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CASE STUDY: EVALUATING FARM PROCESSED CANOLA AND CAMELINA MEALS AS PROTEIN SUPPLEMENTS FOR BEEF CATTLE

Llewellyn, D. A., Regional Livestock Specialist, Washington State University
Rohwer, G., Collaborator, Bar Diamond, Inc.
Norberg, O. S., Agent, WSU/Franklin County Extension
Kimura, E., Agent, Texas A & M AgriLife Extension
Neibergs, J. S., Extension Economist, Washington State University
Fransen, S. C., Extension Agronomist, Washington State University

ABSTRACT

Canola and camelina meals were evaluated as protein supplements for beef cattle. Beef heifers were fed a control diet of canola meal, camelina meal, or soybean meal (a traditional protein supplement) for 90 days. Canola meal resulted in the highest cumulative weight change and average daily gain (ADG). Soybean meal had the highest dry matter and crude protein degradability measured in situ, among all meals evaluated. Canola meal exhibited acceptable rumen degradability characteristics. Camelina meal had lower degradability for both dry matter and crude protein and some palatability issues were encountered when fed to beef heifers.

INTRODUCTION

As the oilseed based biofuel industry gains strength and expands production of transportation fuels to meet the Renewable Fuel Standard (RFS2) standards and high value bio-based products, the net result is a readily available supply of residual byproduct meal feedstuffs. First generation biofuel grains such as dried distiller's grains with solubles (DDGS) have been successfully used in ruminant diets for many years. The oilseed meals represent another option for livestock producers. In an era characterized by escalating feed costs for beef cattle producers, oilseed byproducts can provide opportunities to the animal feeding industry as a source of low cost crude protein (CP).

Less well known and researched are meals from the biodiesel refining industry, including canola (Brassica napus or Brassica campestris) and camelina (Camelina sativa), both members of the Brassicaceae family. Each has unique and different agronomic challenges in stand establishment, weed control, diseases, and harvesting (Hang et al., 2009). Canola is a genetically improved rapeseed as plant breeders significantly reduced the amounts of erucic acid and glucosinolates from the seed making the meal palatable and acceptable for feeding (Great Plains Canola Production Handbook, 2009). Camelina can be used as a rotational crop in dryland cereal grain crop rotations in the Western United States (Hulbert et al., 2012). Soybean (Glycine max) meal and cotton (Gossypium spp.) seed meal have been the industry standards for supplemental protein and fat for many years (Lalman, 2004). Canola meal has been used for some time; camelina meal received FDA approval as a feed ingredient for beef cattle in 2009 (USDA AgMRC, 2015).

Bio-fuel byproduct oilseed meals (i.e. canola and camelina meal) have the potential to supply supplemental nutrients required by grazing beef cattle at a lower cost than traditional protein supplements such as alfalfa hay and soybean meal. The objectives of this study were to evaluate the feeding value and in situ rumen degradability of on-farm processed canola and camelina meals as alternatives to traditional protein supplements, and provide management mitigation strategies when newly discovered issues emerge for these lesser known meals as they are adapted as commercial supplements.

METHODS

All of the animal activities contained in this proposal will be conducted in accordance with the animal handling guidelines of the Institutional Animal Care and Use Committee (IACUC) at Washington State University (ASAF #04229-002).

PREPARATION AND DETERMINATION OF CHEMICAL COMPOSITION OF OILSEED MEALS

Canola meal and camelina meal from on-farm processing (C Farms Energy, LaCrosse, WA), commercially produced canola meal and soybean meal, were utilized in the experiments (Table 1). Camelina and canola were raised under dryland conditions in Eastern Washington State and were harvested with a rotary-type combine during late July. The seed was bulk stored and allowed to pass through a #6 screen to remove the foreign material. Following cleaning, the seed was subjected to cold pressing through a screw press (M70, OilPress.com, Eau Claire, WI 54703, USA) at a rate of 34 to 36 kg/h. A head

temperature of 43° to 49°C was maintained as the oil and meal exited the press. Commercially produced canola and soybean meals were sourced through a local feed retailer (PerforMix Nutrition Systems, Moses Lake, WA).

