Protection of Canola (Low Glucosinolate Rapeseed) Meal and Seed Protein from Ruminal Degradation - Review -

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ABSTRACT : Canola meal and seed are poor sources of ruminal undegraded protein (RUP). On average, canola meal and canola seed contains 35 and 14% RUP, respectively. Several protection methods are effective in reducing ruminal degradation of canola protein and in increasing RUP without affecting total tract protein digestibility. Heat (e.g., dry heat, moist heat and jet-sploding) and chemical (e.g., formaldehyde) treatments are the most common methods used to reduce ruminal degradability of canola protein. In most cases, heat treatments were found to be more effective than chemical treatments in protecting canola protein form ruminal degradation. Despite improvement in RUP content and intestinal availability of RUP, data form several studies showed little or no improvement in animal performance as a result of increasing the RUDP level of canola meal and seed. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 4 : 535-542*)

Key Words : Canola, Meal, Seed, Ruminal Undegraded Protein, Heat Treatment, Chemical Treatment

INTRODUCTION

Protein requirements of ruminants are met by microbial protein synthesized in the rumen, dietary protein that escapes rumen degradation and endogenous protein (NRC, 1996). Dietary protein requirements for ruminants are usually expressed in terms of ruminal degraded (RDP) and undegraded (RUP) protein (NRC, 1989, 1996).

To achieve maximum productivity, a combination of RDP and RUP should be fed especially for rapidly growing ruminants and high producing diary cows. In such situations, microbial protein production is often insufficient to meet animal requirements. Ruminant requirements for RUP can be satisfied by feeding dietary proteins with naturally low ruminal degradability (i.e., corn gluten meal, brewers grain and dehydrated alfalfa) or by feeding a highly degradable dietary protein which has been protected from ruminal microbial degradation (Windschitl and Stern, 1988; Griffin et al., 1993).

Canola (low glucosinolate rapeseed) meal is a common dietary protein source for ruminants in Canada. Like soybean meal protein, protein of canola meal is rapidly degraded in the rumen and is considered a poor source of RUP (Ha and Kennelly, 1984; Kirkpatrick and Kennelly, 1987). Feeding canola meal as the sole dietary protein source might not satisfy the protein requirements of high producing lactating dairy cows and rapidly growing ruminants (NRC, 1989, 1996).

Different physical and chemical methods have been researched to reduce the ruminal degradation of canola meal and seed and thus increase the amount of protein available postruminally. Physical methods of protecting dietary protein from ruminal degradation include heat treatment (e.g., dry heating and moist heating, and jet sploding) and coating with materials which are resistant to ruminal degradation such as blood, whey protein, and casein. Chemical treatments can be divided into two categories; treatments (e.g., formaldehyde) in which the chemicals combine with dietary protein and treatments (e.g., NaOH and propionic acid) in which the chemicals denature the protein structure. The objective of this review is to look at different methods that have been used to protect canola meal and seed protein from ruminal microbial degradation and show how such protection influences animal performance.

HEAT TREATMENT

Heat treatment is one of the most common methods used to reduce ruminal protein degradation and to increase the postruminal supply of amino acids. The technique is based on the fact that dietary protein consists of different fractions, which respond differently to various heat inputs (a function of both temperature and time of heating). According to Sniffen et al. (1992), five protein fractions can be identified namely non-protein nitrogen, rapidly degradable true protein, intermediately degradable true protein, slowly degradable true protein and unavailable protein. The non-protein nitrogen and the rapidly degradable true protein fractions denature at lower heat inputs and become intermediately or slowly degradable fractions based on the level of heat input. The slowly

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degradable protein fraction responds at higher heat inputs and usually becomes unavailable (heat damaged) protein via the Maillard reaction (Van Soest, 1987).

An optimum heat input varies from one dietary protein to another. The objective is to minimize the soluble fraction and maximize the slowly degradable fraction with little or no increase in the indigestible fraction (Van Soest, 1987). For a given protein source, the optimum heat input depends on several factors including moisture content, pH, carbohydrate content and composition, protein content and the presence of Maillard reaction-inhibiting materials such as sulfite (Van Soest, 1987).

Changes in the relative proportions of the protein fractions as a result of heat treatment can be detected by analyzing for soluble protein, neutral detergent insoluble protein and acid detergent insoluble protein. As the heat input increases, soluble protein decreases and the amount of protein associated with neutral detergent fiber increases (table 1). Moderate heat input will have little impact on the amount of protein associated with acid detergent fiber. However, heat-damaged protein generated by excessive heat input is usually characterized by elevated concentrations of acid detergent insoluble protein (table 1).

