Feeding value of peas for backgrounding beef heifers

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Chen, J.-Q., Okine, E. K., Price, M. A. and Khorasani, G. R. 2003. **Feeding value of peas for backgrounding beef heifers.** Can. J. Anim. Sci. **83**: 779–786. Four diets in which peas progressively replaced barley [0% (0P), 30% (30P), 50% (50P), and 100% peas (100P)] and one in which canola meal (CM) replaced 10% of the barley, were fed to 90 beef heifers (initial weight 215.8 ± 13.8 kg). The heifers achieved average daily gains (ADGs) of 0.72, 0.80, 0.79, 0.83, and 0.76 kg d^{-1} on the five diets, respectively, with the difference between the 0P group and the 100P group being significant (P = 0.028). The total feed costs of gain were $0.786, 0.779, 0.799, 0.860, and 0.817 kg^{-1} for the five groups, respectively, with the cost of gain being significantly greater (P < 0.05) for the 100P group than for the 0P, 30P or 50P groups. The latter three were not significantly different from each other. Three rumen-cannulated steers (575 ± 56.3 kg) were used to estimate the degradability of the dry matter (DM) and N in the barley straw (BS), CM, barley grain (BG) and peas used in the feeding trial. The rumen undegradable protein (RUP) levels supplied by the five diets were 17.5, 19.0, 19.9, 21.5, and 22.5%, respectively, and all of them met the requirements of these cattle. The RUP content of peas ground through a 1-mm screen was lower than that of peas ground through 2- or 4-mm screens (P < 0.01), which were themselves not significantly different from each other (P = 0.67). The low RUP content of peas was not a limiting factor for growth in backgrounding cattle.

Key words: Cattle, field peas, dry matter intake, feed conversion efficiency, rumen metabolism

Chen, J.-Q., Okine, E. K., Price, M. A. et Khorasani, G. R. 2003. **Valeur nutritive du pois pour les bovins de boucherie en semi-finition**. Can. J. Anim. Sci. **83**: 779–786. On a servi à quatre-vingt-dix génisses de boucherie (poids initial de 215,8 ± 13,8 kg) quatre rations dans lesquelles l'orge avait été remplacé par une proportion grandissante de pois [0 % (0P), 30 % (30P), 50 % (50P) et 100 % (100P)] et une cinquième où le tourteau de canola remplaçait 10 % de l'orge. Les animaux ont atteint un gain quotidien moyen de 0,72, 0,80, 0,79, 0,83 et 0,76 kg par jour, respectivement, l'écart entre le groupe 0P et le groupe 100P étant significatif (P = 0,028). Le coût des aliments nécessaires à l'obtention d'un tel gain s'établissait respectivement à 0,786, 0,779, 0,799, 0,860 et 0,817 $ par kilo et le gain coûtait significativement plus cher (P < 0,05) pour le groupe 100P que pour les groupes 0P, 30P et 50P qui ne montraient pas de variation appréciable. Les chercheurs ont recouru à trois bouvillons (575 ± 56,3 kg) canulés au rumen pour estimer la dégradation de la matière sèche et de l'azote contenus dans la paille d'orge, le tourteau de canola, l'orge et le pois employés lors des essais. Les cinq rations contenaient respectivement 17,5, 19,0, 19,9, 21,5 et 22,5 % de protéines non dégradables (PND) et satisfaisaient toutes aux besoins des animaux. La teneur en PND du pois moulu et passé au tamis de 1 mm était inférieure à celle de la farine de pois passée au tamis de 2 ou de 4 mm (P < 0,01), qui ne présentaient pas de variation significative (P = 0,67). La faible concentration de PND du pois n'entrave pas l'engraissement des bovins en semi-finition.

Mots clés: Bovins, pois de grande culture, ingestion de matière sèche, valorisation des aliments, métabolisme du rumen

Western Canada is one of the main pea-growing areas in the world, and a major pea exporter to the European Union (EU). Field peas (*Pisum sativum*) were traditionally grown in Canada for human use, and only downgraded peas were used as animal feed, but with more cultivars available and increased production levels, more and more peas are being used in animal feeds. Western Canada (Manitoba, Saskatchewan and Alberta) produces almost all of Canada's dry peas and is also Canada's main cattle-producing region (Statistics Canada 2001). Thus, feeding peas to cattle presents a realistic, on-farm value-adding opportunity for pea growers, many of whom background beef steers and replacement heifers.