All feeds included in this study were analyzed for dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), ash, and ether extract (EE; a measure of fat content). Crude protein was determined by micro-Kjeldahl procedure (AOAC, 1975) and by multiplying the resulting N concentrations by 6.25. Non-fiber carbohydrate (NFC) was calculated by difference (100 – CP – EE –NDF – Ash). Methods of analysis used were in accordance with the National Forage Testing Association (NFTA, 2015).

BEEF HEIFER PERFORMANCE STUDY

In the fall and winter of 2012/2013 a producer-cooperator was engaged (Rosman Angus, Creston, WA) in our case study, utilizing crossbred beef replacement heifers (n = 37; average age = approximately 9 months and body weight [BW] = 290 ± 22 kg at initiation of the study) to compare on-farm processed canola meal and on-farm processed camelina meal to commercial soybean meal. Heifers were of Hereford X Angus breeding. All heifers were offered a basal low-quality diet consisting of mainly wheat (Triticum spp.) straw (35 g/kg CP and 789 g/kg NDF; tabular values NRC, 2000) and adequate alfalfa hay (165 g/kg CP and 329 g/kg NDF) to achieve maintenance. Treatments included: 1) Control, base forage of wheat straw/alfalfa hay; 2) camelina meal (385 g/kg CP [DM basis] fed at 1.9 g/kg of body weight [BW]); 3) canola meal (278 g/kg CP [DM basis] fed at 2.5 g/kg of BW); 4) soybean meal (543 g/kg CP [DM basis] fed at 1.4 g/kg of BW). Heifers were individually fed supplement treatments three days per week prorated to deliver their desired daily allotment. The oilseed supplements were fed to meet the nutritional requirements for growth of beef heifers at their given age, weight, and physiological status (NRC, 2000) and to provide equal amounts of protein across oilseed meal treatments. All animals had continuous access to water and salt.

On the day before weighing (14:00 h), heifers were gathered and placed in a dry lot and fed 2.5 kg per animal (as fed basis) of a moderate quality grass hay, and restricted from all other feed and water until processing the following morning (07:30-10:00 h). Initial body weights were collected at study initiation, then every 45 days until the end of the study.

Heifers were gathered at each supplementation occurrence, fed individually in confinement (07:00 - 09:00 h) with each animal representing an experimental unit in a completely randomized design (approximately 10 replications per treatment). The cattle were provided with supplement based on a % of BW basis and the quantity provided was recalculated at each weighing. BW data were collected on day 1 and BW and average daily gain (ADG) data collected on days 45 and 90.

IN SITU RUMINAL DEGRADATION STUDY

The in situ experiment was conducted at the facilities of Bar Diamond, Inc., Parma, ID, and followed a protocol adapted from Dhanoa et al. (1999) and Olaisen et al. (2003). One Holstein steer fitted with a rumen cannula (Model 9C, Bar Diamond, Inc., Parma, Idaho) was used to ferment the oilseed meals in Dacron bags for 24 and 48 h. The animal was maintained on an alfalfa hay diet (CP = 193 g/kg; NDF = 383 g/kg; DM basis) with continuous access to clean water and NW River Mineral (Western Stockman's, Caldwell, ID). Samples of the oilseed meals included: on-farm processed canola meal; on-farm processed camelina meal; and commercially processed soybean meal were the same feeds as used in the heifer feeding study. For the purpose of comprehensive evaluation of oilseed meals available in the Pacific Northwest (PNW), commercially processed canola meal was included in the degradation experiment. Samples for the in situ experimentation were ground through a Wiley Mill (Model 2, Thomas Scientific, Swedesboro, NJ) to pass a 2-mm screen. Dried, numbered, pre-weighed Dacron bags (5 cm × 10 cm; 53 ± 10 µm pore size; Ankom Co., Fairport, NY, USA) were filled with approximately 1.5 g of ground feed sample and then heat sealed with an impulse sealer (Model CD-200; National Instrument Co., Inc., Baltimore, MD).