Table 1. Effect of heat treatment on protein fractions of unheated (control) and heated canola meal

	Protein fraction, % of CP		
	Soluble	Neutral detergent insoluble	Acid detergent insoluble
Dry heat[1]			
Control	32.5	12.3	5.1
125℃ for 10 min	16.6	46.4	7.0
145℃ for 10 min	9.7	67.6	35.5
Moist heat[2]			
Control	32.4	8.4	5.4
127℃ for 15 min	7.0	26.3	6.6
127℃ for 70 min	9.7	70.2	41.1
Micronization[3]			
Control	18.3	30.4	7.2
125℃ for 35 to 50 sec	4.3	49.5	16.3

[1] McKinnon et al. (1995).
[2] Moshtaghi Nia and Ingalls (1992).
[3] Jackman (Unpublished data).

Dry heat treatment

Dry heat treatment was one of the first methods utilized to protect canola meal protein from ruminal degradation. Mir et al. (1984) showed that ruminal degradability of canola meal protein is reduced by heating to 110℃ for 2 h or to 120℃ for 20 min. The results of that study were one of the early indications that temperature is more important than duration of heating in protecting canola meal protein from ruminal degradation. Lindberg et al. (1982) studied the effect of different heat inputs (heating to 100, 150 and 200℃ for 1 h) on ruminal degradability of rapeseed. They found that heating to 100℃ had no effect on ruminal protein degradability. However, heating to 150 and 200℃ reduced ruminal degardability of rapeseed protein by 18 and 52%, respectively.

The effect of short-term heat input (125 and 145℃ for 10, 20 and 30 min) on canola meal protein has been studied by McKinnon et al. (1991). They found that heating canola meal to 125 or 145℃ for 10 min or more reduced dry matter and crude protein degradability of canola meal. At 125℃, the proportional increase in RUP was more than the increase in acid detergent insoluble protein. However, at 145℃ the proportional increase in acid detergent insoluble protein was more than the increase in RUP, indicating the presence of heat-damaged protein.

Mustafa et al. (1997) determined ruminal crude protein degradability of heated canola meal (125℃ for 20 min) relative to other protein sources (table 2). The results indicated that heated canola meal is a better source of RUP than soybean meal, canola meal and borage meal. However, when compared with corn gluten meal, heated canola meal was found to have a lower RUP value.

Using the mobile nylon bag technique, McKinnon et al. (1995) determined the intestinal protein availability of heat-treated canola meal used in their previous study. Heating canola meal to 125℃ for up to 30 min increased the amount of dietary protein available for digestion in the small intestine without affecting the total tract digestibility of crude protein (table 3). However, heating to 145℃ resulted in heat-damaged protein with lower intestinal and total tract digestibility. It was concluded from the two studies that heating canola meal at 125℃ for 10 to 30 min is a viable method to reduce ruminal degradability of canola meal protein without compromising the intestinal digestibility of RUP.

The performance of feedlot cattle fed four levels (22, 28, 32 and 34% of crude protein) of RUP was examined by McKinnon et al. (1993a). The different levels of RUP were achieved using urea, unheated canola meal, heated canola meal and corn gluten meal. The results of the experiment showed that daily gain of calves fed 28% RUP were higher than of those fed 22% RUP. However, over the entire course of the trial no difference was observed between the different levels of RUP. The results also indicated that there were no benefits in term of animal performance from feeding RUP in excess of 28% of the total protein (table 4).

Table 2. In situ crude protein kinetic parameters and effective degradability of heated canola meal relative to other protein sources[1]

	Protein source					SEM
	Heat canola meal[2]	Canola meal	Soybean meal	Corn gluten meal	Borage meal	
Kinetic parameter						
Soluble, % of CP	12.5^{c}	29.8^{b}	11.7^{c}	2.3^{d}	31.9^{a}	0.44
Slowly degradable, % of CP	86.6^{b}	70.2^{c}	88.3^{b}	97.7^{a}	45.4^{d}	1.44
Degradation rate, %/h	1.4^{c}	6.0^{b}	10.3^{a}	0.5^{c}	9.8^{a}	0.37
Effective degradability, %	34.3^{d}	68.0^{b}	71.2^{a}	11.2^{e}	61.7^{c}	0.85

$^{a-e}$ Means in the same row with different superscripts are different ($p<0.05$).
[1] Adapted from Mustafa et al. (1997); [2] Heated at 125 C for 20 min.