In recent years, some work has been done to explore the utilization of peas in ruminant feeds. However, most of the work has been done with dairy rather than beef cattle (Corbett 1997; Ellwood 1998). Therefore, our objectives were to compare diets with different inclusion levels of peas with an all-barley diet and a canola meal diet when fed to backgrounded beef cattle (exp. I). A second experiment (exp. II) was designed to investigate the kinetic digestion characteristics of ground peas and of the five diets used in exp. I. The effects of particle size on the digestion characteristics of peas were also investigated.

MATERIALS AND METHODS

This project was conducted at the University of Alberta's Kinsella Research Station, Kinsella, Alberta, and at the Metabolic Unit of the Edmonton Research Station, Edmonton, Alberta. The cattle were managed in compliance

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Abbreviations: **ADF**, acid detergent fiber; **ADG**, average daily gain; **BG**, barley grain; **CP**, crude protein; **DMI**, dry matter intake; **EDCP**, effective degradability of crude protein; **EDDM**, effective degradability of dry matter; **FCE**, feed conversion efficiency; **NDF**, neutral detergent fiber; **RDP**, rumen degradable protein; **RUP**, rumen undegradable protein.

Table 1. Diet formulation for the five diets used in the pea-feeding study (g kg^{-1}, as-fed basis)

Ingredient	0% peas (0P)	30% peas (30P)	50% peas (50P)	100% peas (100P)	Canola meal
Barley straw	412	412	412	412	412
Barley grain	573	403	286		516
Pea		170	287	573	
Canola meal					57
Premix[z]	15	15	15	15	15

[z]Premix containing Monensin, 440 mg kg^{-1}; Ca, 50 mg kg^{-1}, P, 1.4% mg kg^{-1}, K, 6.6 mg kg^{-1}, Mg, 3.3 mg kg^{-1}, lysine, 4.9 mg kg^{-1}, methionine, 2.3 mg kg^{-1}, Co, 4.25 mg kg^{-1}.

with the Canadian Council on Animal Care (CCAC) policies for welfare in animal research.

Animal Selection and Treatments

Experiment I

Ninety Kinsella Hybrid heifers were selected for this study at an initial body weight of 215.8 ± 13.8 (SD) kg. Heifers were assigned at random to 15 pens: three pens for each of the five diets. Five different types of diet were formulated using the COWBYTES ration-balancing program (Alberta Agriculture Food and Rural Development 1999) with the goal of being isocaloric and achieving about 0.8 kg (1.75 lb) gain d^{-1} for each diet (Table 1):

- 0P: 100% barley grain + barley straw;
- 30P: 30% peas + 70% barley grain + barley straw;
- 50P: 50% peas + 50% barley grain + barley straw;
- 100P: 100% peas + barley straw;
- CM: 10% canola meal + 90% barley grain + barley straw.

The CM diet was formulated to be isonitrogenous with the 30P diet. The variety of peas used in this experiment was Espace; they were purchased directly from a nearby grower. Barley and peas were coarsely rolled. The concentrate and straw were fed separately; the concentrate was fed once a day at about 0900, except on weighing days, and the straw was fed in a separate bin about 30 min after the concentrates. The heifers had continuous free access to water.

Animals were weighed on 2 consecutive days at the beginning and again at the end of the experiment, and weighed once every 2 wk between 0900 and 1000 before feeding, during the course of the experiment. The amount of feed offered to each pen was adjusted after each weighing in an attempt to maintain the target rate of gain. The prices of ingredients used to calculate costs were the actual purchase price, plus a processing fee of \$7 t^{-1} for the peas and \$12 t^{-1} for barley. Health was continually monitored by the herdsmen; sick animals were treated appropriately and the treatments recorded.

Experiment II

Three rumen-cannulated Kinsella Hybrid steers (575 ± 56.3 kg) were used to estimate the degradability of the DM and N in barley straw (BS), canola meal (CM), barley grain (BG) and peas (P2) used in exp. I, using polyester bags (5 × 10 cm with pore size of 50 ± 15 µm; ANKOM Co., Fairport, NY) placed in the rumen. Steers were adapted for 15 d with 4 kg concentrates and 6 kg hay d^{-1} (as-fed basis) and free access to water.