The measurements of rumen disappearance were replicated four times. To ensure enough material was available for all analyses; two bags for each feed at each time point and incubation cycle were used. To account for winter cold stress on the animal during the oilseed meal incubations, the effective temperature is calculated from either the heat index or wind chill where the average temperature is greater than 50°F or less than 1°F; otherwise the ET is the average temperature (based on the Fahrenheit scale). The degrees outside the thermo-neutral zone (TZ) are equal to ET – 32. Five 3T PVC digestion tubes (Bar Diamond, Inc., Parma, Idaho) were filled with the pre-filled bags. One tube was used for each time point and incubation cycle. Each tube was soaked in 37-39°C water for 20 minutes to reduce lag time associated with wetting. The tubes for each incubation cycle were inserted into the rumen below the rumen mat by descending time. All digestion tubes for an incubation cycle were withdrawn from the rumen at one time. After removal from the tubes, the bags were gently rinsed with cool water to remove large particles of rumen contents. Zero hour bags were soaked in water for 20 minutes at 37-39°C then rinsed and processed as other bags noted above. The bags were then grouped by time point and placed in zippered mesh bags. The mesh bags were placed in a top loading washing machine (Model La5700SK; Whirlpool Corp., Benton Harbor, MI, USA) and rinsed twice.

Primary rinse is 14 minutes at 48°C followed by 8 minutes at 24°C. The individual bags were dried at 95°C for 24 hours and transferred to desiccators. After cooling, the bags were weighed. One bag from each time point and incubation cycle was opened and the contents analyzed for residue nitrogen by micro-Kjeldahl and ash (AOAC, 1975). The second bag from each time point and incubation cycle was subjected to NDF digestion as described by Mass et al. (1997). The NDF rinse followed the final water rinse to remove bacterial contamination. Following weighing, the NDF residues were analyzed for residue nitrogen by micro-Kjeldahl and ash. Dry matter, OM, and CP disappearance coefficients were determined after drying the residues following the NDF rinse.

DATA ANALYSIS

Analysis of variance for chemical composition, heifer performance, and ruminal nutrient degradation data were analyzed with the Mixed procedures of SAS (SAS version 9.4, SAS Institute Inc., Cary, NC) to determine main effects and interactions of data. All treatments in this experiment were considered fixed while replications were random effects. Least square means were used to separate means at the significant level of $P<0.05$. Mean separation was conducted with PDMIX800 in SAS, which is a macro for converting mean separation output to letter grouping (Saxton, 1998). Preplanned orthogonal contrasts were used to compare differences between TZ's and supplements.

RESULTS

CHEMICAL COMPOSITION OF OILSEED MEALS

The chemical composition of the oilseed meals utilized in our studies is presented in Table 1. Not only were variations observed in the feeds for the analytes quantified, but processing method (on-farm vs. commercial) affected the fat levels. The CP content for CanolaM was higher (P<0.01) than CanolaFP; soybean meal had higher (P<0.01) CP than all other meals evaluated. NDF was higher (P<0.02) for CanolaFP than SBM. ADF was higher (P<0.05) for CanolaFP than all other meals. The fat content (EE) was highest (P<0.01) for CanolaFP, and both CanolaFP and CamelinaFP had much higher (P<0.01) fat content than the commercially processed meals owing to the greater amount of residual oil, Table 1.

	Oilseed Meals (g/kg of DM)				
Item[1]	CanolaFP	CanolaM	CamelinaFP	SBM	SEM[2]
DM	926	901	932	889	3.8
CP	278	418	385	543	9.1
NDF	351	269	234	155	21.7
ADF	285	203	175	71	13.3
Ash	68	89	67	81	.6
NFC	217	245	400	283	43.5
EE	195	33	130	10	4.8
ADL	100	89	62	12	.3

Table 1. Chemical composition of oilseed meals (g/kg of DM).
[1]DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; NFC = nonfiber carbohydrate; EE = ether extract (fat); ADL = acid detergent lignin.
CanolaFP = on-farm processed canola meal; CanolaM = commercially processed canola meal; CamelinaFP = on-farm processed camelina meal; SBM = commercially processed soybean meal.
[2]SEM = standard error of the mean.