Table 3. Effect of dry heat treatment on ruminal, intestinal and total tract disappearance of dry matter and crude protein of canola meal samples incubated in the rumen for 12 h[1]

	Control	Temperature						SEM
		125℃			145℃			
		Duration, min			Duration, min			
		10	20	30	10	20	30	
Dry matter disappearance, %								
Rumen	63.1^{a}	45.2^{b}	43.7^{b}	41.7^{c}	32.6^{d}	32.0^{d}	31.2^{d}	1.3
Intestinal[2]	51.9^{ab}	61.2^{a}	59.4^{a}	61.5^{a}	43.6^{b}	44.9^{b}	35.8^{c}	2.5
Total tract	82.3^{a}	78.7^{a}	77.1^{a}	77.6^{a}	61.9^{b}	62.6^{b}	55.9^{c}	1.6
Crude protein disappearance, %								
Rumen	64.3^{a}	33.8^{b}	31.0^{c}	30.6^{c}	24.6^{d}	24.9^{d}	19.7^{e}	1.1
Intestinal[2]	80.5^{a}	85.5^{a}	83.0^{a}	84.2^{a}	54.4^{b}	59.3^{b}	49.0^{b}	3.5
Total tract	93.0^{a}	90.4^{a}	88.3^{a}	89.0^{a}	64.4^{bc}	69.4^{b}	57.9^{c}	2.7

$^{a-c}$ Mean in the same row with different superscripts are different ($p<0.05$).
[1] Adapted from McKinnon et al. (1995); [2] Percentage of rumen undegraded dry matter or crude protein.

Table 4. Effect of rumen undegraded protein level of performance of feedlot cattle[1]

	Ruminal undegraded protein level, % of dietary protein				SEM
	22	28	32	34	
Dry matter intake, kg/d					
Day 0 to 56	8.2	8.3	8.0	8.1	0.20
Day 0 to finish	8.8	8.9	8.6	8.8	0.20
Daily gain, kg					
Day 0 to 56	1.19^{b}	1.32^{a}	1.26^{ab}	1.21^{ab}	0.03
Day 0 to finish	1.28	1.33	1.31	1.29	0.03
Feed conversion					
Day 0 to 56	6.95	6.27	6.38	6.71	0.18
Day 0 to finish	6.98	6.67	6.69	6.89	0.14

^{a,b} Means in the same row with different superscripts are different ($p<0.05$).
[1] Adapted from McKinnon et al. (1993).

Jones (1993) studied the effects of short-term heat treatment (125℃ for 20 min) on ruminal degradability of canola presscake relative to canola meal. He found that heat treatment reduced ruminal crude protein degradability of canola presscake and canola meal by 33 and 56%, respectively. Feeding heated canola presscake or heated canola meal up to 11% of the diet increased milk protein yield and total milk yield in heifers but not when fed to multiparous cows (Jones 1993).

Moist heat treatment

Moist heat treatment (autoclave) is an alternative technique to dry heat treatment. Moshtaghi Nia and

Ingalls (1992) heated canola meal at 127℃ with steam pressure of 117 kPa for 15, 30, 45, 60 and 90 min. They found that moist heat treatment decreased ruminal degradability and increased intestinal availability of canola meal without adversely affecting total tract digestibility of either dry matter or crude protein. The authors also found that moist heat treatment of canola meal for 45 min or more reduced total tract protein digestibility relative to unheated canola meal.

The influence of moist heat on ruminal and intestinal disappearance of amino acids from canola meal was studied by Moshtaghi Nia and Ingalls (1995). The authors reported that autoclaving at 127℃ with steam pressure of 117 kPa for 15 or 45 min reduced the concentration of lysine by 15.9 and 29.2%, respectively and that of arginine by 8.0 and 15.2%, respectively. The concentrations of other amino acids were not affected. Moist heat treatment was also found to reduce the degradation of amino acids in the rumen and increase the intestinal availability of amino acids (table 5). The authors reported that heating for 15 min was less harsh than 45-min heating.

Table 5. Effect of moist heat treatment of canola meal on intestinal availability of individual amino acids after 16 h of ruminal incubation (g/16 g N)[1]

	Heat treatment[2], min		
	0	15	45
Amino acid			
Threonine	1.51	3.08	2.81
Valine	1.51	2.83	2.10
Methionine	0.77	1.50	1.58
Isoleucine	1.17	2.22	1.65
Leucine	2.46	5.28	4.84
Phenylalanine	1.46	3.06	2.86
Histidine	0.62	1.55	1.56
Lysine	1.74	3.03	2.49
Arginine	1.61	3.67	3.16

[1] Adapted from Moshtaghi Nia and Ingalls (1995).
[2] Heated at 127℃ with steam pressure of 117 kPa.

From the results of Moshtaghi Nia and Ingalls (1992, 1995), it can be seen that moist heat treatment for 15 or 30 min is an effective method for protecting canola meal protein from microbial degradation in the rumen and results in a substantial increase in amino acids available for intestinal digestibility. The effects of feeding moist heat-treated canola meal on the performance of dairy and beef cattle are yet to be determined.

