CANODEV RESEARCH INC.

FINAL PROJECT REPORT

An evaluation of the use of canola screenings in creep feed and in the diets of feedlot cattle

T. A. McAllister[1] K. Stanford[2], J. D. Popp[3], S. Pylot[4] and J. J. McKinnon[5]

[1]Research Centre, Agriculture and Agri-Food Canada, Lethbridge, Alberta, [2]Alberta Agriculture, Food and Rural Development, Lethbridge, Alberta, [3]Alberta Agriculture, Food and Rural Development, Medicine Hat, Alberta, [4]Supertech Feeds, Strathmore, Alberta and [5]University of Saskatchewan, Saskatoon, Saskatchewan

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ABSTRACT

Coarse canola screenings (CS) were obtained from a commercial canola crushing plant and evaluated *in situ* and in digestibility and feedlot experiments using Romanov x Suffolk lambs. The major constituent (60%) of the CS used in this study was canola (whole seed, broken seed, immature seed), with the remainder weed seeds (25%) and chaff/dust (15%). The five pelleted experimental diets had 95, 75, 45, 20 and 0% CS, respectively with CS substituted for whole barley. The control (0% CS) diet was 70% barley, 20% alfalfa hay and isonitrogenous (13% CP) to the 20% CS diet. *In situ*, effective rumen degradability of protein was highest for CS as compared to barley or alfalfa and linearly increased ($P < 0.01$) with increasing CS content of diets. Likewise, the rate of protein disappearance increased ($P < 0.05$) with increasing dietary CS. Digestibilities of DM, organic matter, acid detergent fibre and neutral detergent fibre were linearly reduced with increasing dietary CS while nitrogen retention for lambs receiving 95% CS was reduced 3 fold compared to lambs receiving the Control diet. In the feedlot, growth and feed conversion efficiency were linearly reduced ($P < 0.001$) with increasing dietary CS, although saturation of carcass fat was also linearly reduced ($P < 0.001$) with increasing dietary CS. Reductions in lamb performance with increasing dietary CS were likely related to the high levels of crude fat (9% on DM basis) and inorganic matter (dirt/dust) in CS. As CS are usually valued at 86% of barley, incorporation of CS in feeder lamb diets up to a maximum of 45% would provide the greatest economical returns. A second study was conducted to evaluate canola screenings as a creep feed. Supplementing the canola screenings-based creep feed with barley resulted in higher body weights of first-calf cows after 42 and 63 days on pasture. However, body condition scores and backfat thickness of cows did not differ between treatment groups. Conception rates tended to be higher and number of days pregnant greater, in cows whose calves had access to the 75:25 barley:canola screenings creep

feed. Increasing the energy content of canola screenings by including barley grain had little effect on overall calf gains, however, calves fed the 75:25 creep feed gained more in the first 42 days on pasture than did those with access to the screenings-only creep feed. A final study was conducted to determine the value of feeding canola screenings (CS) in combination with barley grain (BG) for buffering the ruminal environment in growing cattle. Four diets (75:25, 50:50, 25:75 and 0:100 BG:CS) were fed in a 4 x 4 Latin square experiment (Exp. 1) involving four ruminally fistualted steers (698 ± 70 kg) and in an 83-d feedlot finishing trial (Exp. 2) involving 80 individually fed crossbred steers (initial weight 430 ± 9 kg). In Exp. 1, ruminal fluid was collected 0, 2, 4, 6, 8, 10, 12 and 14 h after the morning meal. Ruminal pH increased linearly ($P < 0.05$) with increasing proportion of CS (quadratic effect ($P < 0.05$) in 4-h and 6-h samples). Total VFA decreased linearly ($P < 0.01$), acetate to propionate ratios increased quadratically ($P < 0.10$), and ammonia-N increased linearly ($P < 0.05$) at all time points as CS in the diet increased. Detailed information on the effect of canola screenings will be reported in the M. Sc. thesis of Mr. Steve Pylot (Department of Animal and Poultry Science, University of Saskatchewan) and were not included in the orifinal agreement with Canodev. In Exp. 2, average DM intake (10.67 kg d^{-1}) was unaffected ($P = 0.21$) by CS level, but ADG and feed efficiency were linearly reduced ($P < 0.01$), and finished weight quadratically reduced ($P < 0.05$) by CS. Increasing CS in the finishing diet increased ($P < 0.10$) carcass yield (%) and reduced ($P < 0.05$) carcass fat. Canola screenings effectively mediated ruminal conditions on high concentrate diets, but growth performance was reduced. However, costs of gain with 25% and 50% CS were comparable to those calculated for 80:20 BG:barley silage diets, making canola screening a viable alternative during times of silage shortages.

INTRODUCTION

Due to fluctuations in the value of cereal grains and other traditional feed ingredients, low-cost byproducts will likely become increasingly important feeds if Canadian livestock are to remain globally competitive. In western Canada, one of the more widely available byproduct feeds is canola screenings, which is produced during seed cleaning and consists of a mixture of canola, cereal grains, weed seeds, chaff and dust (Darroch et al. 1990). Canola screenings are commonly classified as either "fines" or "coarse screenings" as determined by their respective contents of crude protein (CP) and crude fat. Fines average 17-21% CP, with 15-25% crude fat and 23-33% acid detergent fibre (ADF; Beames et al. 1986) and have been the subject of a number of previous studies (Bell and Shires 1980, Keith and Bell 1983, Beames et al. 1986, Tait et al. 1986, Darroch et al. 1990). Coarse canola screenings (CS) are lower in CP and crude fat than fines (10-16% CP, 7-16% crude fat) and studies evaluating their use in ruminant diets have been limited (Pylot et al. 1998). As CS in 1997 were approximately equal in value to good-quality alfalfa hay and worth $25 tonne^{-1} less than barley, the substitution of CS into ruminant diets could be economically advantageous, provided that the screenings did not impair animal performance or carcass quality.

Although CS may represent a valuable feed resource, basic information such as the *in situ* kinetics and apparent DM, OM, ADF, NDF and N digestibilities of diets containing varying proportions of CS have not previously been reported. Potentially, CS fed with appropriate vitamin and mineral supplementation should meet the nutrient requirements of growing steers or lambs. Supplementing diets with up to 75% canola meal was found to have no effect on feed intake or apparent nutrient digestibility of lambs (Mustafa et al.