BEEF HEIFER PERFORMANCE STUDY

No significant differences were observed in BW of the heifers at the initiation of the study. Cumulative BW change and cumulative ADG (over the entire study) was significantly (both, P = 0.04) affected by feed type (Figures 1 and 2).

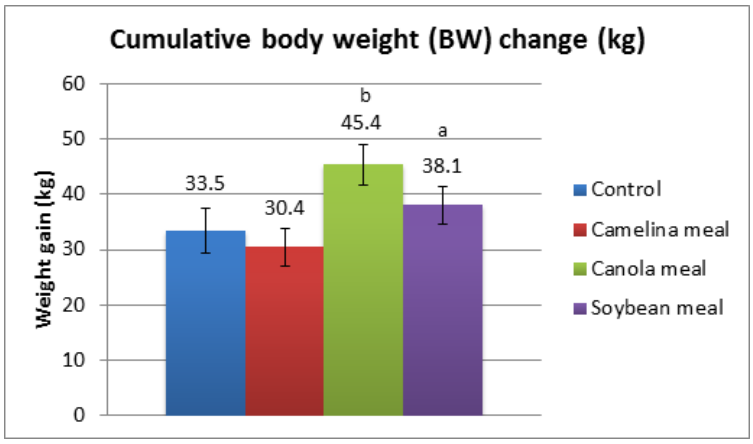

Figure 1. Cumulative body weight (BW) changes for the entire 90 d experiment of heifers fed on-farm processed or traditional protein supplements. Bar means with different superscripts are significantly different (P<0.05).

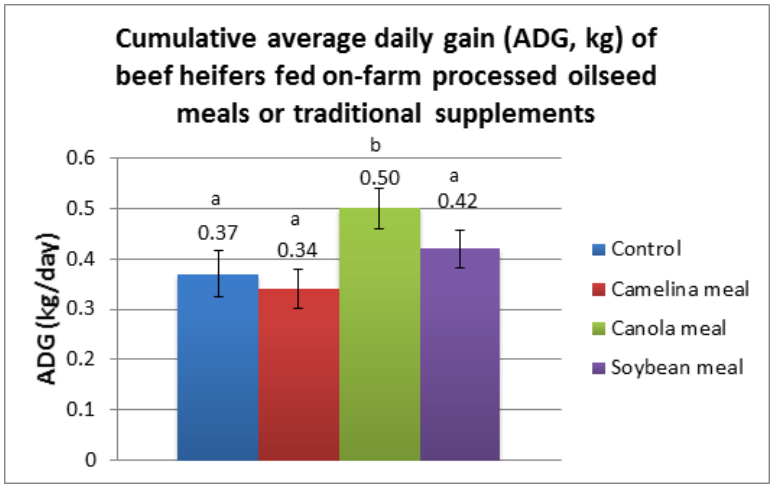

Figure 2. Cumulative average daily gain (ADG) for the entire 90 d experiment of heifers fed on-farm processed or traditional protein supplements. Bar means with different superscripts are significantly different (P<0.05).

Feeding canola meal resulted in a 49% increase (P<0.01) in BW weight over the entire 90 day feeding period when compared to camelina meal (Figure 1). Likewise, the heifers fed canola meal gained more BW (36%; P<0.04) than the heifers on the control diet. Body weight gains at the initiation of the study were very low due to the low-quality wheat straw diet. Growth of heifers was largely dependent on supplement treatment. In addition, in the first 45 days of the study, heifers exhibited palatability issues with the camelina meal which likely contributed to lower gains. In the first several days of the experiment, the producer-cooperator noted significant supplement refusal among heifers on the camelina meal treatment. This continued, but declined as time progressed in the first feeding period as heifers became acclimated to the camelina meal.