Jet-sploding

Jet-sploding involves rapid steam heat treatment under high pressure for a short period of time utilizing the moisture within the seed. The length of time the seed remains inside the jet-sploder and the temperature applied, depend on the targeted internal seed temperature. The process was used to increase RUP of whole canola seed (table 6) and has been described by Kennelly et al. (1993).

Table 6. Effect of Jet-sploding on effective ruminal degradability and total tract digestibility of whole canola seed relative to canola and soybean meal[1]

	Ruminal degradability		Total tract	
	Dry matter	Crude protein	Dry matter	Crude protein
Whole canola seed				
Unheated	83.7[a]	86.7[a]	91.7[a]	93.1[b]
Extruded	83.7[a]	86.2[a]	90.0[ab]	93.3[b]
Jet-sploded	42.6[c]	60.8[c]	79.8[c]	87.9[c]
Canola meal				
Unheated	63.6[b]	66.1[bc]	80.5[c]	92.6[b]
Extruded	65.2[b]	65.0[c]	82.4[c]	93.5[b]
Soybean meal				
Unheated	77.4[a]	68.2[b]	96.5[a]	99.0[a]
Extruded	75.1[a]	66.4[bc]	94.9[a]	98.8[a]

[a,b,c] Means in the same column with different superscripts are different ($p<0.05$).
[1] Adapted from Deacon et al. (1988).

Deacon et al. (1988) compared ruminal degradability and intestinal digestibility of jet-sploded whole canola seed heated at 121℃ internal seed temperature with other protein sources. The results showed that Jet-sploding reduced effective crude protein degradability of canola seed. However, total tract digestibility of canola seed protein was also reduced (table 7).

The inclusion of jet-sploded canola seed up to 4.5% of the diet in early lactation had positive effects on milk yield of dairy cows while no benefits were obtained from adding Jet-sploded canola seed to diets of mid to late lactating cows (Kennelly et al., 1993). However, inclusion of Jet-sploded canola seed in dairy rations depressed milk protein concentration and altered milk fatty acid composition. As the inclusion rate of Jet-sploded canola seed increased up to 29% of the concentrate, the concentration of palmitic acid (C16:0) decreased while that of oleic acid (C18:1) increased with no effect on the concentration of linoleic (C18:2) or linolenic (C18:3) acid (Kennelly et al., 1993).

Micronization

Micronization is a form of heat treatment in which feedstuffs are subjected to rapid surface and internal heating by the application of infrared light. The technique has recently been used to reduce ruminal degradability of canola meal and seed (figure 1).

Wang et al. (1999) found that micronization

reduced ruminal degradability of total and essential amino acids of whole canola seed by reducing the soluble and increasing the slowly degradable amino acid fraction. Micronization was also found to reduce total tract amino acid digestibility of whole canola seed. However, this adverse effect was not noted from micronized ground canola seed, suggesting that utilization of amino acids from micronized canola seed is largely influenced by method of processing. As with moist heat-treated canola meal, the feeding value of micronized canola meal and seed for dairy and beef cattle has not been determined.

Table 7. Effect of acetic acid treatment on ruminal degradation characteristics of canola meal[1]

	Canola meal	
	Treated	Untreated
Dry matter (DM)		
Soluble, % of DM	33.8[a]	26.2[b]
Slowly degradable, % of DM	53.5[a]	58.9[b]
Degradation rate, %/h	15.1[a]	6.1[b]
Effective degradability, %	71.1[a]	55.4[b]
Crude protein (CP)		
Soluble, % of CP	31.9[a]	18.1[b]
Slowly degradable, % of CP	62.9[a]	72.7[b]
Degradation rate, %/h	18.3[a]	5.4[b]
Effective degradability, %	78.8[a]	51.9[b]

[a,b] Means in the same row with different superscripts are different ($p<0.05$).

[1] Adapted from Khorasani et al. (1993).

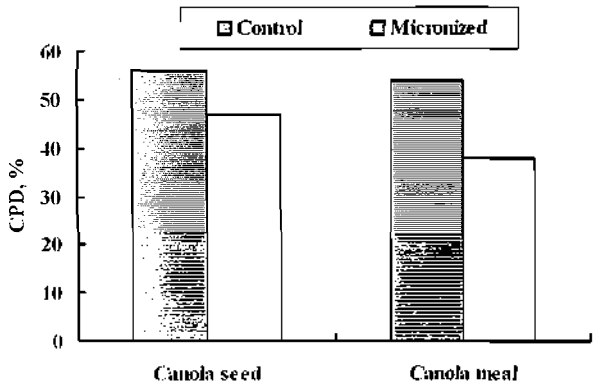

Figure 1. Effect of micronization on ruminal crude protein degradability (CPD) of canola seed[1] and canola meal[2]

[a,b] Means within each canola products are significantly different ($p<0.05$).

