenic acid were higher in expeller meal. Linoleic acid content within the finished meal is a function of the residual oil, with solvent meals containing less linoleic acid relative to expeller and cold press meals.

Protein content: of finished meal varies both within and between crushing plants. Crude protein in the finished meal is positively correlated with canola seed protein content and negatively correlated with canola seed oil content (Figure 6). Due to the location of crushing plants taking part in this project, canola seed was derived from crops grown in NSW, Victoria, South Australia and Western Australia and harvested as part of the 05/06 harvest crop.

Fibre content: of finished meal was similar for both solvent and expeller meals.

Water soluble carbohydrates: or free sugar content, was also similar for both solvent and expeller meals.

Glucosinolate levels: were low in all finished meal samples. The change in glucosinolate content from seed through each stage of processing is shown in Figure 4. Data is expressed on an oil free and 10% moisture basis to take account of the major changes occurring with oil extraction. There was a decline in glucosinolate content with increasing levels of heat during processing, with both expeller and solvent extracted meals showing reduced glucosinolate levels compared to cold press meals.

Sinapine levels: also showed a trend to decline with heat processing (Figure 5), the greatest reduction occurring with desolventising and toasting (DT).

Amino acid profile: for canola meal is shown in Table 5 and 6. There is a trend for higher total lysine in crude protein with cold press meal, with both expeller and solvent extracted meals having lower total lysine levels. Table 6 identifies total, reactive and revert lysine in finished meal.

Mineral assay: results are shown in Table 7. Figure 4 and Table 8. identifies the relationship between total phosphorus and phytate phosphorus. Phytate phosphorus is identified as representing 87% of total phosphorus content. Cold pressed canola meal is shown to have less IP_5 phytate bound phosphorus than expeller or solvent meals. Figures 3. provides the correlation between phytate phosphorus and total phosphorus.

Figure 1 Oil content of seed, in-process and finished meal canola samples (%, as received)

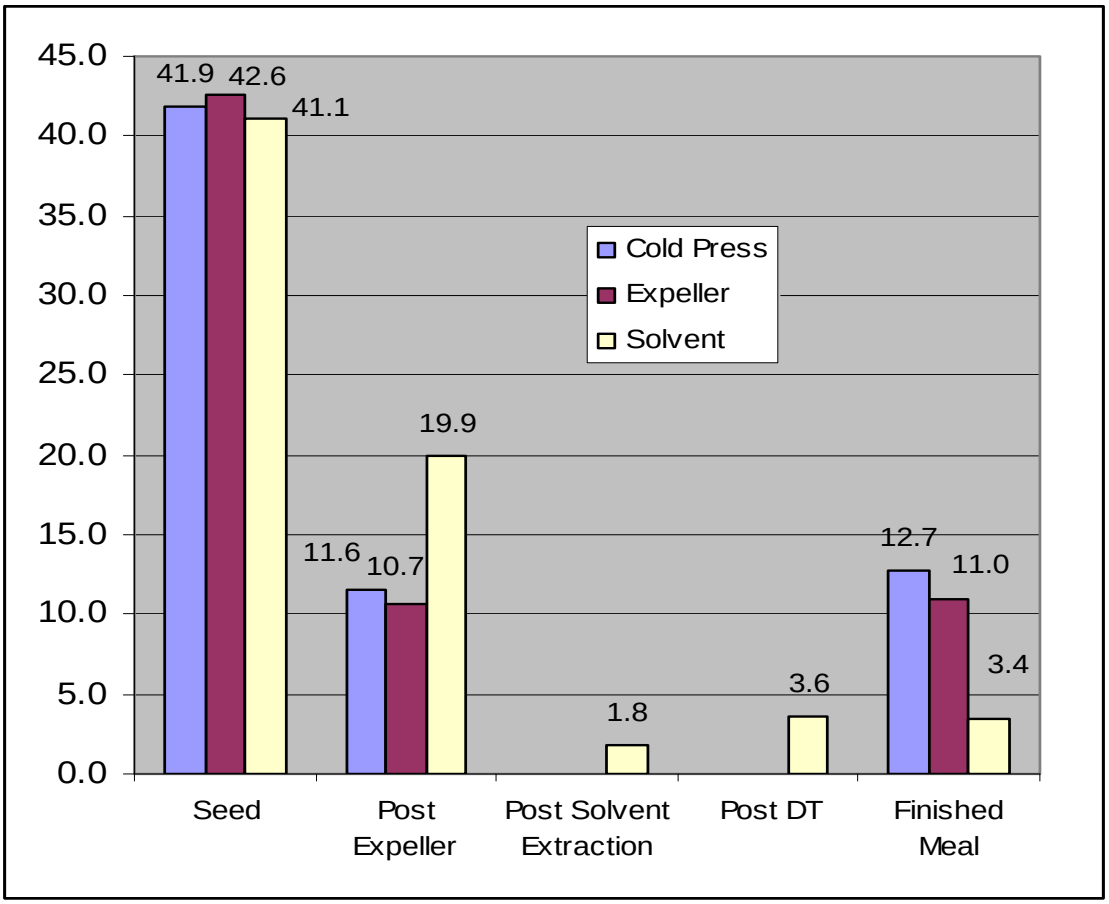


Table 1 Chemical Composition of canola seed (as received)

		Expeller Extracted Meal					Solvent Extracted Meal				
Nutrient	Units	n	Mean	Min.	Max.	SD	n	Mean	Min.	Max.	SD
Moisture	%	36	5.8	4.9	6.7	0.47	27	5.8	5.3	6.3	0.27
Crude Protein	%	36	23.7	20.1	28.9	2.27	27	23.7	22.2	26.4	1.06
Crude Fat	%	36	42.4	35.5	46.4	2.42	27	41.1	36.2	42.6	1.41
Glucosinolates	µmoles/g	36	6.1	3.6	7.9	1.11	27	6.3	4.1	9.2	1.01
Sinapine	g/kg	12	6.8	6.0	7.5	0.060	9	6.4	6.1	6.9	0.28

Table 2 Chemical Composition of expeller and solvent extracted canola meal (as received)

		Expeller Extracted Meal					Solvent Extracted Meal				
Nutrient	**Units**	**n**	**Mean**	**Min.**	**Max.**	**SD**	**n**	**Mean**	**Min.**	**Max.**	**SD**
Moisture	%	41	7.1	3.9	11.9	2.15	27	10.7	9.3	12.0	0.86
Crude Protein	%	41	36.3	31.6	41.7	2.62	27	37.3	33.3	42.5	1.87
Crude Fat	%	41	11.1	8.5	17.0	1.55	27	3.4	1.8	4.8	0.7
Linoleic Acid	%	41	2.40	1.90	3.47	0.312	27	0.87	0.45	1.16	0.161
Crude Fibre	%	17	10.6	9.6	13.2	0.98	9	9.85	9.1	10.2	0.39
NDF	%	17	24.1	20.9	28.1	1.88	9	24.1	21.7	27.2	0.90
ADF	%	17	16.9	15.8	19.3	0.88	9	16.4	14.6	17.2	0.81
Free Sugars	%	17	9.8	8.8	10.5	0.54	9	10.5	10.0	11.1	0.47
Ash	%	17	6.3	5.5	7.1	0.47	9	7.3	6.7	8.7	0.60
Glucosinolates	µmoles/g	41	5.26	2.36	8.92	1.720	27	1.73	0.49	3.09	0.790
Sinapine	g/kg	17	9.7	8.2	11.0	0.876	9	7.9	6.8	9.3	0.828
Bulk Density	kg/hl	41	59.2	54.0	66.5	2.39	27	52.4	47.5	52.5	2.61