Canola meal's ability to promote greater BW gains and ADG are attributed to the higher fat content and therefore the ability to deliver more energy than soybean meal. The difference in fat content (i.e., 195 vs. 10 g/kg for canola meal and soybean meal, respectively) will affect heifer gains (NRC, 2000). Even though the fat content of camelina meal was greater than soybean meal (130 vs. 10 g/kg), it failed to promote gains observed with canola meal. In our study, with our base wheat straw forage being of very low quality, fat content may be more important than the supplement's ability to enhance forage utilization by increasing forage intake and digestion. Fat content alone cannot explain why camelina meal failed to promote the gains achieved with canola meal. The physical characteristics of camelina meal may contribute to the lower digestibility (reported in the subsequent in situ study, Table 3) and reduced palatability. In a qualitative test in our laboratory, camelina meal exhibited what appears to be seed coat mucilage (Figure 3). Five grams of each oilseed meal were mixed with 20 ml of DI water, vortexed, and allowed to stand for one hour. We determined the presence of seed coat mucilage could be a contributing factor to the acceptability and palatability of camelina meal. The tubes show the viscosity of the oilseed meal/water mixture and the relative amount of settling of the mixture after one hour. Settling of the meal was most rapid for SBM, CanolaM, and CanolaFP, respectively. After one hour, the CamelinaFP (Tube 12) only settled minimally with an apparent thick, viscous material (mucilage) which retained the meal in suspension indefinitely. To our knowledge, this has not been reported previously for camelina meal. Palatability issues in our study for camelina meal have not been reported either. More detailed laboratory investigations are required to quantify the amount of mucilage and its effect on feeding value.

Average daily gain is also influenced by supplement (Figure 2). Consistent with BW changes, feeding canola meal resulted in higher ADG when compared to camelina meal and control diets (P<0.01 and P<0.05, respectively). No significant differences (P=0.16) in ADG were observed between canola meal and soybean meal. The percentage change in cumulative BW among the treatments was in agreement with the percentage change for ADG. Therefore, BW change translated into higher gains.

Figure 3. Qualitative analysis of oilseed meals.
CanolaM = tube 2; CanolaFP = tube 3; CamelinaFP = tube 12; SBM = tube 13.
5 g of each oilseed meal was vortexed with 20 ml water and allowed to stand for one hour.

IN SITU RUMINAL DEGRADATION STUDY

Main effects and interactions for ruminal degradation are presented in Table 2. Ruminal dry matter degradation (DMDEG) and crude protein degradation (CPDEG) were influenced by feed (P<0.0001) and hours of incubation (P<0.01). In addition, TZ was used to account for cold stress on the animal during the oilseed meal incubations. The effective temperature (ET) is calculated from either the heat index or wind chill where the average temperature is greater than 50°F or less than 1°F, otherwise the ET is the average temperature. The degrees outside the thermo-neutral zone (TZ) are equal to ET – 32. TZ had the potential to affect CPDEG (P<0.05). Statistically significant interactions for feed x hours of incubation were observed for DMDEG and CPDEG (both P<0.01). Likewise, a feed x temperature interaction was present for CPDEG (P<0.05). Organic matter degradation (OMDEG) was not influenced by feed type, hours of incubation or TZ during the study.

	DMDEG	OMDEG	CPDEG
Feed (F)	****	ns	****
Hours (H)	**	ns	**
TZ (T)	ns	ns	*
F × H	**	ns	**
F × T	ns	ns	*
H × T	ns	ns	ns
F × H × T	ns	ns	ns

Table 2. ANOVA results for digestion study. DMDEG = dry matter degradation; OMDEG = organic matter degradation; CPDEG= crude protein degradation; **** P <0.0001, *** P < 0.001, ** P<0.01, * P<0.05, ns = nonsignificant.