The BS, CM, BG, and pea grain (P2) samples were ground through a 2-mm screen, to determine the rumen degradable protein (RDP) and rumen under-gradable protein (RUP) contents of the five diets. In addition, two more portions of peas were ground through 1- and 4-mm screens (P1, P4), to study the effects of particle size. Polyester bags were labeled, in duplicate, with a permanent black marker. Approximately 2 g of barley straw and 3 g of concentrates were weighed into each bag, which was then closed with a plastic clip. Duplicate bags were placed in a larger netting bag and then put into the rumens of the cannulated steers at designated times and removed from the rumens together. Straw samples were incubated for 0, 4, 12, 24, 48, 72, 120, and 240 h; concentrate samples were incubated for 0, 4, 8, 12, 16, 24, 36, 48, and 72 h. Zero hour disappearance was estimated by washing duplicate bags containing each sample, without placing them in the rumen.

Upon removal from the rumen, bags were immediately rinsed with cold water for a few minutes to arrest fermentation, and frozen at –15ºC for later washing in an automatic washing machine. Bags were washed in cold water four times using a 15-min washing period each time (Mathison et al. 1999). After washing, the bags were dried at 75ºC for 72 h, weighed and equilibrated in the air for 24 h. Subsamples of residue were then taken from the bags for chemical analyses.

Feed Sampling and Chemical Analysis

Individual feed ingredients and the residue in bags were sampled for analysis. The chemical composition of those diets was calculated from ingredient composition. Dry matter (DM) was determined by drying to a constant weight at 110°C. Crude fat (Goldfish Extraction method), and ash (550°C, overnight) were determined by the method of the Association of Official Analytical Chemists (AOAC 1990). Crude protein (CP, N × 6.25) was determined with Leco FP-428 Nitrogen Analyzer (Leco Corporation, St. Joseph, MI). Analyses of neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin were carried out using the filter bag technique (ANKOM Company, Fairport, NY).

Statistical Analyses

Analysis of variance was used to test the effects of diet on performance and of particle sizes on degradability using the General Linear Model procedure of the SAS Institute, Inc. (1996). The effects of diets on ADG were analyzed using individual cattle as the experimental unit. The effects on feed conversion efficiency (FCE), straw consumption d^{-1}, and feed cost kg^{-1} gain were analyzed using the pen as the experimental unit. The Fisher's (protected) LSD procedure (Steel and Torrie 1980) was used for means separation. The non-linear parameters A, B, and Kd were estimated by fitting the data using a non-linear regression procedure, based on Marquardt's method (Marquardt 1963), performed by the NLIN procedure of the SAS Institute, Inc. (1996). The estimates of A and B were constrained so that (A + B) did not exceed 100. The significance level was set at $P < 0.05$.

Table 2. Chemical composition of the dietary ingredients used in the pea-feeding study (DM basis, g kg^{-1})

	Barley straw	Barley grain	Peas	Canola meal
DM	905	850	865	883
Crude protein	39	119	200	396
Ether extract	16	17	9	26
NDF	779	226	186	376
ADF	460	75	72	203
Ash	67	27	32	93

Calculation of Degradability, RDP and RUP Content

Percentages of disappearance of DM and CP were calculated from the proportion of DM and CP remaining in the bag at each time after incubation in the rumen. The disappearance rate was fitted to the following equation (Ørskov and McDonald 1979):

$$\text{Disappearance} = A + B \times (1 - e^{-t \times Kd})$$

Where: A = soluble fraction (% of total), B = degradable fraction (% of total), t = time of rumen incubation (h), and Kd = rate of degradation (% h^{-1}).

The effective degradabilities of DM (EDDM) and CP (EDCP) were calculated by using the equation of Ørskov and McDonald (1979). The RDP and RUP fractions were calculated for each feedstuff using the following two equations [National Research Council (NRC) 2001]:

$$\text{EDDM and EDCP} = A + B[Kd/(Kd + Kp)]$$
$$\text{RUP} = B\,[Kp/(Kd + Kp)] + C$$
$$\text{RDP} = 100 - \text{RUP}$$

Where: A, B, Kd were as defined above, Kp = rate of passage from rumen (% h^{-1}), and C = undegradable fraction (% of total).

A Kp rate of 6% h^{-1} was assumed in this experiment for concentrates (Michalet-Doreau and Cerneau 1991; Walhain et al. 1992; Goelema et al. 1998), and 2% h^{-1} was used for DM of straw (von Keyserlingk and Mathison 1989), to calculate EDDM, EDCP, RUP and RDP. Lag time of barley straw was calculated using the procedure of McDonald (1981).

RESULTS AND DISCUSSION

Experiment I

The data from one heifer in the 100P group were excluded from the analysis for reasons assumed to be unrelated to the experiment. Although she showed no clinical signs of illness, this heifer gained only 37.7 kg during the 100 d of the study, while the other heifers in the 100P group averaged 83.0 kg during the same period.