Table 3 Fatty acid composition of oil (percentages of mass individual fatty acids identified) in expeller and solvent extracted canola meal

	Expeller Extracted Meal n=41				Solvent Extracted Meal n=27			
Fatty Acid	**Mean**	**Min.**	**Max.**	**SD**	**Mean**	**Min.**	**Max.**	**SD**
C14:0	0.08	0.02	0.11	0.021	0.14	0.06	0.26	0.037
C16:0	5.17	4.61	6.26	0.354	7.45	6.46	8.31	0.510
C16:1	0.66	0.44	0.87	0.091	1.82	1.06	2.72	0.401
C18:0	2.05	1.78	2.35	0.162	2.00	1.62	2.40	0.265
C18:1	58.81	54.84	62.04	1.673	53.90	51.79	57.55	1.540
C18:2	21.61	20.06	25.34	1.025	25.43	23.63	27.44	1.012
C18:3	9.66	7.66	11.29	0.998	7.87	6.88	9.03	0.509
C20:0	0.46	0.28	0.59	0.069	0.34	0.18	0.48	0.082
C20:1	0.82	0.61	0.97	0.077	0.47	0.26	0.66	0.093
C22:0	0.24	0.03	0.48	0.067	0.20	0.12	0.37	0.055
C22:1	0.12	0.03	0.54	0.102	0.07	0.02	0.14	0.036
C24:0	0.19	0.06	0.76	0.118	0.17	0.01	0.34	0.082
C24:1	0.14	0.01	0.29	0.049	0.13	0.04	0.34	0.070

Table 4 Fatty acid profile of oil in canola seed, in-process and finished meal samples from expeller and solvent extraction processing systems (percentages of mass individual fatty acids identified)

Extraction Process	Fatty Acid	Seed	Expeller	Post Solvent	Post DT	Finished Meal
Expeller	C16:0	4.2	5.0			5.17
Solvent	C16:0	4.3	4.7	7.26	7.17	7.45
Expeller	C18:0	2.0	2.0			2.06
Solvent	C18:0	2.1	2.0	2.19	1.97	2.00
Expeller	C18:1	61.8	58.9			58.90
Solvent	C18:1	61.7	60.7	52.86	54.20	53.90
Expeller	C18:2	19.3	21.4			21.52
Solvent	C18:2	19.3	20.4	25.80	25.33	25.43

Table 5 Amino acid content of expeller and solvent extracted canola meal (g/kg, as received)

	Expeller Extracted Meal n=9				Solvent Extracted Meal n=17			
Amino Acid	**Mean**	**Min.**	**Max.**	**SD**	**Mean**	**Min.**	**Max.**	**SD**
Methionine	7.0	6.2	7.6	0.50	7.2	6.7	7.7	0.26
Cystine	8.6	7.7	9.4	0.53	8.7	8.2	9.4	0.39
M+C	15.6	14.0	17.0	0.95	16.0	15.0	17.3	0.64
Lysine	19.7	17.7	21.1	1.05	20.2	19.5	21.4	0.58
Threonine	15.0	13.7	16.1	0.71	15.6	14.9	16.5	0.46
Tryptophan	4.9	4.2	5.4	0.40	5.1	4.8	5.4	0.18
Arginine	21.5	18.6	23.9	1.67	22.1	20.8	24.0	0.92
Isoleucine	13.9	12.5	14.9	0.80	14.3	13.5	15.2	0.45
Leucine	24.3	21.5	26.4	1.54	25.3	23.7	27.4	1.03
Valine	17.9	16.4	19.0	0.88	18.6	17.5	19.5	0.53
Histidine	9.5	8.5	10.2	0.51	9.9	9.3	10.5	0.36
Phenylalanine	14.1	12.3	15.4	1.00	14.6	13.7	15.6	0.50

Table 6 ***Amino acid content of expeller and solvent extracted canola meal (% in crude protein)***

	Expeller Extracted Meal n=17	Solvent Extracted Meal n=9	All Meal n=26
Amino Acid	**Mean**	**Mean**	**Mean**
Methionine	1.98	1.94	1.96
Cystine	2.44	2.36	2.41
M+C	4.43	4.33	4.39
Lysine	5.59	5.46	5.55
Threonine	4.25	4.23	4.24
Tryptophan	1.37	1.37	1.37
Arginine	6.09	5.98	6.05
Isoleucine	3.92	3.87	3.91
Leucine	6.88	6.85	6.87
Valine	5.08	5.03	5.06
Histidine	2.68	2.67	2.68
Phenylalanine	3.99	3.95	3.98

Figure 2 Total lysine in crude protein of cold press, expeller and solvent extracted canola meal samples (% in crude protein). Data points represent individual daily samples

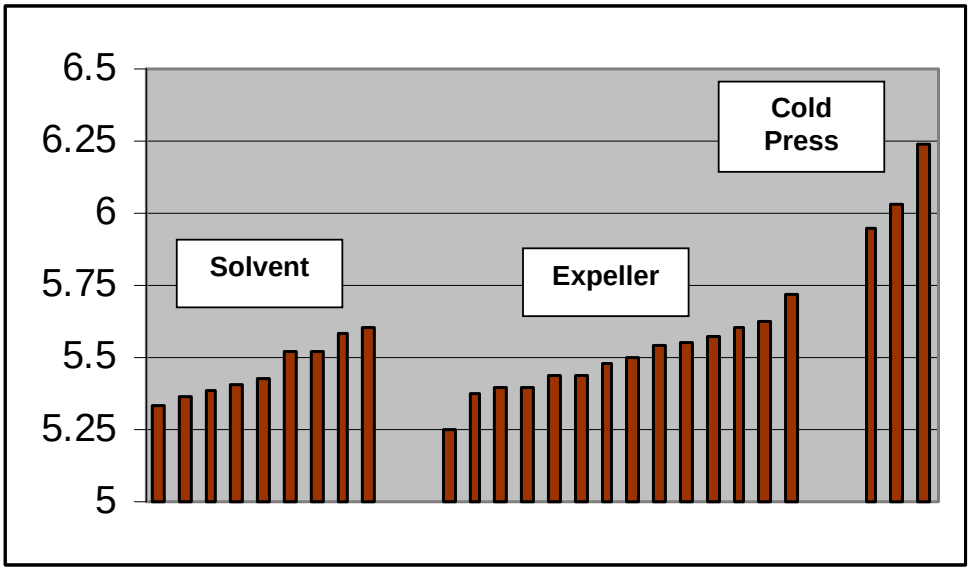


Table 7 Total, reactive and revert lysine content of cold pressed, expeller and solvent extracted canola meals (g/kg, as received)