The DMDEG and CPDEG disappearance coefficient means are presented as feed by hours and pooled over TZ due to the significant interaction observed in the feed by hours (Table 3). Soybean meal had the highest (P<0.05) 24 and 48 hour DMDEG and CPDEG of meals. The disappearance did not differ between 24 and 48 hours indicating that soybean meal is rapidly digested. On-farm and commercially processed canola meal were similar in DMDEG at 24 hours, but CanolaM was lower (P<0.05) at 48 hours than CanolaFP. CanolaFP had greater (P<0.05) DMDEG at 48 hours than at 24 hours. CamelinaFP had the lowest DMDEG and CPDEG at both times of all supplements evaluated.

	DMDEG†		CPDEG†	
	24 hrs	48 hrs	24 hrs	48 hrs
SBM	0.9126 (0.0108) A	0.9166 (0.0101) A	0.9470 (0.0187) A	0.9476 (0.0136) A
CanolaFP	0.7778 (0.0049) B‡	0.8067 (0.0104) B	0.8941 (0.0103) AB	0.9068 (0.0067) A
CanolaM	0.7399 (0.0185) B	0.7537 (0.0148) C	0.8291 (0.0277) B‡	0.8402 (0.0241) B
CamelinaFP	0.5248 (0.0296) C	0.5961 (0.0112) D	0.5908 (0.0386) C	0.6667 (0.0090) C
Contrasts§				
TZ -37 vs -29	*		*	
TZ -37 vs -25	ns		*	
TZ -29 vs -25	ns		ns	
SMB vs all others	****		****	
CamelinaFP vs all others	****		****	
CanolaFP vs all others	***		****	
CanolaFP vs CanolaM	**		**	
CamelinaFP vs CanolaFP and CanolaM	****		****	

Table 3. Interaction of main effect of feed by hours on DM and CP disappearance coefficients.
†Treatment means followed by the same letter within a column are not significantly different at P<0.05. Values in parenthesis are standard errors.
‡Significant difference for hours of incubation was observed at P<0.05.
**** P<0.0001, *** P<0.001, ** P<0.01, * P<0.05, ns = nonsignificant
SBM = soybean meal; CanolaFP = on-farm processed canola meal; CanolaM = commercially processed canola meal; CamelinaFP = on-farm processed camelina meal.
§To account for cold stress on the animal during the oilseed meal incubations, the effective temperature is calculated from either the heat index or wind chill where the average temperature is greater than 50°F or less than 1°F, otherwise the ET is the average temperature. The degrees outside the thermo-neutral zone (TZ) are equal to ET – 32.

Predetermined orthogonal contrasts were utilized to make comparisons for TZ and oilseed meal treatments. With greater deviation in ambient temperature from the thermo neutral zone (TZ of -37 vs. -29), there was a greater probability (P<0.05) to influence DMDEG and CPDEG. For -25 vs. -37, TZ influenced (P<0.05) CPDEG as well. Soybean meal had a higher (P<0.0001) rumen DMDEG and CPDEG coefficients when compared to the average of all other oilseed meals evaluated (.9146 vs. .6998 and .9473 vs. .7880, for DMDEG and CPDEG, respectively). CamelinaFP exhibited lower (P<0.0001) DMDEG and CPDEG than all other feeds tested (.5605 vs. .8179 and .6288 vs. .8941, for DMDEG and CPDEG, respectively). CanolaFP had higher (P<0.001) DMDEG and higher (P<0.0001) CPDEG than all oilseed meals grouped together (.7922 vs. .7406, and .9004 vs. .8036, respectively). Comparing the two forms of canola meal, CanolaFP had higher (P<0.01) DMDEG and higher (P<0.01) CPDEG with treatment means of .7923 vs. .7468 and .9006 vs. .8347, respectively. Finally, comparing CamelinaFP vs. the average of the two canola meals, CamelinaFP had significantly lower (P<0.0001) DMDEG and CPDEG (.5605 vs. .7695 and .6288 vs. .8676, for DMDEG and CPDEG, respectively).