Chemical Composition of Main Ingredients

The chemical composition of the dietary ingredients is shown in Table 2. They were similar to those reported by Christensen and Mustafa (2000), but the fat content (ether extract) of the peas was only 9 g kg^{-1}, which is lower than any of the five cultivars (range 10 to 21 g kg^{-1}) reported by Christensen and Mustafa (2000). The canola meal contained 396 g kg^{-1} crude protein, and high NDF and ADF values (376 and 203 g kg^{-1}, respectively) compared to those reported by Bell and Keith (1991), though close to that reported by Khorasani et al. (1994).

Table 3. Actual composition (g kg^{-1}) of the diet consumed by the backgrounding heifers (as-fed basis)

Ingredient	0% peas (0P)	30% peas (30P)	50% peas (50P)	100% peas (100P)	Canola meal
Barley straw	350	332	350	380	340
Barley grain	634	458	316	–	580
Peas	–	193	317	603	–
Canola meal	–	–	–	–	64
Premix	16	17	17	17	16
Chemical composition[z]					
Dry matter	870	872	875	881	873
Crude protein (DM basis)	94	111	119	140	113
NDF (DM basis)	424	405	410	414	427
ADF (DM basis)	216	208	214	224	219

[z]Calculated from ingredient chemical composition.

Table 3 shows the nutritive contents of the five diets as consumed, calculated from the ingredients in Table 2. With the exception of CP content, which increased with increasing levels of peas, there was little difference in chemical composition among the five diets (Table 3). The 94 g kg^{-1} CP of the 0P diet was probably insufficient to meet the requirements of growing cattle, while the 100P diet probably had a higher protein content than required (140 g kg^{-1}).

Dry Matter Intake

The concentrates were formulated as the isocaloric, totally mixed rations shown in Table 1. There was no significant difference ($P = 0.35$) in total dry matter intake (DMI) among the five diets (Table 4). However, the concentrates and straw were fed separately, and the cattle did not consume the actual amount of straw that had been anticipated (Table 3). Only the 100P group (380 g kg^{-1}, on an as-fed basis) came close to the designed straw consumption level of 412 g kg^{-1}. The 100P group had significantly higher straw consumption ($P < 0.05$) than the 30P group, perhaps because the former had a higher CP content, enabling the rumen microbes to digest the straw and allowing the cattle to consume more of it. It is accepted that feeding high-protein diets increases straw consumption (Church and Santos 1981; Nelson et al. 1985). None of the other differences in straw intake were significant

Average Daily Gain

The target weight gain was about 0.8 kg d^{-1} (1.75 lb d^{-1}) for all treatments, and with the exception of the 0P group (0.72 kg d^{-1}) this target was achieved (Table 4). Cattle fed the 100P diet gained 15.3% ($P = 0.028$) more than the 0P group, but there were no other statistically significant differences in gain among the diet groups. Cattle fed the 0P diet grew 10% more slowly than expected, possibly because of the low CP content of the diet. Thus, although energy was not limiting,

Table 4. Average daily gain and dry matter intake of the heifers on the five diets during the 100-d experiment

Diet[z]	Animal number (*n*)	Initial liveweight (kg)	Final liveweight (kg)	Average daily gain (kg d^{-1})	DMI (kg d^{-1}) Straw	Concentrate	Total
0P	18	216.4 ± 13.4	288.6 ± 28.3	0.72 ± 0.20*b*	2.0*ab*	3.5	5.5
30P	18	216.2 ± 12.6	296.4 ± 17.1	0.80 ± 0.11*ab*	1.9*b*	3.6	5.5
50P	18	213.9 ± 15.9	293.2 ± 24.8	0.79 ± 0.15*ab*	2.0*ab*	3.5	5.5
100P	17	216.5 ± 16.1	299.5 ± 21.6	0.83 ± 0.12*a*	2.2*a*	3.4	5.6
CM	18	216.3 ± 12.2	292.5 ± 19.1	0.76 ± 0.12*ab*	2.0*ab*	3.7	5.7

[z]See Table 3 for details.
a,b Numbers in the same column bearing different letters are significantly different ($P < 0.05$).

the low dietary protein intake may have affected the growth potential of the rumen microbes and hence microbial protein synthesis. Similar results to these were reported by Anderson (1998), who fed peas and wheat middlings as the only grain sources to heifers from 222 kg to 294 kg liveweight over 84 d. He reported an average daily gain of 0.84 kg d^{-1} for the pea group and 0.78 kg d^{-1} for the wheat middlings group, somewhat lower than the target of 0.91 kg d^{-1} (2 lb d^{-1}).