	Cold Pressed	Expeller	Solvent
Total Lysine	20.68	19.58	20.17
Reactive Lysine	17.80	15.46	15.42
Non Reactive - % of total	13.9%	21.0%	23.5%

Table 8 Mineral content of canola meal (as received)

		Canola Meal n=26			
Mineral	**Units**	**Mean**	**Min.**	**Max.**	**SD**
Calcium	%	0.56	0.45	0.67	0.056
Phosphorus	%	0.96	0.79	1.19	0.116
Phytate-P (1)	%	0.83	0.63	1.01	1.084
Phytate-P in Total-P	%	85.9	67.0	95.0	-
Chlorine	%	0.10	0.06	0.13	0.019
Potassium	%	1.26	1.05	1.44	1.010
Sulphur	%	0.62	0.50	0.70	0.057
Magnesium	%	0.47	0.38	0.55	0.052
Copper	mg/kg	3.9	3.0	4.7	0.39
Iron	mg/kg	138	78	457	78.4
Manganese	mg/kg	52	40	61	6.5
Zinc	mg/kg	45	36	54	4.9

(1) IP_5 and IP_6 combined

Table 9 Phytate phosphorus content of cold press, expeller and solvent extracted canola meal samples

	Total Phosphorus (mg/g)	Phytate-P IP_6 (mg/g)	Phytate-P IP_5 (mg/g)	Phytate-P $IP_6 + IP_5$ (mg/g)	Proportion of phytate-P in total P (%)	IP_6: IP_5
Solvent	10.19	7.989	0.831	8.820	0.866	10.00
Expeller	9.57	7.586	0.857	8.444	0.882	9.28
Cold Press	8.40	7.030	0.197	7.227	0.861	41.19

Figure 3 Relationship between total and phytate phosphorus in canola meal

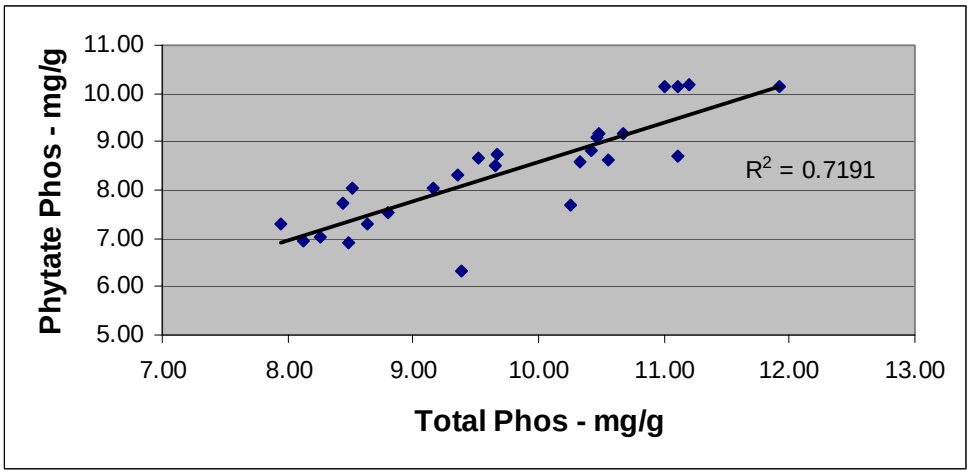


Figure 4 Glucosinolate content of seed, in-process and finished meal canola samples (µmoles/g, oil free 10% moisture basis)

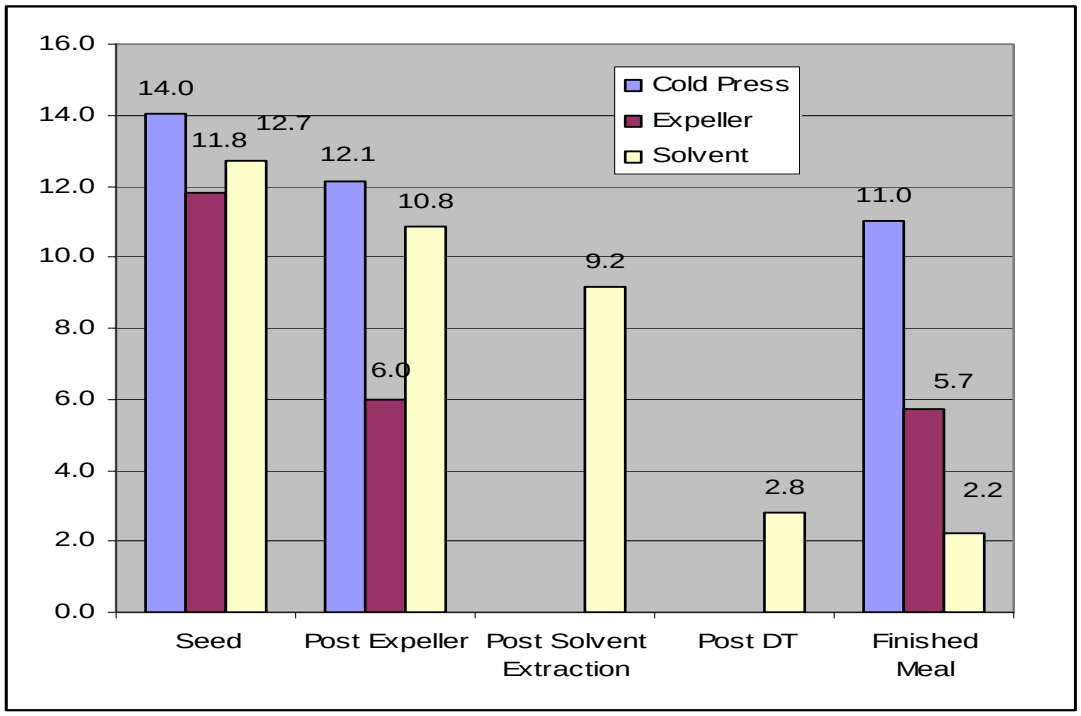


Figure 5 Sinapine content of seed, in-process and finished meal canola samples (g/kg, oil free 10% moisture basis)