1997). However, elevated levels of fibre and crude fat along with the possibility of anti-nutritional factors in some constituents of CS may reduce ruminant growth performance.

Tesfa (1993) determined that fibre digestion was impaired when canola oil was 6.7% of dietary DM. Consequently, the relatively high oil content of CS may affect fibre digestion, particularly if CS were to constitute a large proportion of the diet. Despite the potential for reduced fibre digestion, a high concentration of canola oil in the diet may have off setting benefits. Due to the high oleic acid ($C_{18:1}$) content of rapeseed/canola oil, adding 6.5% rapeseed to the diet was found to reduce the cholesterol content of lamb (Solomon et al. 1991), while canola seed added at 10% of dietary DM increased the amounts of long-chain unsaturated fatty acids in beef (Hussein et al. 1996). As decreased dietary cholesterol and increased levels of long-chain unsaturated fatty acids have been found to reduce the incidence of atherosclerosis (Mattson and Grundy 1985), the addition of CS to ruminant diets may have positive human health benefits.

To further evaluate the use of coarse canola screenings in ruminant diets, the goals of the present study were six fold:

(1) to compare the *in situ* degradation of crude protein (CP) and dry matter (DM) of coarse canola screenings to that of alfalfa and barley.

(2) to compare the apparent digestibilities (DM, organic matter (OM), acid detergent fibre (ADF), neutral detergent fibre (NDF), nitrogen (N)) for rapidly-growing feedlot lambs of diets containing varying levels of coarse canola screenings with those of a standard alfalfa-barley diet.

(3) to determine if adding coarse canola screenings to the diet can alter the composition of lamb fat.

(4) to determine the maximum level of coarse canola screenings that can be economically added to the diets of rapidly-growing feedlot lambs.

(5) To evaluate canola screenings as a creep feed.

(6) To evaluate canola screenings as a component of the diets of feedlot cattle.

MATERIALS AND METHODS

All animals involved in this study were cared for in accordance with the standards set by the Canadian Council on Animal Care (1993).

Chapter 1

Diets

A representative 500 g sample of CS was obtained from a commercial canola crushing plant in Lethbridge AB and sorted into its constituents (Table 1). The commercial plant supplied CS as a 10 mm pellet, after first hammermilling the screenings and passing them through a 1 mm screen. Monthly proximal analyses of CS over the previous year were obtained from the commercial crushing plant, with averages and ranges shown in Table 1. Prior to addition to the diets, CS were subjected to proximate analysis. Five experimental diets were formulated with CS incorporated at rates of 0, 20, 45, 70 and 95% on an as fed basis and whole barley substituted for CS (Table 2). For the Control (0% CS) diet, a standard lamb grower for western-Canada (75% barley and 20% alfalfa hay) was used. Control and 20% screenings diets were balanced to be isonitrogenous.

In Situ Evaluation of Dry Matter and Crude Protein

Two ruminally cannulated Jersey steers (450 kg) were offered a diet consisting of 50% alfalfa-timothy cubes (70:30; 13% CP) and 25% of each of the 70% and 20% diets presented in Table 2. Steers were adapted to the diet for 14 d prior to the *in situ* study. Dried, pre-weighed nylon bags (10 x 11 cm; 53 µm pore size) containing 3.0 g of a dietary constituent (rolled barley, pelleted alfalfa, pelleted CS) or a complete, pelleted diet (95% CS, 20% CS, Control) were placed in the rumen of each steer. After 2, 4, 8, 12, 24, 48 and 72 h of incubation in the rumen, three bags of each sample type were removed from

each steer. Bag washing and calculations of DM disappearance were performed as described by McAllister et al. (1990). Dry matter disappearance not attributable to microbial digestion was estimated by incubating bags in water at 37° C for 2 min. Residues from triplicate bags were pooled for N analysis. Digestion kinetics of DM and CP were determined without correction for microbial protein using the equation of Ørskov and McDonald (1979):

$$p = a + b(1 - e^{-ct})$$

where p = proportion of DM disappearance at time t, a = soluble faction, b = slowly digestible fraction, c = the fractional rate of disappearance of b (5% h^{-1}) and t = duration of ruminal incubation (h), with the constraint that $a + b \leq 1$. The constraints a, b, and c were calculated using the NLIN procedure of the SAS institute, Inc. (1993). Effective rumen degradability of CP (EDCP) was estimated using the equation of Ørskov and McDonald (1979):

$$EDCP = a + (bc)/(k+c)$$

with an estimated solid outflow from the rumen (k) of 5% h^{-1} (Windschitl and Stern 1988). *In situ* data were analysed using the GLM procedure of the SAS Institute, Inc. (1993). Orthogonal contrasts were performed for level of screenings in complete diets (0, 20%, 95%) while dietary constituents were compared using the least squares mean linear hypothesis test.

Digestibility trial

Six Romanov-Suffolk ram lambs (initial weight 20.4 ± 0.1 kg) were used in a replicated three by three Latin square design study with three 21-d periods to evaluate voluntary feed intake and digestibility of the Control, 95% and 45% CS diets shown in Table 2. Lambs were penned individually for the first 14 d of each period and were then moved to individual crates for the last 7 d. Water was available *ad libitum* throughout the trial. For the first 7

d of each period, lambs were allowed to adapt to the diets. Orts were removed and weighed on a daily basis and each day 10% more feed was offered than was consumed the previous day. *Ad libitum* intake was then monitored for 5 d and the lambs fed at 95% of *ad libitum* for the last 9 d of the period. Total collections of feces and urine were conducted daily for the last 7 d of each period. Acid (45 mL of 8 N H_2SO_4) was added each morning to the urine collection jugs to prevent volatization of ammonia from the urine. The daily production of feces and urine was subsampled daily (10%), composited over each period and stored at -30°C until analysed.

Individual Feeding Trial

Fifty-four Romanov-Suffolk lambs were used to evaluate the five experimental diets (Table 2) in an individual feeding trial. The lambs (initial weight 22.9 $\pm$ 0.2 kg) were blocked by breed, sex and live weight and randomly allocated to individual pens using a randomized block design. Water and pelleted complete diets were provided to the lambs *ad libitum*. Lambs were fed once daily and orts were collected and weighed weekly. Lambs were weighed weekly and were shipped for slaughter after reaching 45 kg.