DISCUSSION

Based on needed feeds and supplements, nutrition accounts up to 60% of the total annual operating costs in a PNW cow/calf operation (Neibergs and Nelson, 2008). Forage quality in the Pacific Northwest declines throughout the summer grazing season as forages mature (Ganskopp and Bohnert, 2001). Likewise, crop residues found in the Pacific Northwest (i.e., grain straws, corn stover, and residues of grass seed production) are lacking in sufficient protein to meet the requirements of beef cattle. Efficient use of low-quality forage depends on protein supplementation to provide an adequate supply of ruminal nitrogen (N) to support maximum microbial digestive activity. Oilseed meals produced in the PNW represent an opportunity for beef producers to meet these protein needs. Meals can replace DDGS because of local availability and reduced transportation costs compared to other commodities produced in other areas of the United States and Canada.

Soybean meal has been extensively used as a protein supplement. Canola meal is emerging as a competitive alternative to soybean meal and other traditional supplements. Processing methods significantly influence the chemical composition of oilseed meals. Bell (1993) reviewed the nutritional value of canola meal. Our chemical composition for canola meal supports those reported by Bell (1993) with exception of on-farm processed canola meal is much higher in fat content (195 vs. 35.9 g/kg EE). However, we reported the fat content of the commercially extracted canola meal at 33 g/kg EE, which is consistent with his values. These differences are attributed to the efficiency of the oil removal process (on-farm vs. commercial). The nutrient content of the commercially processed canola meal in our study is similar to that reported by NRC (2000), but CP was much lower for the on-farm processed product (i.e., 418 g/kg vs. 278 g/kg). In addition, the NDF content of the on-farm processed canola meal was higher than the NRC (2000) values. The chemical composition of camelina meal utilized in our study was similar to that used by Moriel et al. (2011). In addition, camelina meal in our study had similar CP content to that which was reported by Grings et al. (2015), but was much higher than CP reported by Moriel et al. (2011). As with most byproduct feeds, care must be taken to have the oilseed meals analyzed for chemical composition to identify lot to lot variations. The 24 or 48 hour disappearance that we observed for in situ DMDEG of camelina meal was much lower than the in vitro dry matter digestibility (IVDMD) of camelina meal reported by Moriel et al. (2011).

Canola meal resulted in significantly higher gains (47%; P<0.05) than camelina meal. There are likely two reasons for this: first, the canola meal fed in our experiment likely enabled the heifers to digest their base forage more effectively; and secondly, the additional fat (about 50% more for the CanolaFP when compared to CamelinaFP) provided more energy in the diet of the CanolaFP heifers. Generally for beef cattle, provision of ruminally degradable protein results in maximizing intake and digestion of the low-quality forage (i.e., <7% CP; Köster et al., 1996; Olson et al., 1999; Mathis et al., 2000; Bohnert et al., 2011). It has also been determined that low-level protein supplementation could be employed post-weaning in the fall to increase BW and body condition scores (BCS) prior to cows entering winter grazing season (Llewellyn et al., 2006). Other investigators have utilized protein supplements to support growth and production of stocker cattle (Lusby et al., 1982; Lusby and Horn, 1983). In our 90 day study, camelina meal resulted in the lowest gain of all three oilseed meals evaluated. Moriel et al. (2011) observed no differences in gain between camelina meal and soybean meal over two thirty-day feeding periods leading up to the breeding season. Heifers in our study responded similarly, but gains were less than 50% of those observed by Moriel et al (2011). These differences are partially explained by the low quality wheat straw base forage in our study. Wheat straw has little nutritional value but was chosen because it is readily available to livestock producers in Eastern Washington at an affordable price. In contrast, Moriel et al. (2011) and Grings et al. (2015) utilized bromegrass hay as the base diet to evaluate the oilseed meals. Bromegrass hay has much higher nutrient content and available net energy than wheat straw. In total, the differences in gains between our study and the higher gains reported by Moriel et al. (2011) and Grings et al. (2015) is because of the bromegrass hay's ability to deliver more nutrition.

The extremely low DMDEG and CPDEG for CamelinaFP were not expected and may be a causative factor along with the lower quality base diet in the lower performance of the beef heifers in our feeding case study. The CPDEG and DMDEG was acceptable for both canola meals and the soybean meal to serve as a protein supplement and promote adequate forage utilization of low-quality forage as well as good performance.

