Ruminal Fermentation and Utilization of Unconventional Feeds in Western Canada

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Introduction

Changes to agricultural policies and the introduction of new cash crops to western Canada has made available many unconventional ingredients that can be used as ruminant feeds. Most unconventional feeds are either crop residues or agro-industrial byproducts. Crop residues are high in fiber, low in nitrogen and of low digestibility. They include cereal and legume straws and stalks. Agro-industrial byproducts result from processing of crops such cereals (e.g. milling, alcohol fermentation), oilseeds, sugar beet, and citrus fruits. Developing feeding programs for ruminants based on unconventional feeds should take into accounts several problems that might be associated with these feeds. Several unconventional feeds are made of heterogeneous materials, which makes it difficult to obtain a uniform product. A second challenge is the fact that processing (e.g. grinding, pelleting, ammoniation) might be necessary for many unconventional feeds to improve animal performance. Proper utilization of unconventional feeds by ruminants will not only benefit the animal industry but will also increase the economic return of many cash crops in western Canada. The objective of this paper is to review the nutritional value of unconventional ruminant feeds, which are available in western Canada. Discussion will be limited to research data available in scientific publications.

Classification of Agro-industrial byproducts

Based on their nutrient content agro-industrial byproducts can be divided into:

1- Feeds high in fiber and low in nitrogen. These include milling byproducts such as oat hulls and pea hulls.
2- Feeds high in fiber and high in protein content. These include distillers' and brewers' grains and several oilseed meals.
3- Feeds low in fiber and high in protein. These include mainly oilseed meals

4- Feed low in fiber and low in protein. These are usually byproducts of food processing for human consumption and include products such as molasses and citrus pulps and potato peels.

Some agro-industrial byproducts such as screenings and feed grade cereal and legume seeds do not fit within any of the above groups. Byproducts, which result from cleaning of cereal grains and oilseed usually, contain high proportions of dust, chaff and weed seeds. Consequently they are high in ash and fiber contents. They also contain moderate levels of starch or fat depending of the source of the parent material. Feed grade peas and beans are high in starch and protein but low in fiber. Due to the great differences in chemical composition, the energy content of unconventional feed varies considerably among unconventional feeds (Table 1). Some of the chemical entities which affect energy content include ash, fat, neutral detergent fiber, lignin, and the amount of protein associated with neutral and acid detergent fiber Weiss et al. 1992).

Table 1. Energy content of some unconventional feeds

	Total digestible nutrients (%)	Digestible energy (Mcal kg^{-1})
Screenings		
Grain screenings	74.7	3.3
Canola screenings	55.7 (67.8)	2.5 (3.0)
Caraway / coriander screenings	58	2.6
Pea screenings	70	3.1
Lentil screenings	70	3.1
Hulls		
Canola hulls	50	2.2
Oat hulls	57	2.5
Ammoniated oat hulls	58.0	2.6
Pea hulls	65	
Feed grade legume seeds		
Chickpeas	82-89	3.6-4.0
White kidney beans	75	3.3
Oilseed meal		
Borage meal	68	3.0
Hemp meal	60	2.7
Ensiled mint byproduct	54	2.4
Fenugreek hay	61	2.7
Fenugreek straw	49	2.2

Grain Screenings

Screenings are byproducts result from cleaning of cereal grains, oilseeds or legume seeds. The potential of screenings as animals feeds has increased significantly in the last few years due to the elimination of transportation subsidy. Two main types of screenings are available in western Canada: grain screenings and canola screenings. The main energy source in grain screenings is non-structural carbohydrates while fat is the main energy source in canola screenings. Both types of screenings are high in neutral detergent fiber, however, due to their small particle size and the extensive processing prior to feeding they are low in effective fiber content.

Grain companies and seed cleaning plants are making grain screening a viable feed source for ruminants in western Canada. In Saskatchewan alone the grain industry produces 60,000 tonnes of grain screening per year. Grain screenings are usually defined as that portion of crop which remains after the grain has been cleaned and consists of whole and damaged grains, weed seeds, chaff, dirt and dust and other foreign materials. Grain screenings are usually divided into number one (contain more than 35% of parent materials), number two (contain over 15% of parent material) and refuse screenings (contain less than 15% of parent material).