[1] Adapted from Wang et al. (1997).

[2] Adapted from Jackman (Unpublished data).

CHEMICAL TREATMENTS

Several chemicals have been used to reduce ruminal degradability of canola meal protein. These include formaldehyde, acetic and propionic acid, and sodium hydroxide. Generally, chemical treatments do not alter protein structure very drastically and thus less acid detergent insoluble protein will be formed (Loerch, 1986).

Formaldehyde treatment

Formaldehyde treatment is by far the most common chemical treatment used to protect dietary protein from ruminal degradation. Formaldehyde forms revisable cross linkages with amino acids and amide groups which reduce protein degradability in the rumen (Antoniewicz et al., 1992; Waltz and Stern, 1989). These linkages are usually broken under the acidic conditions of the abomasum. However, irreversible cross linkages are also possible due to overprotection.

Similar to other protection methods, formaldehyde reduces ruminal degradation of dietary protein by reducing the rapidly soluble fraction and the rate of degradation of the slowly degradable fraction. Early work of Sharma et al. (1974) showed that formaldehyde treatment (0.7 g/100 g crude protein) of rapeseed meal did not increase the flow of total nitrogen, non-ammonia nitrogen or the concentrations of amino acids leaving the rumen. In contrast, Bailey and Hironaka (1984) found that treating rapeseed meal with formaldehyde (0.5 g/100 g of crude protein) reduced ruminal degradability of crude protein by 74%.

The effect of formaldehyde treatment (0.8 g/100 g of crude protein) on protein quality of canola meal has been studied by Mir et al. (1984). Although formaldehyde was effective in reducing ruminal degradability of canola meal protein, it was found to have a detrimental effect on true digestibility. The authors concluded that overprotection of the protein is due to the formation of irreversible cross linkages which are resistant to enzymatic digestion.

Rae et al. (1983) studied the effect of feeding formaldehyde-treated canola meal (1.2 g/100 g of crude protein) to Holstein cows in early lactation. No effect of formaldehyde-treated canola meal was observed on feed intake, milk yield, or milk composition. The author concluded that formaldehyde treatment might have reduced the availability of specific amino acids particularly tyrosine and lysine, whose availability might have limited milk yield. Supplementation of formaldehyde-treated canola meal with tyrosine (50 g/cow/day) was found to increase milk yield by 3.4% (Rae et al., 1982).

Other chemicals

Acid (e.g., hydrochloric, acetic and propionic acid) and alkali (e.g., sodium hydroxide) treatments have

also been used to reduce ruminal degradation of protein supplements (Waltz and Loerch 1986; Waltz and Stern, 1989). Mir et al. (1984) showed that treating canola meal with a 50% NaOH solution (3 g/100 g of crude protein) reduced ruminal protein degradability without affecting true protein digestibility.

The response of canola meal protein to chemicals other than formaldehyde and sodium hydroxide has been inconsistent. Khorasani et al. (1989) studied the effects of treating canola meal with different chemicals on ruminal degradability and intestinal digestibility of crude protein. Treatments included spraying with hydrochloric, acetic, formic, and propionic acid at 2.5 and 5% (v/w) followed by drying at 105℃ for 20 h. All chemical treatments were found to reduce ruminal protein degradability with no adverse effects on intestinal digestibility of RUP except for the hydrochloric acid treatment.

In contrast to these results, McKinnon et al. (1991) found that treating canola meal with acetic or formic acid (30 ml/kg of DM) did not reduce RUP. The effects of acid treatment reported by Khorasani et al. (1989) might have resulted from the combination of heat and acid rather than the acid treatment alone.

Table 8. Effects of inclusion rate of acetic acid treated canola meal on milk yield and milk composition of early lactation dairy cows[1]

	Replacement level[2], %			Contrast[3]	SEM
	0	50	100		
Dry matter intake, kg/d	20.4	21.2	20.3	NS	0.51
Yield, kg/d					
Milk	28.6	30.4	30.8	L	0.82
Fat	1.1	1.1	1.1	NS	0.04
Protein	0.9	1.0	1.0	NS	0.03
Lactose	1.4	1.5	1.5	L	0.04
Composition, %					
Fat	3.7	3.7	3.5	NS	0.02
Protein	3.3	3.2	3.2	NS	0.06
Lactose	4.7	4.9	4.8	NS	0.01

[1] Adapted from Kennelly and Khorasani (1993).
[2] Replacement of untreated with treated canola meal.
[3] Contrast L=Linear; NS=Not significant ($p<0.1$).