Quite likely, palatability issues with camelina meal have not been previously reported because most investigations with camelina meal utilized mixed rations where it is a component, thereby not forcing the animals to eat it alone. It is likely that the mucilage observed in camelina meal is similar to that observed in flaxseed (Anderson and Lowe, 1947). Additional research will be required to confirm and quantify the presence of seed coat mucilage; the implications to palatability and forage utilization may be substantial.

On-farm processed meals have the potential to deliver more fat (and therefore energy) per unit of feed than their commercial, solvent-extracted counterparts. Methods of removing the oils from canola and camelina have implications in the feeding value of the meals. In particular, on-farm processed meals may have substantially greater levels of fat than those produced commercially. This observation is owing to the reality of small-scale equipment limitations to mechanically remove the oil when compared to more sophisticated processing such as solvent extraction which is the most extensively utilized method of producing soybean oil in the Western world (NSRL, 2013). In our study, the fat content of CanolaFP was significantly greater than the commercially processed meals.

The heifers in our study may have benefited from the additional fat provided by CanolaFP, resulting in greater cumulative BW gains as well as greater ADG. Providing supplemental fat has been practiced for a variety of rationales. Feeding additional fat to beef cattle to alter various physiological processes has been investigated. In some cases supplemental fat can be relatively less expensive and raise the energy density of the diet as well as supply more energy to high-producing classes of livestock such as lactating dairy cows. Chilliard (1993) suggested that supplemental fats can alter the fatty acid content of animal products such as meat and milk. Lammoglia et al. (1999ab) suggested that fat supplementation to pregnant beef cows can result in increasing cold tolerance in their newborn calves. Several studies have also demonstrated that supplemental fat can affect reproduction in high-producing dairy cows (Boland, 2002). The provision of supplemental fat has been shown to affect the diet digestibility in beef cattle on forage diets, in some cases, negatively (Hess et al., 2008). Livestock producers should consider these responses when feeding alternative high fat protein supplements, as those evaluated in our study. In particular, it has been shown that protein supplements can be provided to beef cattle on a prorated basis (such as three or four days per week instead of daily) to take advantage of a ruminant's ability to recycle nitrogen. If large amounts of fat enter the rumen on these feeding occurrences, depressions in forage utilization may occur.

For producers to make decisions regarding inclusion of alternative oilseed meals, systematic valuations must be conducted. Neibergs et al. (2015) suggested a method to determine the market value of canola and camelina meals to supply protein in livestock diets. Using least cost ration formulation and economic substitution, it is possible to compare canola and camelina meals to other traditional protein supplements for unique feeding situations. However, supplement cost is only one factor to consider in supplementation programs. We demonstrated in these experiments significant differences exist in digestibility and animal response across a range of supplements related to their chemical composition and potential impacts on palatability. Antiquality component differences among the feeds, such as those observed with camelina meal, have a bearing on expected animal performance.

CONCLUSIONS

On-farm processed oilseed meals, particularly canola meal, was demonstrated to be an acceptable alternative protein supplement for beef cattle on low-quality forage diets with animal performance to meet or exceed that from soybean meal. Canola meal rumen degradability is satisfactory and the delivery of additional energy from the higher fat content of the on-farm processed meal can result in better animal performance. Camelina meal resulted in the lowest heifer gains and lowest rumen degradability of all feeds evaluated. The on-farm processed meals have higher fat and can supply more energy. Protein supplements can be provided to beef cattle on a prorated basis (such as three or four days per week instead of daily) to reduce labor and take advantage of ruminants' ability to recycle nitrogen; but producers should be cautioned that if large amounts of fat enter the rumen at one time, depressions in forage utilization may occur.

More research is indicated to determine the factors causing reduced digestion, palatability, and animal performance of cattle being fed camelina meal. When commodity prices of traditional protein supplements are taken into account, PNW grown oilseeds and meals represent a viable alternative for cattle producers.

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6584 W. Duroc Road | Maroa, IL 61756 | T (217) 794-3700 | F (217) 794-5901