Grain screens are highly variable and may contain various proportions of small whole grain kernels, cracked grain, grain dust, forage residue, small rocks, dirt and metal. Particle size of the screened grain may be a problem and should be closely monitored. In many instances, the grain screenings are 95% grain and very economical. The smaller the particle size, the greater the risk of acidosis. Grain screens should be limited to a maximum of 50% in growing diets and 25% to 30% in finishing diets.

Grain screenings are usually processed (grinding and pelleting) to enhance digestibility and to destroy weed seeds. Variations in chemical composition of grain screening pellets (**GSP**) were investigated by Marx et al (2000). The authors determined chemical composition of 18 loads of grain screening pellets collected over a two-year period (Table 2). Carbohydrate was the main component of GSP with starch constituting about 40% of the total carbohydrates. Grain screening pellets contained more soluble protein and non-protein nitrogen than barley. Neutral and acid detergent insoluble protein were also higher in GSP than barley. The authors found greater variations in fat and starch contents for GSP than for barley. However, CP of GSP was less variable than that of barley. One possible explanation is the fact that GSP are sold based on their protein content and therefore other ingredients may be added to keep protein level constant. Grain screenings pellets are characterized by high ruminal protein (more than 80%) and starch (more than 90%, Table 2) degradability. Ruminal degradability of protein and starch of GSP are expected to be similar to those of barley. However, ruminal degradability of NDF should be higher in barley than GSP, mainly because of the higher acid detergent lignin content of GSP. A major difference in ruminal degradability between GSP and barley is the higher rate of protein and starch degradation of GSP. This is mainly due to their high soluble dry matter and starch content.

Table 2. Chemical composition and ruminal degradabilities of grain screening pellets relative to barley.

	Grain screenings pellets	Barley	SEM
Chemical composition			
Ash (%)	7 ± 0.8*a*	2 ± 0.4*b*	0.2
Neutral detergent fiber (%)	34 ± 1.7*a*	23 ± 4.4*b*	0.8
Acid detergent fiber (%)	21 ± 2.1*a*	6 ± 2.5*b*	0.6
Starch (%)	26 ± 6.2*b*	57 ± 3.5*a*	1.2
Crude protein (CP, %)	15 ± 1.1	13 ± 2.5	0.5
Soluble protein (% CP)	34 ± 3.5*a*	28 ± 3.4*b*	0.8
Non-protein nitrogen (% CP)	22 ± 6.4*a*	11 ± 5.4*b*	1.4
Neutral detergent insoluble protein (% CP)	16 ± 3.2*a*	12 ± 5.5*b*	1.1
Acid detergent insoluble protein (% CP)	7.8 ± 1.5*a*	3 ± 1.6*b*	0.4
Digestible energy (Mcal kg^{-1})	3.7	3.3	-
Ruminal degradability			
Crude protein degradability (%)	81*b*	86*a*	0.7
Starch degradability (%)	93*b*	97*a*	1.0
Neutral detergent fiber degradability (%)	22*b*	44*a*	1.5

Adapted from Marx et al (2000).
a,b Means in the same row followed by different letters are different ($P < 0.05$).

Canola Screenings

Canola screenings are byproducts resulting from cleaning of canola seed before oil extraction. Canola screening contain 18 to 22% CP, 17 to 21% fat, 38% NDF and 20 to 32% ADF. The effects of processing (grinding and pelleting) on the feeding value of canola screenings have been investigated by Pylot et al. (2000a). The authors showed that steers fed pelleted canola screenings as the only feed, consumed less dry matter and showed had lower whole-tract fiber digestibility. The negative impact of processed canola screenings on feed intake and fiber utilization by steers is likely resulted from the disruption ruminal fermentation due to the exposure of ruminal microbes to polyunsaturated fatty acids from processed canola screenings.

Table 3. Effects of processing on chemical composition and nutrient digestibilities of canola screenings

	Canola screenings		
	Unprocessed	Pelleted	SEM
Chemical composition			
Ash (%)	14.3	13.0	ND
Neutral detergent fiber (%)	37.8	33.4	ND
Acid detergent fiber (%)	28.0	24.0	ND
Ether extract (%)	16.0	17.6	ND
Crude protein (%)	17.4	17.8	ND
Intake and digestibility coefficients			
Intake (kg d^{-1})	10.7*a*	7.4*b*	0.13
Dry matter digestibility (%)	49.5*b*	58.2*a*	1.16
Crude protein digestibility (%)	57.1*b*	68.2*a*	0.95
Neutral detergent fiber digestibility (%)	37.1	37.2	1.54
Fatty acids digestibility (%)	48.8*b*	62.6*a*	0.22
Gross energy digestibility (%)	51.5*b*	61.5*a*	1.21

ND Not determined
a,b Means in the same row followed by different superscripts are different ($P < 0.05$).
Adapted from Pylot et al. (2000a).