Khorasani et al. (1993) treated canola meal with 3% acetic acid to study the effect of such treatment on milk yield and composition of mid (experiment one) and early lactation (experiment two) dairy cows. Results of the first experiment indicated that replacement of untreated canola meal with acid-treated canola meal at 0, 33, 67 and 100% in the concentrate had no effect on milk yield or milk composition (table 8). However, a similar replacement in the second experiment tended to increase milk yield without affecting feed intake or milk composition.

In recent years, several researchers have treated whole canola seed with alkaline hydrogen preoxide (Aldrich et al., 1997a, b; Hussein et al., 1996). Treatment was found to reduce ruminal biohydrogenation of fatty acids and thus improve the delivery of unsaturated fatty acids to the small intestine. However, the treatment was less effective in increasing the flow of RUP to the small intestine (Hussein et al., 1996). When compared with ground canola seed, feeding alkali-treated whole canola seed to dairy cows at 11.2% of the diet dry matter had no effect on milk yield or milk fat percentage (Aldrich et al., 1997b). Furthermore, no effects on fatty acid composition were observed. These results suggest that feeding alkali-treated canola seed to dairy cows has little benefit over feeding crushed untreated canola seed.

NON-ENZYMATIC BROWNING

Non-enzymatic browning involves reaction between sugar aldehyde groups and free amino groups in the presence of heat (Windschitl and Stern, 1988). Factors which control non-enzymatic browning include type and concentration of reducing sugars, temperature and duration of heating, moisture level, and pH of the reaction mixture (Cleale et al., 1987a, b). Byproducts such as lignosulfonate that contain reducing sugars can also be used to reduce ruminal protein degradation. Lignosulfonate is a non-toxic byproduct of the paper and wood industry, which contains high levels of reducing sugars (Windschitl and Stern, 1988). It is derived from the spent sulfite liquor that is generated during the sulfite digestion of wood. The treatment utilizes reducing sugars and heat to invoke the Maillard reaction.

Lignosulfonate treatment of canola meal involves mixing canola meal with an aqueous solution of lignosulfonate followed by heating at 100℃ for 1 or 2 h (Stanford et al., 1995; Beauchemin et al., 1995; McAllister et al., 1993). Lingnosulfonate treatment has been shown to reduce protein solubility and increase the amount of protein associated with neutral and acid detergent fiber. The treatment also increased RUP value of canola meal by reducing the soluble protein fraction and the rate of degradation of the slowly degradable protein fraction (table 9). These changes in protein composition and degradability of canola meal were achieved by a combination of lignosulfonate and heat treatment rather than by lignosulfonate alone (Stanford et al., 1995). Despite the fact that lignosulfonate treatment was very effective in improving RUP value of canola meal, feeding lignosulfonate-treated canola meal failed to improve the performance

Table 9. Effect of lignosulfonate (LSO_3) treatment of canola meal on ruminal crude protein kinetic parameters and effective degradability

	Crude protein kinetic parameters			
	Soluble fraction, %	Slowly degradable fraction, %	Degradation rate, %/hour	Effective degradability, %
Experiment one[1]				
Control	19.9	72.8	15.7	74.9
5% LSO_3+1 hour heat	15.0	78.8	9.0	65.5
10% LSO_3+1 hour heat	12.6	84.5	6.3	59.5
Experiment two[2]				
Control	33.6	61.3	6.9	69.1
7% LSO_3+1 hour heat	18.9	64.7	1.9	36.7
Experiment three[3]				
Control	27.8	46.9	8.5	55.1
5% LSO_3+1 hour heat	15.4	42.9	2.3	31.5

[1] Cheng et al. (1993); [2] Stanford et al. (1995); [3] Beauchemin et al. (1995).

of young lambs (Stanford et al., 1995) or suckling calves (Beauchemin et al., 1995) when compared with untreated canola meal.

CONCLUSIONS

Several physical and chemical methods are successful in reducing the ruminal degradation of canola meal protein without compromising the quality of protein available for digestion in the small intestine. Heat treatment seems to be more effective than chemical treatment in protecting canola meal protein from ruminal degradation. Furthermore, some chemicals such as formaldehyde might have detrimental effects on digestibility of RUP. In most of the studies reviewed, animal performance did not show significant improvements as result of feeding protected canola products. Research priority should be given to more comprehensive studies to identify feeding situations where ruminants can benefit from feeding protected canola products.

REFERENCES

Aldrich, C. G., N. R. Merchen, J. K. Drackley, S. S. Gnozalez, G. C. Fahey, Jr, and L. L. Berger. 1997a. The effects of chemical treatment of whole canola seed on lipid and protein digestion by steers. J. Anim. Sci. 75: 502-511.