Feed Conversion Efficiency (Feed /Gain) and Economic Analysis

Feed conversion efficiency values of the concentrate portion (FCE, DM concentrates consumed per unit liveweight gain) of these five diets are shown in Table 5. Dry matter consumed per unit of gain decreased with inclusion level of peas, the differences among the treatments being significant ($P = 0.003$). The 0P group had significantly poorer concentrate FCE than either the 100P or the 50P group. In terms of total dry matter FCE, the 100P, 50P and 30P groups had better FCE than the 0P and CM groups. However, Anderson (1998) reported no significant difference in FCE among the pea, barley only, and barley plus canola diets.

The unit cost of both concentrate and total diet increased with the inclusion level of peas because of their relatively high price (Table 5). The unit price of the feed consumed ranged from \$0.090 kg^{-1} for the 0P diet to \$0.112 kg^{-1} for the 100P diet, reflecting the high unit cost of peas. The price of the 100P diet was only 24.4% higher than the 0P diet, because cattle fed the 100P concentrate consumed more straw. The difference in feed cost kg^{-1} gained (Table 5) between the 0P and 100P groups reduced to 9.4%, because of the improved FCE with the higher peas content. The 100P group had significantly higher feed cost kg^{-1} gained than the 0P, 30P or 50P groups (P = 0.009, 0.005, and 0.024, respectively), and tended to be significantly higher than that of the CM group ($P = 0.090$). The 30P group had the lowest cost kg^{-1} gain. In the Anderson (1998) experiment, the feed costs kg^{-1} gain were US\$ 0.45, 0.44, and 0.37, for peas, barley only, and barley plus canola, respectively.

Experiment II

Ruminal Degradation Characteristics of Peas

Although the period allowed for adaptation to the diet was quite short, the authors are confident that for the purpose of this study, the 2-wk adaptation period provided reliable measures for specific digestibility kinetics. After 24 h rumen incubation, more than 95% of the CP had disappeared from the peas, with almost 100% disappearance by 36 h (Table 6). This was consistent with the results of Bayourthe et al. (2000), who reported more than 99% disappearance of CP from peas by 48 h. In contrast, Aguilera et al. (1992) found that CP residue from peas was still detectable after 72 h incubation. Differences between the present results and those of Aguilera et al. (1992) could be explained by the degradation rate difference of peas in the rumen of sheep, and the particle size as indicated by the value of fraction A. In the present study the values of fraction A (60.7, 46.1, and 41.4% for DM of P1, P2, and P4) were much higher than that (27.7%) reported by Aguilera et al. (1992). Similarly, about 90% of the DM of pea grain had disappeared by 36 h incubation, and almost 100% had disappeared by 48 h in the rumen in the present study.

The rapid rate of disappearance of both DM and CP from peas in the present study posed some difficulties in the use of the general equation used to calculate percentage disappearance and to solve for fractions A, B, and Kd. Use of the published equation made the sum of fractions A and B greater than 100%, clearly a physiological impossibility.

Results showing A + B > 100 have been reported in the literature (Arieli et al. 1995; Petit et al. 1997), and a study by Goelema et al. (1999) even reported a negative value for fraction A. A plausible explanation for A + B > 100 could be that some material (possibly microbial cells) was adsorbed onto the feed particles from the rumen fluid. To overcome the analytical difficulties, Marquardt's method (Marquardt 1963; Michalet-Doreau and Cerneau 1991) was used, and a boundary forcing A + B ≤ 100 was set. The estimated parameters of rumen degradation of feeds are shown in Table 7.

Particle size had a significant effect on the degradability of peas (Table 7). The difference between DM and CP degradation for different screen sizes may be due to the increased area to mass ratio of the particles; increased fragmentation favors nutrient solubilization and degradation by microorganisms (Snow and O'Dea 1981).

Most parameters of P2 and P4 in the present study were not significantly different from each other. This may be because, despite the big difference between the screen pore sizes (2 vs. 4 mm), the real distribution of particle sizes is unknown. However, as indicated by the values of fraction A of DM, the difference between P2 and P4 was only 11.4%, while the difference between P1 and P2 was 31.7%, which suggests real variation in particle size.