Despite the negative effects on feed intake and fiber utilization, processing of canola screenings improved whole tract digestibility of dry matter and fatty acids. It is not clear however, whether the improvement was due to increased nutrient availability of processed canola screenings or simply a result of a reduced dry matter intake. It should be noted that the fat level of the processed canola screenings was 16% (DM basis). When fed to provide 10% fat in diet dry matter, feeding processed canola screening did not result in any negative effects on ruminal digestion or feed intake typically noted at this level of dietary fat.

Pylot et al. (2000b) conducted an experiment to determine the feeding value of canola screenings for beef steers. Processed canola screenings were included to replace 25, 50, 75 and 100% of barley in the diets. The authors found that, despite a high fiber level, processed canola screenings is a poor source of effective fiber in finishing diets. Performance and cost of gain for steers fed processed canola screening up to 50% of the diet were comparable with those fed a conventional finishing diet consisting of 80% barley grain and 20% barley silage.

Feed Grade Legume Seeds

The rapid increase in the production of legume seeds in western Canada is largely fueled by the food market. However, as production increases, more of legume seeds will be feed grade and made available as animal feeds. Legume seeds are excellent source of fermentable carbohydrates for ruminants. However, the expected high protein solubility may reduce the protein quality of feed grade legume seeds. Feed grade legume may include chickpeas, faba beans, beans, and lupins.

Chickpea is one of the most rapidly growing pulse crops in western Canada. The area under chickpea production in Saskatchewan has increased from 2400 hectares in 1996 to 460,000 hectares in 2001. Canada now is the fourth largest exporter of chickpea in the world market. As production increase, more chickpea that is not suitable for human consumption (i.e. feed grade), will be made available as animal feed. There are two commercial types of chickpeas, which differ in origin, seed color and size. The Desi type has a smaller seed size and a thicker seed coat than the Kabuli type. The two types of chickpeas also differ in their chemical composition with the Kabuli type having lower fiber, higher starch and higher fat content than the Desi type (Table 5). Protein content is similar in the two types of chickpea (average 22% DM basis) with more than 60% of total protein is buffer soluble. Neutral and acid detergent insoluble protein levels are low in both types of chickpeas.

Table 5. Chemical composition and ruminal protein degradability of feed grade chickpeas.

	Kabuli chickpeas		Desi chickpeas		
	Unheated	Heated	Unheated	Heated	SEM
Chemical composition					
Ether extract (% DM)	8.3*a*	8.1*a*	6.4*b*	6.1*b*	0.04
Neutral detergent fiber (% DM)	10.5*d*	17.6*c*	23.9*b*	29.4*a*	0.47
Acid detergent fiber (% DM)	5.5*b*	6.0*b*	12.9*a*	12.8*a*	0.17
Starch (% DM)	38.4*a*	37.7*a*	31.8*b*	31.5*b*	0.33
Crude protein (CP, % DM)	22.5	22.7	22.2	22.4	0.15
Soluble protein (% CP)	70.1*a*	22.3*c*	64.5*b*	22.3*c*	0.88
Non-protein nitrogen (% CP)	20.5*a*	16.4*a*	13.0*b*	13.4*b*	0.11
Neutral detergent insoluble protein (% CP)	2.3*d*	13.9*a*	4.9*c*	10.8*b*	0.56
Acid detergent insoluble protein (% CP)	0.7*d*	1.2*c*	1.6*b*	1.9*a*	0.04
Ruminal protein degradability					
In situ soluble fraction (% CP)	53.7*a*	23.9*c*	49.1*b*	16.6*b*	0.63
In situ degradable fraction (% CP)	46.5*d*	76.3*b*	50.9*c*	83.7*a*	0.61
Degradation rate (% h^{-1})	5.0*a*	2.2*d*	3.8*b*	3.0*c*	0.07
Effective degradability (%)	76.8*a*	46.6*c*	71.4*b*	47.7*c*	0.66

a,b Means followed by different letters are different ($P < 0.05$).
Adapted from Mustafa et al. (2000)