After shipment to a commercial plant, but prior to slaughter, lambs were ultrasounded at the third lumbar vertebra to measure the maximum depth of the longissimus muscle 'B' and subcutaneous fat depth, 'C' perpendicular to 'B' using an Aloka SSD model 500 SEM (Aloka Co. Ltd., Tokyo, Japan) real-time ultrasound scanner equipped with a 1.5 cm, 2-MHZ probe. Collection of ultrasound data was as described by Stanford et al. (1995b). Carcass weight was measured 30 min post slaughter. Body wall thickness was measured at the grade rule (GR) site, 11 cm from carcass midline between the 12th and 13th ribs (Kirton and Johnson 1979). Samples of kidney fat and subcutaneous fat over the *Longissimus* muscle were stored in liquid nitrogen for subsequent fatty acid analysis.

Chemical analyses

Feed and feces samples were dried at 105°C for 24 h to determine DM. Ashing samples in a muffle furnace at 500° C for 12 h were used to determine OM. Feces and feed were dried at 55° C for 48 h and either ground through a 1 mm screen prior to analysis for starch and NDF, or ground for 3 min in a Wig-L-Bug Amalgamator (Crescent Dental Mfg. Co., Lyons, IL) prior to N analysis in a Carla Erba® NA 1500 Carbon-Nitrogen elemental analyser (Carla Erba Srumentazione, Rodano, Milan, Italy). Oil content of canola screenings and the pelleted diets was determined by ether extraction (method 920.39, AOAC, 1990). Neutral detergent fibre was determined using the procedure of Van Soest *et al.* (1991), with the exception that α-amylase was added to feed samples to solubilize starch and facilitate filtering.

In order to prepare methyl esters of fatty acids, duplicate 15 g samples of kidney or subcutaneous fat were placed in tubes containing 4 mL of 35:45:20 (vol:vol:vol) boron trifluoride:methanol: hexane. The tubes were sealed and placed in a boiling water bath for 1 h. After cooling, 2 mL of hexane and 3 mL of 1% (wt:vol) sodium chloride solution were added to each tube before mixing the tubes and allowing them to settle. For analysis of the methyl esters, 25 µL samples of the hexane layer were diluted in 1 mL of hexane and injected onto a BPX 70 capillary column (0.25 mm x 25 mm; film thickness 0.25 µm; Rose Scientific, Edmonton, AB) on a Varian Model 3600 gas chromatograph equipped with a split port injector and a flame ionization detector.

Statistical analyses

Data were analysed using the REG and GLM procedures and means compared using the least-squares-mean linear hypothesis test (SAS Institute, Inc., 1993). For the digestibility trial, the model included lamb, diet, period and period by diet interaction. Data for the individual feeding experiment were analysed with sex, diet and diet by sex interaction

included in the model and initial weight as a covariate. Carcass data were analysed both with and without carcass weight included as a covariate. Least-cost diets including CS were determined by setting the first derivative of a quadratic equation to 0 and solving for the proportion of CS (Steel and Torrie 1980).

Chapter 2

Creep feed experiment

Seventy eight cow-calf pairs, blocked by weight, sex of calf, and reproductive and body condition of dam, were randomly assigned to two treatment groups on pasture near Olds, Alberta. Animals were kept on pastures of equal size and vegetative composition, and calves were provided access to creep feed consisting either of 100% canola screenings, or 75% canola screenings/25% barley grain (as-fed basis).

Feedlot experiment

Eighty Charolais crossbred steers (430 kg) were randomly assigned to five diets in which the non-supplement portion consisted of 1) 95% canola screenings; 2) 75% canola screenings/20% barley grain; 3) 50% canola screenings/45% barley grain; 4) 25% canola screenings/70% barley grain and a typical feedlot diet consisting of 5) 75% barley grain/20% barley silage (as-fed basis). The remaining 5% of all diets was a screenings-based supplement containing vitamins and mineral in accordance with NRC recommendations. Cattle were penned and fed individually to allow individual estimates of feed intake and feed efficiency.

RESULTS AND DISCUSSION

Chapter 1

Composition of canola screenings

Weed seeds were estimated to be 25% or less of the CS in the present study, with canola (immature, cracked and whole) an estimated 60% of the screenings (Table 1). Compared to other studies evaluating canola/rapeseed fines where weed seeds averaged 40% (Beames et al. 1986) and inorganic matter (soil and sand) was up to 40% of the screenings (Bell and Shires 1980), the CS of the present study were a relatively "clean" product comparable to the fines used in the mouse study of Darroch et al. (1990) or one of the sources of fines used in the pig study of Keith and Bell (1983). Although the coarse canola screenings obtained from the commercial crushing plant varied over the course of a year in CP, crude fat and fibre (Table 1), such variations would not limit the utility of CS in ruminant diets. Monthly analysis of samples at cleaning plants over multiple years may enable for accurate predictions of screenings quality at a given point in the year. The safest approach to avoiding unwanted surprises in screenings composition is to conduct a nutrient analysis prior to any purchase.

In situ study: dietary constituents

The slowly digestible protein and DM fractions of alfalfa and CS pellets were equivalent, but lower than those of lightly-rolled barley ($P < 0.05$; Table 3). As the pericarp of the majority of barley kernels was cracked, but the grain was otherwise intact, the slowly digestible fraction of barley would be increased compared to alfalfa and CS which were both ground before pelleting. Although processing of feed is known to increase its susceptibility to microbial attack (McAllister et al. 1990), it was not possible to process the barley for the *in situ* study in a manner equivalent to the alfalfa or CS. In a preliminary study (data not

shown) grinding the barley through a 2 mm screen resulted in a DM disappearance of > 40% at 0 h of rumen incubation.