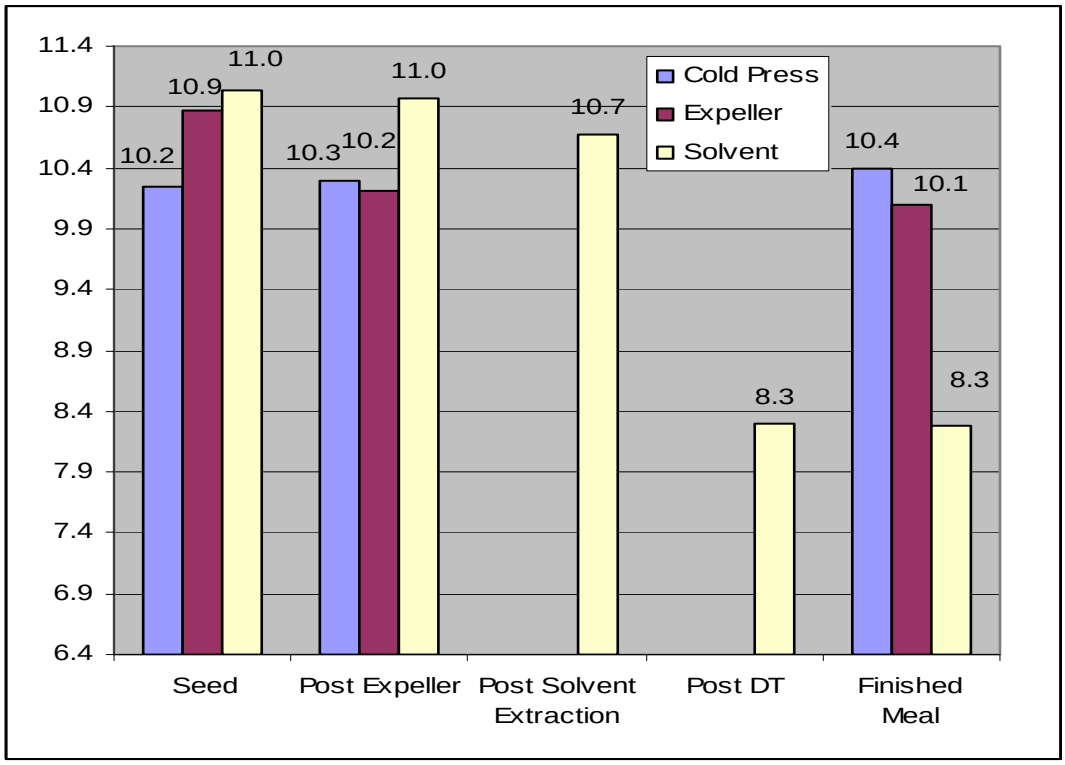
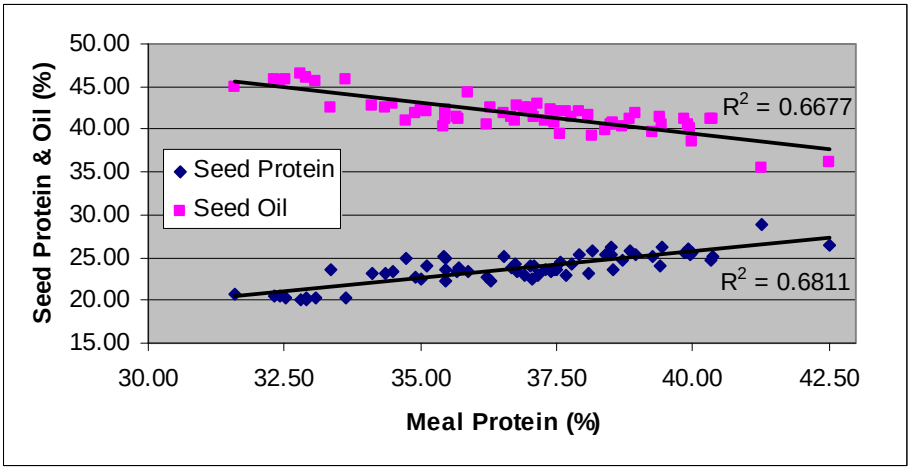


Figure 6 Relationship between the canola seed protein and oil content to finished meal protein content (%, as received)



5 Discussion

5.1 Chemical Composition

5.1.1 Oil Content

The processing systems in use have a significant impact upon the amount of oil extracted from canola seed and the residual oil within the finished meal. The project results provide data relating to the variation occurring between meal samples derived from both expeller and solvent extraction plants. There is a greater range in residual oil in meal resulting from expeller plant processing. Solvent extraction provides a more efficient oil extraction process which results in more consistent finished meal oil content. As residual oil is recognised as impacting upon digestible energy content for pigs, the results of this project support the recommendations of van Barneveld (1998) that expeller processed canola meal samples should be tested for crude protein and fat prior to use, whilst solvent extracted meals samples are more consistent for fat content and only protein analysis is required by stockfeed manufacturers and pig producers.

Canola meal provides a source of linoleic acid to meet the requirements of some livestock species. The level of linoleic acid found in canola meal is of significance, with higher levels being supplied from meals that contain higher residual oil content.

The practice of adding gums back to the finished meal results in an increase in oil content and digestible energy. This process also results in a reduction in meal dust levels. Whilst the results indicate some crushers are not adding back gums to their meal, the typical addition rate is in the order 0.5 – 2%. This addition level is in line with reported gum addition rates within the Canadian canola industry (Hickling 2001).

The fatty acid profile is different between expeller and solvent meal. Whilst there is recognised variation in fatty acid levels in canola seed (McFadden et al. 2006), the data from this project would indicate that there are differences between processing systems. Solvent oil extraction removes a greater amount of oil from the seed, the residual oil left after the solvent process differs from that remaining after expeller extraction. Palmitic acid and linoleic acid were also consistently higher in solvent extracted meal but oleic and linolenic acids were lower than expeller meal. This would suggest that oleic and linolenic acids are more easily removed from the seed under mechanical extraction.

5.1.2 Protein Content

Both canola seed stock and finished meal protein levels have been identified as being highly variable. The major factor affecting meal protein is canola seed protein and oil content. Consistent cropping years will result more consistent finished meal quality. The 2005 harvest year, as identified by McFadden et al. (2006), resulted in variable canola seed quality, with some regions providing high oil content seed whilst others regions experienced a dry finish with lower oil and higher protein seed. Table 10. provides a comparison between the seed samples used within this project and those derived from bulk handler silo samples from the 2005 harvest year. Seed used within this project is in line with the wider harvest sampling, with the exception of some lower oil and higher protein seed in use at one of the crushing plants.

It should be noted that the intent of this project was to assess the potential level of variation which can occur, with crushers being instructed to collect samples when seed was from a consistent source during each sampling week. In some cases this would have been canola seed supplied direct from farm. The 2005 Quality of Australian Canola results have been derived from retained bulk handler silo samples. There would be a level of co-mingling of different individual deliveries consolidated to provide these silo samples.