Ruminal nutrient degradability of feed grade chickpeas was determined by Mustafa et al. (2000). Results showed that both types of chickpeas are highly degraded in the rumen mainly due to their high in situ rapidly soluble fractions. Heat treatment (e.g. moist heating) can be used to reduce ruminal degradability of feed grade chickpea and therefore increase the amount of ruminal undegraded protein available for intestinal digestion (Mustafa et al. 2000). Data on the feeding value of feed grade chickpeas to dairy and beef cattle are limited. A study in the United States by Hadsell and Sommerfeldt (1988) showed that chickpeas can replace 100% of the concentrate dry matter of dairy cow rations in early lactation. However, based on feed efficiency and milk protein percentage, the optimum rate of dietary inclusion was closer to 50% than 100% of the concentrate. Feeding Desi or Kabuli chickpeas to pigs up to 30% of the diet had no detrimental effects on performance or carcass characteristics. However, the inclusion of feed grade chickpeas at that level during the growing stage appeared to depress performance relative to a soybean control diet (Mustafa et al. 2000).

Protein meals from unconventional oilseeds

There is an increasing interest in growing and processing oilseeds that contain high levels of essential oils or fatty acids, which have health benefits for humans. Among these specialty crops, borage (*Borago officinalis*) and hemp (*Cannabis sativa*) are the most commonly grown in western Canada. Borage seed contains 32% oil, 24% gamma linolenic acid (**GLA**) and 3% erucic acid. Hemp seed contains 30-35% oil, 80% of which is polyunsaturated fatty acids. The predominant essential fatty acids in hemp seed are linoleic and linolenic acids; however, many others are also present including GLA. As with other oilseeds, mechanical or solvent extraction of hemp and borage seeds produces meals that are high in protein and low in fat content.

Table 6. Chemical composition and ruminal protein degradability of borage and hemp meals relative to canola and soybean meals

	Protein meal			
	Borage meal	Hemp meal	Canola meal	Soybean meal
Chemical composition				
Ash (%)	14	8	7	7
Ether extract (%)	7	5	6	2
Neutral detergent fiber (%)	35	51	33	13
Acid detergent fiber (%)	23	39	20	4
Crude protein (CP, %)	33	32	40	49
Soluble protein (% CP)	23	9	14 (33)	11
Non-protein nitrogen (% CP)	22	7	8 (26)	5
Neutral detergent insoluble protein (% CP)	19	23	34 (16)	3
Acid detergent insoluble protein (% CP)	10	9	12 (6)	2
Ruminal protein degradability				
In situ soluble fraction (% CP)	7	32	18 (30)[z]	12
In situ degradable fraction (% CP)	90	52	81 (70)	88
Rate of degradation (% h^{-1})	2.9	6.0	4.4 (6.0)	10.3
Effective degradability (%)	39	60	55 (68)	71

Adapted from Mustafa et al. (1997) and Mustafa et al. (1999)
[z]Values between parentheses from Mustafa et al. (1997).

Borage and hemp meal are high in neutral detergent fiber due to the fact that seed hulls are not removed prior to oil extraction. Both borage and hemp meals contain protein level that is comparable to canola meal (Table 6, Mustafa et al. 1997; Mustafa et al. 1999). Protein fractions of borage meal are similar to those of canola meal. However, hemp meal has a lower soluble CP and a higher neutral detergent insoluble CP content than canola and borage meals. Both borage and hemp meal have acid detergent insoluble CP level comparable to that of canola meal.

Ruminal degradability of borage and hemp meal is shown in Table 6. Results showed that hemp meal is a better source of ruminal undegraded protein than borage and canola meal, mainly because of its lower in situ soluble CP fraction and a slower rate of ruminal degradation. About 78% of hemp meal protein can escape ruminal degradation. This is compared with 40 and 47% of CP for borage and canola meal, respectively. Using an in vitro pepsin-pancreatin assay, Mustafa et al. (1999) showed that ruminal undegraded protein of hemp meal and borage meal is highly digestible in the small intestine. The authors found no difference in total tract digestibility between borage meal, hemp meal and canola meal (average 86% of CP).

Feeding trials with lambs and pigs showed that borage meal can be included in rations of growing lambs up to 18% of the diet dry matter with no adverse effects on intake or nutrient digestibilities. In pig diets, the inclusion of borage meal resulted in reduced intake and poor nutrient utilization especially for growing pigs.