The soluble DM and protein fractions were higher ($P < 0.05$) for CS than for alfalfa or barley, in accord with our previous work (McAllister et al. 1998) where 41.4 and 37.1% were reported for CS soluble protein and DM, respectively. The combination of the solubility of canola meal protein with hammermilling and passing the screenings through a 1 mm screen prior to pelleting likely resulted in the high solubility of DM and protein observed for CS in the present study. Although no differences were observed between dietary constituents in the rate of DM disappearance, CS had the highest ($P < 0.05$) rate of protein disappearance of all dietary constituents. The rate of disappearance of CS protein in the present study is comparable with that reported by McAllister et al. (1998), although in that study DM disappearance of CS was more rapid than protein disappearance. As the screenings in the study of McAllister et al. (1998) contained higher CP (23%), lower fibre (25% ADF) and higher crude fat (12 %) compared to those of the present study (15 % CP, 31% ADF, 9% crude fat), differences in the *in situ* kinetics between the two studies would be expected. Generally, dry matter disappearance increases with increasing protein concentration (Kirkpatrick and Kennelly 1987), while increasing fibre has reduced the soluble protein fraction of canola meal (Mustafa et al. 1996). Elevated levels of fat in *in situ* studies may have a variety of effects such as impairing the activity of rumen bacteria or restricting the outflow of material from the nylon bag (McAllister et al. 1998).

Effective rumen degradability of protein (EDCP) was highest for CS ($P < 0.05$) as compared to the other dietary constituents. The EDCP values for canola screenings in the present study were equivalent those reported by (McAllister et al. 1998) and were also similar to EDCP values reported for standard canola meal (Ha and Kennelly 1984; Boila and

Ingalls 1992; Stanford et al. 1995a). In all cases, grain was at least 50% of the diets fed to animals in the aforementioned *in situ* studies.

***In situ* study: complete diets**

The slowly digestible protein and DM fractions increased linearly with decreases in concentration of CS ($P < 0.001$) although quadratic effects of the level of canola screenings on protein ($P < 0.01$) and DM ($P < 0.05$) were also noted. The increased proportion of slowly digestible DM and protein with decreased dietary canola screenings is likely a function of the high solubility of the CS DM and protein which has been found in previous *in situ* studies to be greater than 25% for CP (Mir et al. 1984, Stanford et al. 1995a).

Increasing CS content had a quadratic effect ($P < 0.05$) on the soluble protein fraction and also caused a linear increase ($P < 0.01$) in rate of protein disappearance in complete diets. Increased rates of CP and DM disappearance in the 95% CS diet as compared to 100% CS pellet are likely due to the further processing of CS in the formulation of the diets. All diets were pelleted which necessitated hammermilling the CS and blending in additional ingredients prior to re-pelleting.

Effective rumen degradability of protein linearly increased ($P < 0.01$) with increasing CS content in the diet although a quadratic effect was also noted ($P < 0.05$). For all complete diets, EDCP was equivalent to that of the 100% CS pellet, likely due to the mix of ingredients inherent in CS.

Digestibility trial

Apparent digestibility of NDF and ADF (Table 4) were linearly ($P < 0.01$) and quadratically ($P < 0.05$) reduced by increasing level of CS, likely due to the fat content of the diets. The 95 % screenings diet had approximately double the concentration of crude fat (13%) of the 45% screenings diet (6%), which in turn had double the crude fat concentration of the

control diet (3%). Free canola oil, approaching 10% of DM in ruminant diets, has been demonstrated to exert toxic effects on protozoa and cellulolytic bacteria populations resulting in depressed fibre digestion (Tesfa 1993). In contrast, adding whole or crushed canola seed to provide fat at 5% dietary DM has had no effect on fibre digestion of steers on high or low forage diets (Hussein et al. 1995). The lack of effect on fibre digestion of the moderate levels of crude fat (6% of dietary DM) in the 45% screenings diet could be due to binding of oil by canola seed even though the screenings were crushed in a hammermill prior to pelleting. The inhibition of fibre digestion by dietary fat is thought to be minimized by slow release of fat from the cellular structure of the seed (Murphy et al. 1987) as would be the case when canola is crushed or fed whole (Hussein et al. 1995). However, the 95% CS diet would likely have sufficient free canola oil to produce the observed inhibition of ADF and NDF digestion.

Apparent digestibility of DM and OM in diets linearly decreased ($P < 0.001$) with increasing concentration of CS. Quadratic effects of addition of screenings on DM and OM digestibility were also noted ($P < 0.001$). Mustafa et al. (1996) concluded that lower digestibility of canola meal DM could be attributed to reduced crude protein digestibility when no differences in fibre digestibility were found. Accordingly, all of the nitrogen retention factors measured (Table 4) were linearly ($P < 0.001$) and quadratically($P < 0.01$) reduced by increasing level of CS in the diet. Overall, nitrogen retention on a g day^{-1} basis was reduced three-fold for lambs receiving the 95% screenings diet compared to that of Control lambs, even though the Control diet had 1.4% less CP than the 95% screenings diet. The reduced N retention for lambs on the 95% screenings diet was also reflected in low (115 ± 20 g day^{-1}) weight gains for the 21 d period when lambs received the 95% CS diet, as compared to the mean growth rate for lambs in other periods (329 ± 14 g day^{-1}).

Although a diet with 14.4 % CP should not have limited lamb growth according to NRC recommendations (NRC 1985), a combination of 2 factors was mainly responsible for the low N retention of the lambs receiving the 95% screenings diet: (1) a lowered N digestibility ($P < 0.05$) of coarse canola screenings; (2) an impaired population of rumen microbes due to the toxic effects of free canola oil. The presence of anti-nutritional factors may have also influenced N retention, but would need to be addressed in further studies. Canola has been selected to be low in glucosinolates, but weeds such as stinkweed and wild mustard which may be prevalent in CS (Keith and Bell 1983; Darroch et al. 1990) contain high levels (7 to 8%) glucosinolates (Beames et al. 1986). Due to the variety of weed seeds present in CS (Bell and Shires 1980), anti-nutritional factors such as alkaloids may also be present.

Individual feeding trial-lambs

Organic matter content of CS was 86.0% (Table 1), which is lower than previously reported OM values for high-quality canola meal (91.6%, McAllister et al. 1998; 94.6%, Bell and Keith 1991) and barley (96.4%, Galloway et al. 1993; 97.5%, Bakells, et al. 1993), but equal to that of alfalfa hay in the early bud stage (85.9% OM; Canale et al. 1992). As the CS contained substantial inorganic matter (likely dust and other impurities), the linear ($P< 0.01$) and quadratic ($p < 0.001$) increases in feed intake and reductions in feed conversion efficiency ($P < 0.001$) with increasing level of canola screenings in the diet (Table 5) were likely partly due to the lowered OM content of the screenings. The previously discussed low N digestibility/retention and impaired fibre digestion with increasing dietary CS may have also affected lamb growth performance.