Table 10 Canola seed oil, protein and glucosinolate content relative to published 2005 harvest seed

	Oil 6% moist basis	Protein Oil free 10% moist basis	Glucosinolates 6% moist basis
Project Samples			
n	63	63	63
Mean	41.8	38.9	6.2
Min	35.4	35.6	3.6
Max	46.4	42.7	9.3
SD	2.19	1.88	1.08
CV	5.3%	4.8%	17.4%
McFadden et al (2006)			
n	91	91	91
Mean	41.65	36.36	7.84
Min	36.50	32.10	3.00
Max	46.10	40.20	12.00
SD	1.76	1.96	2.05
CV	4.2%	5.4%	26.1%

The protein content of canola meal is a function of the canola seed protein, oil and carbohydrate fractions, together with the efficiency of oil extraction from the seed and changes in moisture content through processing. The average protein content of both expeller and solvent canola meal were found to be 36.3% and 37.3% respectively. This is higher than comparative results for Australian canola meal published within either the ALFI (2004) 35.7% or Degussa (2001) 35.0% databases. Over recent years, canola breeding programs have been increasing canola seed oil content through plant selection; this has been providing indirect selection pressure against canola seed coat and fibre content with a corresponding increase in finished meal protein (R.J.Mailer, per. comm.).

5.1.3 Bulk Density

Expeller extracted meal is on average 13% heavier than solvent meal. This difference is likely to be a function of the higher oil content of the expeller meal and the physical nature of the meal particles to compact together. Additionally, particle size of the finished meal will have an impact upon bulk density, with finer grinding resulting in heavier meal samples.

5.1.4 Fibre Content

The crude fibre of expeller 11.5% and solvent 10.9% is lower than that reported by van Barneveld (1998) 12.7 – 14.9%. Similarly NDF levels of 24.1% are lower than canola meal results from 2000-2001 samples (Perez-Maldonado 2003) 24.0 – 28.0. Australia has an active canola breeding program which has made considerable progress in breeding canola varieties with both higher oil and protein contents. These breeding programs are resulting in canola seed with less seed coat (Mailer, per com) and a reduction in the fibre content of the seed and resulting meal.

It could be speculated that a decline in fibre levels within canola meal would provide an increase in digestible energy for pig feeding. No measure of energy content was completed within this project.

5.1.5 Anti-nutritional Content

Canola contains a number of glucosinolates which can break down into compounds (thiocyanate, isothiocyanate, oxazolidinethione and nitriles) which have a negative effect upon animal performance. The level of glucosinolates found in canola seed, range 3.6 – 9.2 µmoles/g, are low and reflects the successful breeding of low glucosinolate canola varieties within Australia. McFadden (2006) has reported that the average glucosinolates level for Australian canola seed has remained below 10 umoles/g for the last 10 years although water-stressed sites sometimes result in higher levels.

Heat processing either through expeller or solvent extraction resulted in a reduction in glucosinolate levels when compared to either seed or cold press meal samples. Newkirk et al. (2003) looking at canola meal produced from solvent extraction plants found that the desolventising and toasting process operated in Canadian oilseed processing plants reduced glucosinolate levels by around 40%. The data in this study would indicate that the degradation of glucosinolates during processing is greater than 40%, this being in the order of 50% for expeller and 80% for solvent processed meals.

The glucosinolate levels found for expeller and solvent meals were in the range 0.5 to 8.9 µmoles/g. Mullan et al. (2000) found that glucosinolates levels above 10 µmoles/g depressed pig feed intake when canola meal was fed at 15%. King et al (2001) found that use of canola meal with 4-5 µmoles/g glucosinolates did not affect pig performance, it was concluded that canola meal could be included in weaner, grower and lactating sow diets at up to 25%, 30% and 20% respectively. The level of glucosinolates found within this project is unlikely to have a negative effect on pig performance.

The levels of sinapine 0.68 – 1.1% found are similar to those reported for Canadian canola meal (Hickling 2001) and those reported for Australian canola meal (Perez-Maldonado 2003). Whilst of no significance for pig production, sinapine levels can limit maximum inclusion rates of canola meal in feeds for brown egg laying hens due to resulting “fishy taints” in eggs produced.

Expeller processing did not provide any reduction in sinapine levels. Within samples from solvent processing plants, the heat applied through the desolventising and toasting process resulted in a 22% decline in sinapine levels in the finished meal.

The reduction in glucosinolates and sinapine from the desolventising and toasting process is likely to be a function of the application of moisture and heat as well as longer time period meal is subject to these conditions as it passes through the processing equipment.

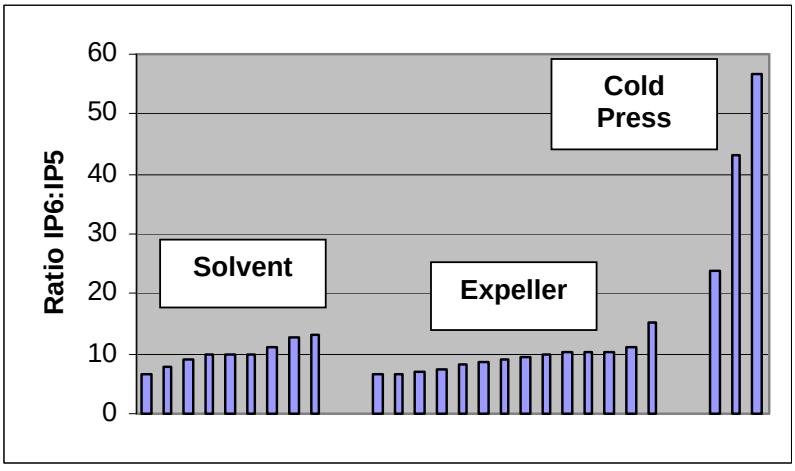
5.1.6 Phytate Phosphorus

It is recognised that phytate phosphorus in plant materials is normally positively correlated with total phosphorus content, the results of this study confirm this relationship for canola meal. The level of phytate phosphorus found within this study 0.83% is higher than that found by Selle et al. (2003) at 0.67%. Additionally the proportion of phytate phosphorus in total phosphorus was also found to be higher (85.9% vs 76.4%). The phytate phosphorus results from this study were derived from HPLC assay methodology, whereas those generated by Selle et. al. were produced from ferric chloride precipitation. Whilst it is uncertain whether the differing assay technique is responsible for provision of higher phytate phosphorus results, the ferric chloride assay is recognised as not recovering all phytate phosphorus in some feed ingredients such as lupins and faba beans.

Phytate, the mixed salt of phytic acid, is predominately found as inositol hexaphosphate (IP_6) and pentaphosphate (IP_5) esters. The advantage of use of the HPLC assay methodology is in the provision of data for the esters of *myo*-inositol phosphate present. Cold press canola meal compared to both expeller and solvent meals has been found to have much lower IP_5 levels and a higher ratio IP_6: IP_5 (Figure7). Mechanical shear forces experienced during oil extraction may be resulting in releasing one P moiety from the phytate molecule (*myo*-inositol hexaphosphate) and effectively partially converting IP_6 to IP_5 in both expeller and solvent extracted meals (P.H. Selle, pers. comm.). It is speculated that there may be a positive processing effect on phytate phosphorus with oilseed crushing as phosphorus from IP_5 is more available than phosphorus from IP_6.