Oat Milling Byproducts

Oat milling to produce various products for human consumption has become an important economic activity in western Canada. Oat hulls are major byproduct of the oat milling industry, which constitute up to 25% of the oat grain weight. Oat hulls are very high in fiber content and their nutritive value for ruminants is greatly affected by fiber components particularly lignin (Table 7). Thompson et al. (2000) showed that in vitro dry matter disappearance of oat hulls obtained from ten different oat varieties is positively correlated with acid detergent lignin content. The vitro dry matter disappearance ranged between 68% (1.3% lignin) and 33% (7.7% lignin). Ruminal fiber degradability of high and low lignin oat hull varieties was determined relative to oat straw (Thompson et al. 2000). Ruminal degradability of fiber components was higher for the low lignin than for the high lignin oat hulls. Ruminal degradability of the low lignin oat hulls was similar to that of oat straw (Table 7)

Table 7. Chemical composition and ruminal fiber degradability of oat hulls.

	Oat hulls		Oat straw
	High lignin[z]	Low lignin[y]	
Chemical composition			
Ash (%)	4.7-6.0	7.3	ND
Neutral detergent fiber (%)	79.9 – 88.2	86.7	83.4
Acid detergent fiber (%)	42.5-49.6	44.1	53.6
Acid detergent lignin (%)	5.4-7.7	1.3	8.0
Crude protein (%)	2.3-4.5	2.3	ND
In vitro dry matter disappearance (%)	33.1-43.3	68.2	ND
Ruminal degradability			
Neutral detergent fiber (%)	11.8*b*	22.5*a*	23.4a
Acid detergent fiber (%)	12.5*b*	22.3*a*	22.8a

[z]Chemical composition is a range for nine oat hull cultivars while ruminal degradability is for one oat cultivar (Calibre).
[y]Chemical composition and ruminal degradability for the low lignin oat hulls is for one oat cultivar (AC Assiniboia)
Adapted from Thompson et al. (2000).

Ammoniation is a chemical treatment, which is commonly used to improve the feeding value of poor quality crop residues. The response to ammoniation has two folds: an increase in digestibility due to partial breakdown of lignin-cellulose-hemicellulose linkages, and a greater feed intake due to the greater supply of ammonia to the rumen micro-organisms. Thompson et al. (2002) studied the effects of ammoniation (3 or 5% of dry weight) on the feeding value of oat hulls for steers. The authors found that ammoniation improve ruminal degradability of neutral and acid detergent fiber by 41 and 35%, respectively (Table 8). Steers fed ammomniated oat hulls consumed more dry matter and showed improved whole tract digestibility of neutral detergent fiber relative to steers fed untreated oat hulls. The authors found only marginal improvement in the nutritive value of oat hulls when level of ammoniation increased from 3 to 5%.

The positive responses to ammoniation in the study of Thompson et al. (2002) should not be expected for all crop residues and agro-industrial byproducts. In an earlier study, McKinnon et al. (1995) found no improvement in the feeding value of canola hull as a result of ammoniation. There are evidences that the response of agricultural byproducts to ammoniation is highly dependent of their hemicellulose content. Agricultural byproducts originated from cereals and grasses (monocotyledons) with high levels of hemicellulose are more responsive to ammoniation than agricultural byproducts originated from legumes (dicotyledons) with low levels of hemicellulose.

Table 8. Effects of ammoniation on the nutritive value of oat hulls.

	Oat hulls	
	Untreated	Ammoniated (3%)
Chemical composition[z]		
Neutral detergent fiber (% DM)	77.5*a*	71.5*b*
Acid detergent lignin (% DM)	5.6	5.5
Crude protein (CP, % DM)	4.4*b*	11.3*a*
Soluble protein (% CP)	34.6*b*	63.7*a*
Ruminal degradability[z]		
Dry matter (%)	30.1*b*	42.3*a*
Neutral detergent fiber (%)	21.4*b*	30.2*a*
Acid detergent fiber (%)	22.1*b*	29.4*a*
Whole-tract digestibility[y]		
Dry matter (%)	32.6*b*	36.0*a*
Neutral detergent fiber (%)	17.0*b*	24.9*a*
Acid detergent fiber (%)	19.6*b*	25.5*a*
Animal performance[y]		
Dry matter intake (kg per day)	8.8*b*	10.2*a*
Daily gain (kg)	0.3*b*	1.3*a*
Feed:gain	0.02*b*	0.12*a*

[z]100% untreated or ammoniated oat hulls
[y]Untreated oat hull = 50% untreated oat hulls + 50% barley silage, ammoniated oat hulls = 50% ammoniated oat hulls + 50% barley silage
a,b Significant difference due to ammoniation.
Adapted from Thompson et al. (2002).