High levels of fat have been reported to reduce palatability (Rule et al. 1994), but in the present study, feed intake increased linearly ($P < 0.01$) with increasing content of CS in the diet. Palatability of the 95% screenings diet was not reduced, but ADG linearly decreased ($P < 0.001$) with increasing concentration of canola screenings in the diet. Lambs receiving

95% screenings did not grow as poorly as their counterparts on the digestibility trial, likely due to gradual adaptation by the rumen microbes to the high fat content of the diet. The ability of rumen microbes to adapt to other factors such as nitrites has been previously recognized (Birnbreier and Hilliger 1993). As an illustration of adaption to CS, the growth rate for the initial 3 weeks of the individual feeding study was low for lambs receiving 95% (263 ± 33 g day^{-1}) or 70% (276 ± 33 g day^{-1}) CS compared to 408, 393 and 356 ± 33 g day^{-1} for 45% CS, 20% CS and Control lambs, respectively.

Ultrasound measurements (Table 5) showed linear reductions ($P < 0.01$) in subcutaneous fat thickness over the ribeye and ribeye depth with increasing dietary concentration of CS. However, when ultrasound data were adjusted by carcass weight, differences in subcutaneous fat thickness between diets were no longer significant, although quadratic effects remained ($P < 0.01$) for ribeye depth. The GR measurement, an indicator of overall carcass fatness (Kirton and Johnson 1979), was also linearly reduced ($P < 0.01$) with increasing dietary concentration of screenings, even when adjusted by carcass weight. Ribeye depth is a commonly used indicator of carcass muscling in lambs (Stanford et al. 1998). Consequently, the influence of CS on carcass muscling and fatness over and above the influence of CS on carcass weight is likely related to the reduced digestibility of fibre and the impaired N metabolism with increasing dietary levels of CS. Reduced fatness of lamb carcasses would be desirable from a consumer standpoint (Ward et al. 1995), although not when coupled with a reduction of carcass muscling.

Fatty acid profiles

Altering the composition of ruminant fat is difficult because of the hydrogenation of unsaturated fatty acids by rumen microbes (Harfoot 1981). Consequently, previous studies (Solomon et al. (1991), Lough et al. (1992), Rule et al. (1994), McAllister et al. (1998) made only minor changes in fatty acid profiles, although in all these studies a maximum of 18%

canola seed was added to the diet (Rule et al. 1994). As one of the dietary treatments in the present study was composed of 95% CS, fatty acid composition of lambs was markedly influenced. Saturated fatty acids were reduced ($P < 0.001$; Table 6) and polyunsaturated fatty acids increased ($P < 0.001$) with increasing dietary content of CS in both subcutaneous and kidney fat. The proportion of saturated fatty acids in subcutaneous fat from lambs fed 95% CS was reduced 11% as compared to composite profiles for the subcutaneous fat of lambs fed high-concentrate diets (Jamora and Rhee 1998), although 4-8 % of fatty acids in the present study were unknowns, a portion of which would be saturated. The only fatty acids not affected by level of CS were linolenic ($C_{18:3}$) in subcutaneous and kidney fat and myristic ($C_{14:0}$) in subcutaneous fat.

The marked changes in lamb fatty acid composition from adding canola screenings to the diet in the present study can be contrasted to those of Solomon et al. (1991) where adding 6.5% whole rapeseed to lamb diets increased the total level of saturated fatty acids relative to the control soybean meal diet, although saturation of certain individual fatty acids was reduced. Saturated fatty acids accounted for between 41 and 47% of all fatty acids measured (Table 6) which is higher than the 38-41% reported by Solomon et al. (1991) for subcutaneous fat taken over the longissimus. As we used Romanov-Suffolk ram and ewe lambs compared to the Hampshire-Suffolk ram lambs in the study of Solomon et al. (1991), minor changes in fatty acid profiles between the studies are likely due to differences in breed and sex (Busboom et al. 1981). Two fatty acids which have been linked with reducing serum cholesterol and subsequently lowered risk of heart disease, oleic$_{(C18:1)}$ and linoleic$_{(C18:2)}$ (Mattson and Gundy 1985), were linearly increased in subcutaneous ($P < 0.05$) and kidney fat ($P < 0.001$)with increasing level of CS. Increasing dietary energy has been shown to elevate linoleic and reduce the proportion of linolenic$_{(C18:3)}$ acid in lamb fat (Field

et al. 1978, Busboom et al. 1981), although reductions in linolenic from increased concentration of dietary crude fat were not apparent in the present study.

The results of the present study demonstrate that the addition of high concentrations of canola screenings to lamb diets markedly alters fatty acid composition, with potential benefits to human health. Negative consequences of reduced saturation of lamb fat such as increased softness or oiliness of fat (Busboom 1991) or altered flavour of the meat (Jamora and Rhee 1998) would need to be evaluated in future studies.

Economics of including canola screenings in lamb diets

In 1997 when this study was conducted, canola screenings were valued at \$115 tonne^{-1}, barley at \$140 tonne^{-1} and alfalfa hay at \$120 tonne^{-1}. Using these costs and the feed conversion ratios from Table 5, the cost of 1 kg gain for each of the diets was calculated (Table 7). Traditionally, canola screenings are priced at 85 to 87% of barley. Accordingly, regressions were performed for 1997 values and two hypothetical scenarios: (1) canola screenings 86% the value of barley; (2) canola screenings equal in value to barley. The maximum rate of inclusion of CS for the estimated lowest cost kg^{-1} gain were 42, 36 and 27% for CS valued at 1997 market price, 86% of barley and 100% of barley, respectively.

Creep feed experiment

Supplementing the canola screenings-based creep feed with barley resulted in higher body weights of first-calf cows after 42 and 63 days on pasture (Table 8). However, body condition scores and backfat thickness of cows did not differ between treatment groups. Conception rates tended to be higher and number of days pregnant greater, in cows whose calves had access to the 75:25 barley:canola screenings creep feed. Increasing the energy content of canola screenings by including barley grain had little effect on overall calf gains, however, calves fed the 75:25 barley:canola screenings creep feed gained more in the first 42 days on pasture than did those with access to the screenings-only creep feed.