Myo-inositol phosphate esters are bound to magnesium and potassium in mineral-phytate complexes (Lott et al. 2000). Mineral analyses of canola meal samples has provided a trend for positive correlations between phytate phosphorus and calcium (R^2 = 0.404), potassium (R^2 = 0.292) and magnesium (R^2 = 0.354). There was no correlation found between phytate phosphorus and meal protein, crude fibre, ADF or NDF.

Figure 7 Ratio IP_6: IP_5 phytate phosphorus for canola meal samples from solvent, expeller or cold press processing



5.1.7 Mineral Content

The mineral results from Australian canola meal are in close agreement with those provided for Canadian canola meal (Hickling 2001). There were no identified differences in mineral content between cold press, expeller and solvent canola meals.

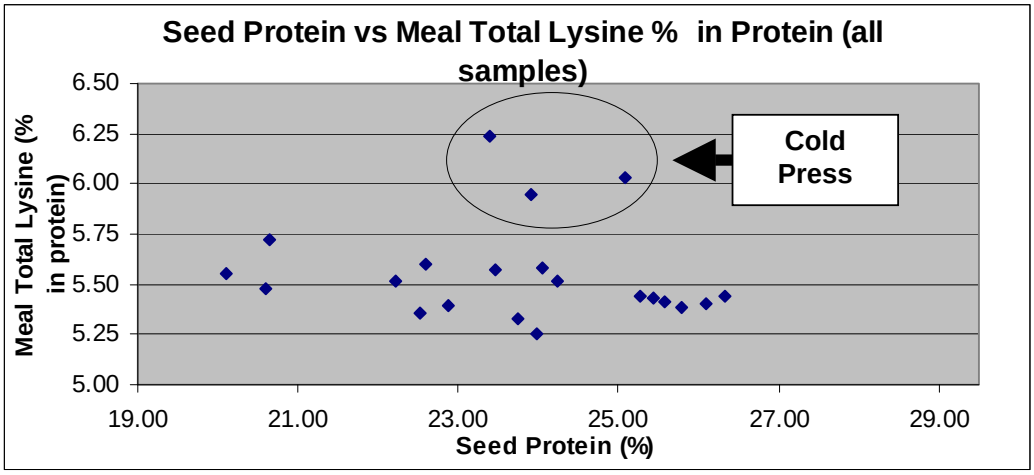
5.2 Protein Quality

This project was undertaken to assess the effect processing has upon meal quality. This work has been in part a result of similar work undertaken in Canada which has identified the negative impact heat processing has upon protein quality.

The results of this study have provided supporting evidence to suggest that both expeller and solvent meal processing systems are reducing meal protein quality for pig feeding applications.

The total lysine content of protein in canola meal from both expeller and solvent plants is 9-10% lower relative to that provided from cold pressed meal. This difference is not due to difference in canola seed stock as shown within Figure 8. Newkirk et al (2003) found that heat applied through desolventising and toasting resulted in a 10% decline in lysine content in addition to a reduction in lysine digestibility. Similarly, the results from van Barneveld (1998) indicate that both expeller and solvent processing reduce total lysine in the protein of canola meal by 16-17%.

Figure 8 Relationship between canola seed protein (%) and finished meal total lysine (% in protein)



Application of heat through steam and pressure results in reduced digestibility and availability of amino acids. A number of studies (van Barneveld 1998, Newkirk et al., 2003) have found that heat processing through both expeller and solvent meal production has a negative impact upon canola meal quality for monogastrics. Lysine has been shown to be more affected by heat processing than other amino acids (Newkirk et al., 2003), this likely to be due to Maillard reactions as canola meal contains considerable quantities of soluble sugars.

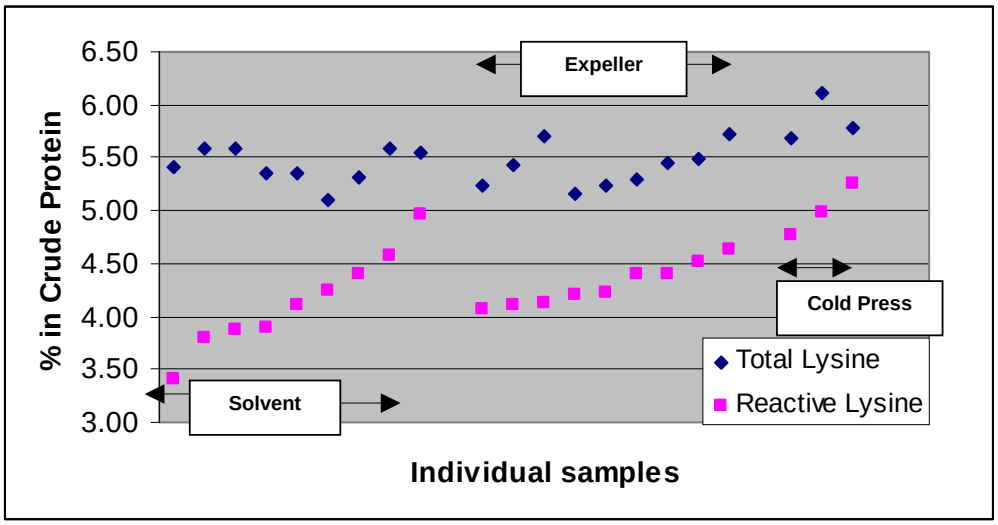
This study has utilised the in vitro reactive lysine analysis as a means of assessing protein quality and the potential of heat damage occurring during processing. Rutherfurd et al. (1997) demonstrated the use of reactive lysine as a measure of available lysine in heat processed feedstuffs. Use of this assay technique for canola meal was validated by van Barneveld (1998). In heat processed feed ingredients, amino acids may form chemical complexes with carbohydrates, although the amino acid may be digested and absorbed, the amino acid complex is unavailable to the animal for metabolism. Lysine is more susceptible to this form of heat damage and conventional in vitro measures may overestimate lysine availability. The measure of reactive lysine is a "chemistry-based" assay, based upon the direct measurement of digestibility of chemically available or "reactive" lysine.

The results of this project identified lower reactive lysine levels for both expeller and solvent canola meal than that found within cold press meal, the amount of lysine becoming unavailable due to heat processing is on average around 9-10%. Data presented in Graph 7 for individual meal samples identifies a large range of reactive lysine results. With solvent extracted meals, there are samples with lower lysine availability loss, these being equivalent to cold pressed meals, whilst other samples are showing significant heat damage.