Aldrich, C. G., N. R. Merchen, J. K. Drackley, S. S. Gnozalez, G. C. Fahey, Jr, and L. L. Berger. 1997b. The effects of chemical treatment of whole canola seed on intake, nutrient digestibilities, milk production, and milk fatty acids of Holstein cows. J. Anim. Sci. 75: 512-521.

Antoniewicz, A. M., A. M. van Vuuren, C. J. van der Koelen, I. Kosmala. 1992. Intestinal digestibility of rumen undegraded protein of formaldehyde-treated feedstuffs measured by mobile nylon bag and in vitro technique. Anim. Feed Sci. Technol. 39:111-124.

Bailey, C. B. and R. Hironaka. 1984. Estimation of the rumen degradability of nitrogen and of nonprotein organic matter in formaldehyde-treated and untreated canola meal. Can. J. Anim. Sci. 64:183-185.

Beauchemin, K. A., D. R. Bailey, T. A. McAllister and K. J. Cheng. 1995. Lignosulfonate-treated canola meal for nursing beef calves. Can. J. Anim. Sci. 75:559-565.

Cheng, K. J., T. A. McAllister and L. M. Rode. 1993. Use of acidulated fatty acids to increase the rumen undegradable protein value of canola meal. In: 10th Project Report: Research on Canola Seed, Oil, Meal and Meal Fractions. Canola Council of Canada. Winnepig, Manitoba, Canada. pp. 178-188.

Cleale, R. M., T. J. Klopfenstein, R. A. Britton, L. D. Satterlee and S. R. Lowry. 1987a. II. Ruminal escape and net portal absorption of soybean protein treated with xylose. J. Anim. Sci. 65:1319-1326.

Cleale, R. M., T. J. Klopfenstein, R. A. Britton, L. D. Satterlee and S. R. Lowry. 1987b. III. Digestibility and efficiency of protein utilization by ruminants of soybean meal treated with xylose or glucose. J. Anim. Sci. 65:1327-1335.

Deacon, M. A., G. De Boer and J. J. Kennelly. 1988. Influence of jet-sploding® and extrusion on ruminal and intestinal disappearance of canola and soybeans. J. Dairy Sci. 71:745-753.

Griffin, C. D., L. D. Bunting, L. S. Sticker and B. Vora. 1993. Assessment of protein quality in heat-treated soybean products using the growth responses of lambs and calves and a nylon bag-rooster assay. J. Anim. Sci. 71:1924-1931.

Ha, J. K. and J. J. Kennelly. 1984. *In situ* dry matter and protein degradation of various protein sources in dairy cattle. Can. J. Anim. Sci. 64:443-452.

Hussein, H. S., N. R. Merchen and G. C. Fahey Jr. 1996. Effects of forage percentage and canola seed on ruminal protein metabolism and duodenal flows of amino acids in steers. J. Dairy Sci. 79: 98-104.

Jackman, J. 1999. Effect of micronization of ruminal degradability of canola meal (unpublished data). University of Saskatchewan, Saskatoon, Saskatchewan. Canada

Jones, R. A. 1993. Effect of heat-treated and untreated

canola presscake on dairy cow performance and milk fat composition. M.Sc. Thesis. University of Saskatchewan, Saskatoon, Saskatchewan. Canada.

Kennelly, J. J. and G. R. Khorasani 1993. Influence of acid treatment of canola meal on rumen fermentation and milk production in dairy cows. Tenth Project Report: Research on Canola Seed, Oil and Meal. Canola Council of Canada, Winnipeg, Manitoba. pp. 107-122.

Kennelly, J. J., G. R. Khorasani, P. H. Robinson and G. de Boer. 1993. Effect of Jet-Sploding and extrusion on the nutritive value of canola meal and whole canola seed for dairy cattle. Pages 131-159. Tenth Project Report: Research on Canola Seed, Oil and Meal. Canola Council of Canada, Winnipeg, Manitoba.

Khorasani, G. R., P. H. Robinson and J. J. Kennelly. 1989. Effect of chemical treatment on in vitro and in situ degradation of canola meal crude protein. J. Dairy Sci. 72:2074-2080.

Khorasani, G. R., P. H. Robinson and J. J. Kennelly. 1993. Effects of canola meal treated with acetic acid on rumen degradation and intestinal digestibility in lactating dairy cows. J. Dairy Sci. 76:1607-1616.

Kirkpatrick, B. K. and J. J. Kennelly. 1987. *In situ* degradability of protein and dry matter from single protein sources and from a total diet. J. Anim. Sci. 65: 567-576.