In replacement heifer management, producers strive to attain high conception rates in their herds and to shorten the postpartum interval after the first calving. Increasing the energy density of canola screenings-based creep feed had little effect on season-long gain of calves, but did improve the biological efficiency of first-calf cows. Canola screenings were found to be a palatable creep feed for grazing calves. Conservation of forage through the use of creep feed may be especially valuable in situations where the pasture availability is a constraint to beef production.

Feedlot experiment

Including 25% canola screenings in place of the barley silage in the finishing diet resulted in a 16% improvement in ADG (Table 9) of feedlot cattle. Cattle fed diets containing 50% canola screenings exhibited ADG similar to those fed the typical feedlot diet, but when the level of screenings in the diet exceeded 50%, the rate of gain of the cattle declined. Intakes of the 25% and 50% canola screenings diets were higher than intake of the barley silage diet; with more than 50% screenings, intake was similar to that of the typical feedlot diet. Among the typical (barley silage) diet, 25% screenings and 50% screenings diets, feed conversion efficiencies were similar, but they declined dramatically with the diets containing 75% and 95% canola screenings.

High (75% and above) levels of canola screenings were also associated with the occurrence of bloat (Table 9). Canola screenings were fed as pellets, and near the end of the trial there was a considerable increase in the amount of fines. Fine particles can increase the incidence of bloat, a problem that may be avoided by increasing the durability of the pellets through use of a pellet binder.

Incorporation of canola screenings reduced the cost of the diet from $159.50 to $133.00 per tonne (Table 9). Cost of gain was identical between the barley grain/barley silage diet and the 50% canola screenings diet. Including canola screenings at levels of 75% and

100% increased the cost of gain, whereas the diet containing 25% canola screenings reduced the cost of gain by 7.0%, compared to the typical feedlot diet. Carcass weight and fat depth were reduced when the diet contained 75 and 95% canola screenings, and the steers on these diets were obviously underfinished (Table 10). Return per carcass was highest for steers fed 50% canola screenings; followed by those fed the typical diet and those fed 25% canola screenings diet, which were similar, and were lowest for those fed 75% and 95% canola screenings. Carcass grades were similar among all diets.

CONCLUSION

In conclusion, canola screenings are a valuable Canadian feed resource, but the lowered digestibility of DM and fibre with impaired N retention and feed conversion compared to barley-based diets would preclude the inclusion of a high proportion of CS (> 50%) in feeder lamb or cattle diets, unless a health-conscious market was to develop for lamb or beef reduced in saturated fat. Assuming a CS price 86% that of barley, a feeder lamb diet of approximately one-third CS and two-thirds barley would give the lowest estimated cost gain^{-1}. Presently, feed costs are the main constraint to profitable beef production in western Canada. Increases in the price of barley grain have resulted in parallel increases in the cost of barley silage and alfalfa hay. Canola screenings can be used as an economical substitute for hay in creep feeds and silage in feedlot finishing diets. Levels of canola screenings in finishing diets should be restricted to no more than 50% of the complete diet. To avoid fines and associated digestive problems such as bloat, handling of pelleted screenings should be minimized and pellets should contain a binder to improve durability. Transition cattle should be adapted to canola screenings in a manner similar to that of barley grain. Screenings could prove especially valuable when silage supplies are low due to poor yields or insufficient land base for production. Canola screenings can significantly lower feed costs if nutrient quality and consistency can be ensured.

Table 1. Analysis on dry matter basis of canola screenings used in the present study and yearly mean and range in screenings composition.

Analysis	Canola screenings[z] in present study	Canola screenings samples collected over 12 month period	
		Range	Mean
Organic matter (%)	86.03	85.7 - 92.1	89.0
Crude protein (%)	15.3	10.9 - 16.2	14.2
Crude fat (%)	8.55	5.2 - 11.6	8.4
NDF (%)	44.87	36.9 - 47.5	41.7
ADF (%)	30.77	22.7 - 33.3	28.8
Calcium (%)	NA[y]	0.90 - 1.22	1.07
Phosphorus (%)	NA	0.33 - 0.53	0.41

[z]Canola screenings consisted of 11.1% whole canola, 16.8% cracked canola, 32.1% immature canola, 15.1% coarse weed seeds, 9.9% fine weed seeds, 15.0% chaff and dust.

[y]NA, not available.

Table 2. Ingredients (kg tonne^{-1}) and composition of experimental diets

Ingredient	Control Diet	95% Screenings	70% Screenings	45% Screenings	20% Screenings
Barley grain, whole	750	0	250	500	750
Canola screenings	0	950	700	450	200
Alfalfa meal	200	0	0	0	0
Molasses, beet	13	13	13	13	13
Canola oil	5	5	5	5	5
Sheep mineral[z]	10	10	10	10	10
Calcium carbonate	16	16	16	16	16
Maxi-Pel[y]	2.5	2.5	2.5	2.5	2.5
Dicalcium phosphate	4	4	4	4	4
Vitamin A, D, E[x]	0.25	0.25	0.25	0.25	0.25
Deccox[w]	0.13	0.13	0.13	0.13	0.13
Analysis, dry matter basis					
Dry matter (%)	90.18	95.26	91.74	90.45	89.41
Organic matter (%)	90.53	83.64	84.60	88.10	91.01
Crude protein (%)	13.0	14.4	14.2	14.1	13.0
Crude fat (%)	2.81	13.17	9.18	5.94	3.47
NDF (%)	37.18	38.78	39.10	35.64	30.47
ADF (%)	18.27	26.69	23.24	18.52	11.98

[z]Contained 93.1% NaCl, 1.25% Mg, 0.9% Zn, 0.94% Mn, 0.13% Cu, 0.003% Se, 1.25% S, 1.25% K, 1.25% Fe.

[y]Feed pellet binder (Mountain Minerals Ltd., Lethbridge, AB).

[x]Contained 10,000 IU g^{-1} vitamin A, 1250 IU g^{-1} vitamin D, 10 IU g^{-1} vitamin E.

[w]Contained 60 g kg^{-1} decoquinate (Rhône-Poulenc Canada, Missisauga, ON).