The range in reactive lysine results for both solvent and expeller meal samples would indicate that there are considerable differences in heat processing conditions being applied within commercial crushing plants. Whilst this variation will impact upon pig performance, it also provides an indication that opportunity exists for crushers to modify processing conditions to potentially reduce the extent of heat damage to protein. The use of reactive lysine analysis has potential to provide a practical analysis tool for use within quality assurance programs.

Use of neutral detergent insoluble nitrogen (NDIN) analysis of canola meal samples has been proposed as a predictor of lysine digestibility (Classen et al. 2004). Analysis of samples within this project provided no data to support the use of NDIN as a measure of the effect of heat processing upon meal quality. The reason behind this outcome is unknown and further work is required to validate the NDIN assay technique as a tool for predicting protein meal quality.

Figure 9 Total and reactive lysine for individual canola meal samples (% in crude protein). Each data point represents daily meal samples.



5.3 Reactive Lysine NIR Calibration

Van Barneveld (2001) demonstrated the use of NIR technology to develop an NIR calibration for reactive lysine. This technology was identified as having practical application within the stockfeed industry to assess the quality of canola meal and the potential impact of heat processing upon protein quality.

The samples and reactive lysine analyses from this project are subject to incorporation within a revised reactive lysine NIR calibration. It is the intent of the current project team to complete this NIR calibration development for further use in canola meal quality work. Such a calibration will provide a lower cost methodology which will provide a powerful tool for use in defining changes in meal quality resulting from processing changes implemented at crushing plant level.

5.4 Effects of Processing

The results of this project provides a number of pieces of evidence which indicate that heat processing applied through both expeller and solvent oil extraction have a negative effect upon meal quality. In summary, these can be listed as:

- Glucosinolate levels reduced in expeller and solvent meals, the level of reduction is greater in solvent than for expeller meal.
- Sinapine levels reduced in solvent meal.
- Total lysine content reduced in both expeller and solvent meals.
- Reactive lysine levels lower in both expeller and solvent meals.
- Phytate-P concentration of IP_5 is increased relative to IP_6 in both expeller and solvent meals.

Data provision, relating to actual crushing conditions from crushing plants has been limited due to commercial confidentiality. However based upon the limited amount of available data, as well as information from overseas, there is a clear link between processing conditions and meal quality.

It is recognised that crushing plants are operated with differing conditions applied in terms of seed conditioning, expeller temperatures, solvent extraction and desolventising and toasting equipment throughput and temperatures. Each crusher will have defined an ideal set of operating conditions to suit their equipment to maximise throughput and oil recovery, both of which can be easily measured. There has to date been no readily available method of assessing the impact of on site changes to processing conditions upon meal quality.

Whilst it could be assumed that meals produced from solvent extraction plants should exhibit higher levels of heat damage than expeller plants, the results of this project, as well as those of van Barneveld (1998) would suggest that similar amounts of heat damage can occur in expeller and solvent extraction processing plants. Based upon this conclusion, it would seem that under Australian oilseed processing conditions, there is significant heat damage occurring within the expeller screw press. In Canada, where only solvent plants operate, industry results have identified that the major heat damage is occurring within the DT process (Classen et al., 2004).

The major processing issues of relevance for the oilseed crushing industry are the effects of temperature applied via steam and pressure within both the expeller and desolventising and toasting operations. It is of note that Australian canola seed is low in glucosinolates, and that application of heat to reduce these levels is not required in canola meal processing.

The amount of variability in reactive lysine results from individual meal samples would indicate that there may be potential for crushers to modify processing conditions to reduce processing temperatures, whilst not losing oil extraction efficiency. This industry potential is subject to further study. The use of reactive lysine NIR technology would provide a lower cost tool for assessment of changes in processing conditions and their impact upon meal quality for pig feeding.

6 Impact on Industry

Canola meal is used as a source of protein, energy and minerals in the diets of livestock. The utilisation of vegetable protein meals by livestock industry is defined within Table 11.

Table 11 ***Vegetable and canola meal use by livestock industry***

Livestock Sector	Feed tonnes (SFMCA est)	Veg. protein usage (SFMCA est)	Canola meal usage (AOF est)	Canola meal % of protein meal (AOF est)
Pigs	1,579,000	221,000	50,830	23
Poultry	2,851,000	342,000	136,800	40
Dairy	2,820,000	141,000	105,750	75
Feedlots	2,579,000	103,000	4,120	4
Aquaculture & other	485,000	39,000	1,950	5
Total	10,314,000	846,000	299,450	

Source: AOF, SFMCA

Generally canola meal is sold to the stockfeed industry based upon its supply of nutrients relative to other competing protein sources such as soybean meal, meat meal and grain pulses. Although the pig industry is a significant user of Australian canola meal, it is also reliant upon the importation of large volumes of soybean meal. Thus there is opportunity for the Australian pig industry to better utilise canola meal as a source of nutrients.

The relative availability of amino acids is defined by the nutritionist, with canola meal amino acid availability being defined as less than that of soybean meal. This lower amino acid availability results in a downgrading of the relative value of canola meal, which results in lower prices paid for canola meal and less efficient utilisation of canola meal's amino acid supply.

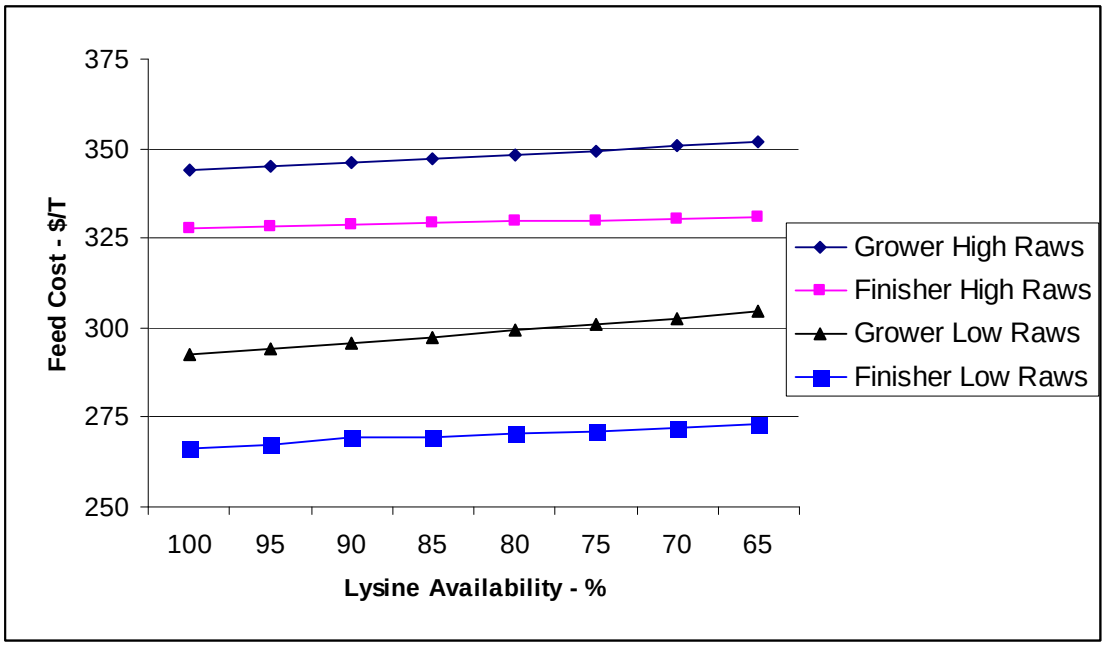
This project has identified that both the expeller and solvent oilseed crushing process has a negative impact upon protein digestibility. The impact of this heat damage can be evaluated based upon varying the amino acid digestibility applied to pig feed formulations. An evaluation exercise has been completed utilising a common basket of pig feed raw materials (Table 12). Due to the present day drought driven escalation in raw material, two data sets have been used to represent higher and lower cost materials.