Byproducts from Essential Oil Extraction

Due to the increased demand for natural flavoring agent and essential oils, the area under aromatic plant production is increasing. Mint is one of the most important aromatic plants in western Canada. The distillation of essential oils results in byproducts that are high in moisture, fiber and protein. Due to the high moisture content of the ensiling of distillation byproducts might yield a desirable product that can be used a ruminant feed. Mustafa et al. (2001) evaluated the feeding value of ensiled spearmint (*Mentha spicata*) byproduct for steers (Table 9). Relative to barley silage, spearmint silage contained higher levels of neutral detergent fiber, acid detergent lignin and crude protein. Dry matter intake as well as whole-tract digestibility of fiber and protein were all lower for steers fed spearmint silage than for those fed barley silage. The authors attributed the poor utilization of spearmint silage by steers to its high lignin and heat damaged protein contents. The digestible energy content of spearmint silage is comparable with that of barley or wheat straw.

Table 9. Chemical composition and nutrient utilization from ensiled mint byproduct relative to barley silage

	Spearmint silage	Barley silage	SEM
Chemical composition			
Neutral detergent fiber (% DM)	56	48	ND
Acid detergent fiber (% DM)	46	30	ND
Acid detergent lignin (% DM)	11	4	ND
Crude protein (CP, % DM)	13	11	ND
Acid detergent insoluble protein (% CP)	32	8	ND
Ruminal degradability			
Dry matter (%)	39.5*b*	57.6*a*	0.44
Crude protein (%)	45.6*b*	73.7*a*	0.78
Neutral detergent fiber (%)	27.4	27.8	0.46
Whole tract digestibility			
Dry matter (%)	45.5*b*	62.8*a*	0.24
Crude protein (%)	29.0*b*	64.8*a*	0.30
Neutral detergent fiber (%)	31.2*b*	47.1*a*	0.28
Gross energy (%)	46.3*b*	65.4*a*	0.27
Digestible energy (Mcal kg^{-1})	1.8*b*	2.6*a*	0.92

a,b Means in the same row followed by different letters differ ($P < 0.05$).
Adapted from Mustafa et al. (2001).

Fenugreek forage

Fenugreek (*Trogonella foenum-graecum*) is a leguminous plant grown mainly in Asia and North Africa. The plant has been introduced to western Canada for seed production and as a forage crop. At a similar stage of maturity, the nutrient profile of fenugreek hay is similar to that of alfalfa hay. Results of in situ and in vitro studies showed that ruminal degradability of dry matter and fiber of fenugreek hay is similar to that of alfalfa hay (Table 10). However, fenugreek protein was found to be more degradable than alfalfa hay protein.

The nutritive value of fenugreek straw was compared with barley straw (Table 10, Mustafa et al. 1996). The chemical composition of fenugreek straw is similar to barley straw except for acid detergent fiber and lignin, which are higher in fenugreek straw than barley straw. As indicated by its lower ruminal degradability, the feeding value of fenugreek straw is expected to be lower than that of barley straw.

Table 10. Chemical composition and ruminal degradability of fenugreek hay and straw

	Fenugreek hay	Fenugreek straw
Chemical composition		
Neutral detergent fiber (NDF, % DM)	44-51	74
Acid detergent fiber (ADF, % DM)	31-37	57
Acid detergent lignin (% DM)	5-6	11
Crude protein (CP, % DM)	13-14	5
Soluble protein (% CP)	53	30
Neutral detergent insoluble protein (% CP)	9	22
Acid detergent insoluble protein (% CP)	8	24
Ruminal degradability		
Dry matter (% DM)	55-65	32
Crude protein (% CP)	81	48
Neutral detergent fiber (% NDF)	30	20
Acid detergent fiber (% ADF)	29	21

Adapted from Mir et al. (1993) and Mustafa et al. (1996).

Conclusions

The role of unconventional feeds in ruminant nutrition continues to increase. The utilization of unconventional feeds will not only benefits the beef industry but will also increase the economic return for several crops in western Canada. For many unconventional feeds, processing is required to improve their feeding value to animals. The cost associated with processing might make some of the seeds uneconomical. Furthermore, processing facilities are not available to all producers. To maximize the feeding value of unconventional feeds, an evaluation system based on detailed analysis of carbohydrate and protein fractions, in situ nutrient degradability, and animal performance studies should be developed..

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