Table 3. *In situ* kinetics of dry matter and crude protein in dietary constituents (alfalfa, whole barley, canola screenings) and three complete diets(95%, 20%, 0% canola screenings)

	Dietary constituents			Complete diets			Effect, level of screenings		
	Alfalfa[z]	Barley[y]	Screen[x]	95%[w]	20%[w]	Control[w]	SEM	Linear	Quadratic
Slowly degradable fraction (%)									
Protein	54.36[a]	89.44[b]	48.88[a]	55.64	58.13	70.48	1.74	***	**
DM	43.89[a]	71.16[b]	36.89[a]	36.65	54.37	53.95	2.62	***	*
Soluable fraction (%)									
Protein	28.75[b]	10.56[a]	35.22[c]	24.30	35.48	26.11	1.77	NS	*
DM	22.68[b]	15.82[a]	33.99[c]	31.71	31.30	31.05	1.95	NS	NS
Disappearance (% h^{-1})									
Protein	4.53[a]	3.00[a]	9.48[b]	18.08	5.50	4.81	1.17	**	NS
DM	5.75	7.30	8.80	12.40	10.60	8.55	1.71	NS	NS
Effective rumen degradability (%)									
Protein	54.58[b]	44.04[a]	67.22[c]	67.73	65.93	60.17	0.78	**	*

[abcd]For dietary constituents, means within a row with different superscripts differ, ($P < 0.05$).

For complete diets, ***= $P < 0.001$, **=$P < 0.01$, *=$P < 0.05$.

[z]Alfalfa, pelleted suncured alfalfa.

[y]Barley, rolled.

[x]Canola screenings, pelleted.

[w]95%, 20% = level of canola screenings in diet; Control= 75% barley +20% alfalfa grass hay.

Table 4. Effects of level of canola screenings on nutrient digestion and N metabolism in lambs

	Diet[z]				Effect of screenings, level	
	95%	45%	Control	SEM[y]	Linear	Quadratic
DM intake (g d^{-1})	1388.8	1577.7	1366.7	63.0	NS	*
Digestibility (%)						
DM	52.3	69.1	68.7	0.5	***	***
OM	57.5	71.8	70.8	0.6	***	***
ADF	18.5.	32.2	30.7	2.0	**	*
NDF	36.7	46.7	45.5	1.3	**	*
N intake (g d^{-1})	31.8	35.5	28.2	1.4	NS	*
Urinary N (g d^{-1})	4.2	3.9	3.3	0.4	NS	NS
N digested (%)	60.5	64.2	66.1	1.7	*	NS
N digested (g d^{-1})	16.7	24.7	19.3	1.0	NS	**
N retained (g d^{-1})	2.2	8.3	6.3	0.7	***	***
N retained (% intake)	7.1	22.4	23.3	2.3	***	**
N retained (% digested)	13.2	32.1	33.6	2.9	***	**

***=$P< 0.001$, ** = $P< 0.01$, * = $P < 0.05$.

[z]95%, 45% = level of canola screenings in diet; Control = 75% barley and 20% alfalfa.

[y]SEM, standard error of the mean.

Table 5. Effect of level of canola screenings on lamb performance and carcass characteristics.

	Diet					Effect of level of screenings	
	Control	95%	70%	45%	20%	SEM	Linear	Quadratic
Number of lambs	11	11	11	10	10	--	--	--
Initial weight (kg)	22.9	23.5	22.6	23.2	23.0	0.2	NS[x]	NS
Final weight (kg)	50.5	45.3	45.7	47.6	49.0	1.5	***	NS
Daily gain (g)	388	300	324	376	355	12	***	NS
Feed intake (g day^{-1})	1580	1807	1466	1512	1413	48	**	***
Feed conversion (feed gain^{-1})	4.1	6.1	4.6	4.2	4.1	0.2	***	***
Ultrasound measurements								
Fat thickness 'C' (mm)[v]	5.7	3.8	4.8	4.7	4.9	0.4	**	NS
Ribeye depth 'B' (mm)	25.2	22.8	25.0	25.6	26.3	0.7	**	*
Adjusted fat (mm)[u]	5.1	4.3	5.0	4.7	4.5	0.4	NS	NS
Adjusted ribeye depth (mm)[u]	24.0	23.8	25.3	25.5	25.4	0.6	NS	**
Carcass measurements								
Carcass weight (kg)	25.4	22.0	23.1	23.8	25.0	0.7	***	NS
GR (mm)	16.1	9.9	12.8	16.3	14.5	1.0	***	*
GR (mm) adjusted[u]	15.0	10.8	13.0	16.3	13.7	1.0	**	*

*, $P < 0.05$;**, $P < 0.01$, ***, $P < 0.001$.

[z]Control, 75% barley and 20% alfalfa-grass hay.

[y]percentage of canola screenings in the diet on an as fed basis.

[x]NS, not significant.

[w]Ultrasound measurements made at the third lumbar vertebra.

[v]Depth of subcutaneous fat perpendicular to the maximum depth of the ribeye.

[u]Adjusted by carcass weight.

Table 6. Effect of level of canola screenings used as a protein supplements on proportions of fatty acids in subcutaneous and kidney fat of lambs.

		Diet						Significance, level	
			Canola Screenings level					Canola Screenings	
Tissue	Fatty Acid	Control [z]	95%	70%	40%	20%	SEM	Linear	Quadratic
Subcutaneous Fat	Saturated[y]	47.42	41.2	44.9	43.9	44.6	0.84	***	NS
	Monounsaturated[y]	36.24	39.47	35.62	36.70	37.67	0.86	NS	NS
	Polyunsaturated[y]	3.74	5.34	5.28	4.88	4.13	0.22	***	NS
	unknown[y]	8.62	5.10	4.28	7.03	8.44	0.35	***	NS
	14:0	3.52	3.19	3.80	3.37	3.08	0.21	NS	NS
	15:0	2.98	0.97	0.98	1.81	2.36	0.11	***	**
	16:0	23.06	20.32	22.54	21.13	21.60	0.58	*	NS
	16:1	2.05	1.29	1.13	1.45	1.45	0.09	***	***
	17:0	6.20	2.82	2.82	4.15	6.04	0.22	***	NS
	18:0	11.53	13.62	14.64	13.33	11.40	0.67	***	NS
	18:1	34.00	37.55	34.00	34.85	35.95	0.84	*	NS
	18:2	3.21	4.84	4.67	4.06	3.71	0.20	***	NS
	18:3	0.52	0.50	0.61	0.82	0.41	0.11	NS	NS
	20:0	0.12	0.26	0.16	0.11	0.08	0.04	**	**
	20:1	0.18	0.63	0.47	0.40	0.26	0.04	***	NS
Kidney Fat	Saturated[y]	56.71	44.94	47.48	52.34	55.50	0.84	***	NS
	Monounsaturated[y]	29.60	35.40	32.15	28.14	28.42	0.86	***	***
	Polyunsaturated[y]	4.83	6.07	6.42	5.48	5.38	0.22	***	NS
	unknown[y]	3.40	3.57	2.79	3.78	3.51	0.35	NS	NS
	14:0	2.79	2.09	3.10	2.84	2.80	0.21	NS	**
	15:0	0.82	0.32	0.38	0.53	0.71	0.11	***	*
	16:0	22.42	15.78	18.94	19.95	21.39	0.58	***	NS
	16:1	0.96	0.66	0.67	0.77	0.79	0.09	***	NS
	17:0	3.40	1.72	1.82	2.45	3.75	0.22	***	NS
	18:0	27.20	24.68	23.12	26.37	26.73	0.67	***	NS
	18:1	28.45	34.01	30.87	26.94	27.36	0.85	***	***
	18:2	4.16	5.44	5.74	4.60	4.87	0.20	***	NS
	18:3	0.67	0.63	0.68	0.88	0.51	0.11	NS	NS
	20:0	0.08	0.35	0.12	0.20	0.11	0.04	***	NS
	20:1	0.22	0.72	0.62	0.43	0.27	0.04	***	NS