Lindberg, J. E., H. S. Soliman and S. Sanne. 1982. A study of the rumen degradability of untreated and heat treated rape seed meal and of whole rape seed, including a comparison between two nylon bag techniques. Swedish J. Agric. Res. 12:83-88.

McAllister, T. A., K. J. Cheng, K. A. Beauchemin, D. R. Bailey, M. D. Pickard and R. P. Gilbert. 1993. Use of lignosulfonate to decrease the rumen degradability of canola meal protein. Can. J. Anim. Sci. 73:211-215.

McKinnon, J. J., R. D. H. Cohen, J. A. Olubobokun and D. A. Christensen. 1993. Supplemental protein sources for feedlot cattle. Pages 165-171. Tenth Project Report: Research on Canola Seed, Oil and Meal. Canola Council of Canada, Winnipeg, Manitoba.

McKinnon, J. J., J. A. Olubobokun, A. F. Mustafa, R. D. H. Cohen and D. A. Christensen. 1995. Influence of dry heat treatment of canola meal on site and extent of nutrient disappearance in ruminants. Anim. Feed. Sci. Technol. 56:243-252.

McKinnon, J. J., J. A. Olubobokun, D. A. Christensen and R. D. H. Cohen. 1991. The influence of heat and chemical treatment on ruminal disappearance of canola meal. Can. J. Anim. Sci. 71:773-780.

Mir, Z., G. K. Macleod, J. G. Buchanan-Smith, D. G. Grieve and W. L. Grovum. 1984. Methods of protecting soybean and canola proteins from degradation in the rumen. Can. J. Anim. Sci. 64:853-865.

Moshtaghi Nia, S. A. and J. R. Ingalls. 1992. Effect of heating on canola meal protein degradation in the rumen and digestion in the lower gastrointestinal tract of steers. Can. J. Anim. Sci. 72:83-88.

Moshtagi Nia, S. A. and J. R. Ingalls. 1995. Influence of moist heat treatment on ruminal and intestinal disappearance of amino acids from canola meal. J. Dairy Sci. 78: 1552-1560.

Mustafa, A. F., J. J. McKinnon, P. A. Thacker and D. A. Christensen. 1997. Effect of borage meal on nutrient digestibility and performance of ruminants and pigs. Anim. Feed Sci. Technol. 273-285.

National Research Council. 1996. Nutrient requirements of beef cattle. Seventh revised edition. National Academic Press. Washington, DC.

National Research Council. 1989. Nutrient requirements of dairy cattle. Sixth revised edition. National Academic Press. Washington, DC.

Rae, R. C., J. R. Ingalls and J. A. McKirdy. 1983. Response of dairy cows to formaldehyde-treated canola meal during early lactation. Can. J. Anim. Sci. 63:905-915.

Sharma, H. R. and J. R. Ingalls. 1974. Effect of treating rapeseed meal and casein with formaldehyde on apparent digestibility and amino acid composition of rumen digesta and bacteria. Can. J. Anim. Sci. 54:157-167.

Sniffen, C. J., J. D. O'Connor, P. J. Van Soest, D. J. Fox and J. B. Russell. 1992. A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. J. Anim. Sci. 70:3562-3577.

Stanford, K., T. A. McAllister, Z. Xu, M. D. Pickard and K. J. Cheng. 1995. Comparison of lignosulfonate-treated canola meal and soybean meal as rumen undegradable protein supplements for lambs. Can. J. Anim. Sci. 75: 371-377.

Van Soest, P. J. 1987. Nutritional Ecology of the Ruminant. Cornell University Press. Ithaca, NY.

Waltz, D. M. and S. C. Loerch. 1986. Effect of acid and alkali treatment of soybean meal on nitrogen utilization by ruminants. J. Anim. Sci. 63:879-887.

Waltz, D. M. and M. D. Stern. 1989. Evaluation of various methods for protecting soya-bean protein from rumen degradation by rumen bacteria. Anim. Feed Sci. Technol. 25:111-122.

Wang, Y., T. A. McAllister, M. D. Pickard, Z. Xu, L. M. Rode and K. J. Cheng. 1999. Effect of micronizing full fat canola seed on amino acid disappearance in the gastrointestinal tract of dairy cows. J. Dairy Sci. 82: 537-544.

Wang, Y., T. A. McAllister, D. R. Zobell, M. D. Pickard, L. M. Rode, Z. Mir and K. J. Cheng. 1997. The effect of micronization of full-fat canola seed on digestion in the rumen and total tract of dairy cows. Can J. Anim. Sci. 77:431-440.

Windschitl, P. M. and M. D. Stern. 1988. Evaluation of calcium lignosulfonate-treated soybean meal as a source of rumen protected protein for dairy cattle. J. Dairy Sci. 71:3310-3322.