Table 12 Raw material costs used within canola meal evaluation (delivered feed mill basis)

Raw Material	Low Cost - $/T	High Cost - $/T
Wheat	240	310
Barley	220	300
Canola Meal	310	350
Soybean Meal	435	435
Meat Meal	410	410
Blood Meal	760	760
Tallow	450	450
Lysine	2000	4000

Based upon growing feeds representing the largest volume of pig feed utilised, the evaluation analysis has been completed using both pig grower and finisher rations. Least cost formulations were generated based upon the grower feed containing 0.70g available lysine/MJ DE and 14.0MJ DE and the finisher feed containing 0.56g available lysine/MJ DE and 13.4MJ DE. Lysine availability was varied from 100% down to 65% in 5% unit increments. Total lysine content of canola meal was based upon 2.0% lysine. The results defined in terms of cost of feed are shown within Figure 10.

Figure 10 Feed rations costs using variable lysine availability for grower and finisher pig diets with either high or low raw material costs



The least cost formulation data is showing the increase in feed cost as canola meal lysine availability is reduced. The rate of increase is greater for grower than finisher feed due to the higher lysine specification. There is also a greater cost increase with higher lysine costs.

Based upon the least cost data used, increasing lysine availability by 10 units (75 to 85%) increases the value provided by canola meal by:

Grower - High lysine cost	$17.70/tonne of canola meal
Finisher – High lysine cost	$9.45/tonne of canola meal
Grower – Low lysine cost	$11.45/tonne of canola meal
Finisher – Low lysine cost	$4.25/tonne of canola meal

It should be noted that the relative value of canola meal will vary with changes in raw material costs and pig feed specifications. This evaluation exercise is completed to provide some indicative figures relating to the added value which can be obtained from increasing lysine availability. Additional changes in availability of other amino acids have not been factored into this evaluation.

Based simplistically upon the added value derived from modifying canola meal crushing conditions to increase lysine availability, there is significant capacity to derive benefits to both the oilseed crushing and pig industries. Based upon an average benefit improvement of 10% units of lysine digestibility, with an approximate pig industry canola meal usage of 45,000 tonnes, this equates to an industry benefit of $450,000 per annum (using $10/tonne benefit). Benefits derived from improved canola meal quality for pig production would also be of value for the poultry industries. The combined pig and poultry industry benefits would potentially exceed $1M per annum based upon existing canola meal usage. A higher quality canola meal would also provide further benefits in allowing higher usage rates within feeds as a replacement for imported soybean meal.

7 Conclusions and Recommendations

The differences in meal quality produced by different types of processors were expected based on earlier studies. However, the differences between processors using the same type of facilities were greater then expected. Clearly there is an opportunity to adjust processing conditions to produce a consistent high quality canola meal. This could be done to improve protein quality and at the same time, reduce negative aspects such as anti-nutritional components.

Australian canola growing and processing conditions are different to those in Canada and generally result in more variation between the finished batches of product. This variability is as critical as the heat damage caused by processing conditions as feed manufacturers typically formulate feed rations to the lowest expected canola meal quality parameter. By determining the optimum conditions for processing it is likely that processors will produce maximum quality, and therefore more consistent quality between plants.

This study has identified the following:

- The major factor affecting meal protein is canola seed protein and oil content.
- Expeller meal is lower in protein and higher in oil content.
- Residual oil in meal from expeller plants is more variable than meal from solvent plants.
- Lower canola meal crude fibre, ADF and NDF than in previous studies may correlate with plant breeding programs aimed at increasing oil and protein which has resulted in less seed coat.
- The glucosinolate levels found for expeller and solvent meals were in the range 0.5 to 8.9 µmoles/g and are unlikely to have a negative effect on pig performance.
- Levels of sinapine (0.68 – 1.1%) found are similar to those reported for Canadian canola meal and those previously reported for Australian canola meal.
- Phytate phosphorus found within this study is higher than that found in previous studies and requires further clarification.
- Mineral analyses are in close agreement with Canadian data.
- Both expeller and solvent meal processing systems are reducing meal protein quality for pig feeding applications.
- Processing results in a 15% loss of total lysine and a further 10% reduction in lysine availability.

Recommendations:

It is recommended that this study be expanded to focus on individual processing factors responsible for changes in meal quality to help the industry better understand linkages between processing conditions and meal quality. This includes a study of the mechanical extraction process and the time, temperature, moisture content and pressure utilised of the seed/expeller cake. It may also take into account the seed stock which may vary in moisture from 4-9% and oil contents from 35-50%. Similarly, the D/T process needs to be better understood and again the effects of temperature, moisture and drying time need to be studied.

Education of end-users is important to help them make better decisions on proportions of canola which can be used in feed rations. The myths used in the past regarding high glucosinolates and sinapine can be removed and decisions based on scientific data can be made available. The development of an Australian canola meal nutritional guide showing proximate analysis of the current canola types and the range of quality based on cultivar and environmental factors.

Measuring meal quality at the point of use will ensure the nutritionist take the maximum benefit in meal formula which in turn will reduce feed costs and improve performance. NIR spectroscopy can already provide almost instant analysis of protein, moisture, glucosinolates and crude protein. This can possibly be expanded to include reactive lysine level and crude fibre, NDF and ADF levels.

The next stage of the project should include:

1. A focussed study on 1-2 expeller and solvent plants. This should involve extraction of specific seed stocks with a wide range of oil, protein and moisture contents. Temperature, time, moisture and pressure should be monitored at all stages and the optimum conditions to give high quality protein with maximum removal of antinutritional components determined for each process.

2. NIR technology should be expanded to measure the important components in canola seed stock and finished meal to assist the processor in extracting the oil and the end-user in determining the optimum formulae. This includes the development of calibrations for reactive lysine, linoleic acid and fibre fractions.

3. An education program needs to be established to satisfy the needs of processors, nutritionists, end-users of the product as to processing requirements, quality parameters of the meal and benefits for stock.

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