[z]Control, diet of 75% barley and 20% alfalfa-grass hay.

[y]Saturated, monounsaturated, polyunsaturated, unknown= sum of all fatty acids in individual category.

Table 7. Estimated lowest costs kg gain^{-1} based on actual 1997 values, and hypothetical scenarios where canola screenings are 86% or equal to the value of barley.

Diet	Actual 1997 Cost kg gain^{-1}	Cost kg gain^{-1} barley=100, alfalfa=120, CS[z] = 86	Cost kg gain^{-1} barley=100, alfalfa=120, CS = 100
Control	0.55350	0.43050	0.4305
20% CS	0.54838	0.39565	0.4100
45% CS	0.53550	0.39060	0.4200
70% CS	0.55775	0.41170	0.4600
95% CS	0.70150	0.52460	0.6100
Predicted least cost diet, % CS	43[y]	36[x]	27[w]

[z]CS, canola screenings.
[y]43% from first derivative of equation: cost kg gain^{-1} = 0.065 screenings^2 + 5.704 barley, with barley = 100-screenings, R^2 = 0.96.
[x]36% from first derivative of equation: cost kg gain^{-1} = 0.0004 screenings^2 - 0.00298 screenings, R^2 = 0.97.
[w]27%, from first derivative of equation: cost kg gain^{-1} = 0.0005 screenings^2 - 0.00259 screenings, R^2 = 0.98.

Table 8. Performance of cows and calves on pasture when calves are provided access to canola screenings-based creep feeds with and without barley grain

	Composition of creep feed for calves (as-fed)	
	100% canola screenings	75% screenings/25% barley grain
No. of cow-calf pairs	37	39
Cows		
Body weight (kg)		
Day 0	438.8	443.2
Day 42	434.6[a]	465.4[b]
Day 63	426.6[a]	448.8[b]
Body condition		
Day 0	2.8	2.8
Day 42	3.1	3.1
Day 63	3.1	3.1
Backfat (mm)	3.4	3.6
Pregnancy		
Days	57[a]	69[b]
Rate	87	100
Calves		
ADG[1] (kg/d)		
Day 0 - 42	1.03[a]	1.18[b]
Day 0 - 63	1.10	1.12
Feed intake (as fed, kg/d)	3.46	2.76

[a,b]Means within a row with different superscripts differ ($P < 0.05$).

[1]ADG: average daily gain.

High (75% and above) levels of canola screenings were also associated with the occurrence of bloat. Canola screenings were fed as pellets, and near the end of the trial there was a considerable increase in the amount of fines. Fine particles can increase the incidence of bloat; this problem may be avoided by increasing the durability of the pellets through use of a pellet binder.

Table 9. Effect of replacing barley silage with canola screenings on performance of feedlot cattle during an 83-day finishing period

	Percentage of canola screenings in the diet				
	0[1]	25	50	75	95
Number of cattle	14	13	13	13	13
Initial weight (kg)	434	424	425	439	430
ADG[2] (kg/d)					
Day 0 to 42	1.21[a]	1.46[a]	1.27[a]	0.75[b]	0.44[c]
Overall	1.23[a]	1.43[b]	1.38[ab]	0.99[c]	0.75[d]
Feed intake (kg/d)					
Day 0 to 42	9.14[a]	10.64[bc]	10.87[b]	9.77[ac]	9.48[a]
Overall	9.17[a]	10.42[bc]	10.87[b]	10.09[ab]	9.55[ac]
Bloat incidents[2]	0	0	0	6	15
Cost of diet ($/tonne DM)[3]	159.5	154	152	139	133
Cost of gain ($/kg)	1.20	1.12	1.20	1.41	1.69

[a-d]Means within a row with different superscripts differ ($P < 0.05$).

[1]The diet with no canola screenings consisted of 75% barley grain and 20% barley silage (as-fed basis). In each of the other diets, canola screenings replaced the barley silage and some or all of the barley grain. All diets contained 5% of a canola screenings-based supplement that provided vitamins and minerals.

[2]ADG: average daily gain.

[3]Calculated assuming $140/tonne for barley grain, $40/tonne for barley silage, $115/tonne for canola screenings, and $210/tonne for supplement.

Table 10. Effect of canola screenings on the carcass traits of feedlot cattle.

	Percentage of canola screenings in the diet				
Item	1	25	50	75	95
No.	14	13	13	13	13
Carcass weight (kg)	302.4[ab]	300.8[ab]	311.9[a]	291.2[bc]	279.6[c]
Average fat depth (mm)	12.2[a]	11.5[a]	11.5[a]	8.5[b]	7.3[b]
Ribeye area cm^2	75.4	78.7	81.4	78.5	77
Marbling score	8.45	8.18	8.6	7.91	7.9
Cutability (%)	56.5	57.7	57.9	58.6	60.5
Grade					
AAA	1	2	1461	1	1471
AA	7	7		5	
A	5	4		7	
B4	-	-		-	
$ per carcass	997	993	1023	961	917

[a,b]Means within a row with different superscripts differ ($P < 0.05$).

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