The fraction A contents of the DM of peas were high (60.7%), intermediate (46.1%), and low (41.4%) for P1, P2,

Table 5. Feed conversion efficiency and feed cost kg^{-1} weight gain of heifers fed the five diets during the study[z]

	Unit price of (as-fed, $ kg^{-1})		Feed conversion efficiency (DM feed/gain)		$ kg^{-1} gain
Diet[w]	Concentrates[y]	Total feed[x]	Concentrates[v]	Total DM[u]	
0P	0.114	0.090	4.8*a*	7.6*a*	0.786*b*
30P	0.126	0.099	4.5*b*	7.0*bc*	0.779*b*
50P	0.130	0.103	4.4*bc*	6.9*c*	0.799*b*
100P	0.153	0.112	4.1*c*	6.8*c*	0.860*a*
CM	0.124	0.097	4.8*a*	7.4*ab*	0.817*ab*

[z]Prices used were as follows: barley, $112.5 t^{-1} and $7 t^{-1} for processing; peas, $140 t^{-1} and $12 t^{-1} for processing; straw, $45 t^{-1} ; canola meal, $212 t^{-1}; mineral (premix), $180 t^{-1}.
[y]Concentrates: grains plus premix.
[x]Total feed = concentrates plus straw.
[w]See Table 3 for details.
[v]SEM = 0.101.
[u]SEM = 0.127.
a–c Numbers in the same column bearing different letters are significantly different ($P < 0.05$).

and P4 ($P < 0.05$), respectively (Table 7). The fraction B contents of the DM of P1, P2, and P4 were 39.3, 53.9 and 58.6%, respectively ($P < 0.05$). The effective degradability of DM of peas at Kp = 6% h^{-1} was significantly higher ($P < 0.05$) for P1 than for P2 and P4 (Table 7). There was no significant effect of particle size on degradation rate of DM. Fraction A, mainly determined by pore size of the nylon bags, and particle size of the sample, varied from experiment to experiment, although peas were ground through the same screen size. For example, the fraction A of DM of P1 in the present study was 79.1% higher than that of peas ground through the same screen size reported by Walhain et al. (1992), but very close to that of peas ground through a 0.8-mm screen reported by Michalet-Doreau and Cerneau (1991). The fraction A of DM of P2 in the present study was 66.4% higher than that reported by Aguilera et al. (1992), even though their peas were also ground through a 2-mm screen.

Fraction A content of the CP of peas was significantly greater for P1 than for P2 and P4 (Table 7), but there was no significant difference between P2 and P4. In the experiment of Petit et al. (1997), the fraction A of CP of peas ground through a 1-mm screen was 59.4%, which was much less than that of P1, and close to the value of P2 in the present study. The differences in results between Petit et al. (1997) and the present study could be due to real particle size distribution, pore size of nylon bags, which was not stated by Petit et al. (1997), or difference in the washing method. Fraction B of CP was significantly less in P1 than in P2 and P4, respectively (Table 7), and they were significantly different from each other ($P < 0.05$). There was no significant difference among the degradation rates of CP of P1, P2, and P4 ($P = 0.74$). The degradation rates of CP were higher than those of DM, as indicated in Table 6, indeed, after 36 h incubation, 99% of CP had disappeared; it needed 48 h for more than 99% of DM to disappear.

The RUP content of P1 was significantly lower than that of P2 and P4 ($P < 0.01$). The RUP contents of P1, P2 and P4 were all lower than the RUP value (22%) of peas reported by NRC (1989). The RUP content at 12 h has been used by some researchers (Goedeken et al. 1990; Mustafa et al. 1998) to express the quality of protein, which was calculated as the ratio of residual CP from the 12-h rumen incubation to the original CP. In the present study, the RUP contents at 12 h were 14.3, 21.6, and 19.4%, respectively, which were very close to the calculated values (Table 7), but all considerably lower than the value (28.5%) reported by Mustafa et al. (1998).

The effective degradability of the CP of peas (Table 7) for P1 was significantly different from P2 and P4 ($P < 0.05$). They were higher than that (73.7%, at Kp = 5% h^{-1}) reported by Mustafa et al. (1998), but lower than the values (94.7, 89.9 and 82.4% for the peas ground through screen size of 0.8, 3.0, and 6.0 mm, respectively) reported by Michalet-Doreau and Cerneau (1991). In the experiment of Michalet-Doreau and Cerneau (1991), effective degradability decreased with increasing screen size. However, in the present study, effective degradability decreased when screen size increased from 1 mm to 2 mm, and remained unchanged when the peas were ground through a 4-mm screen.

Ruminal Degradation Characteristics of the Other Ingredients

For the DM of barley grain, fractions A, B, and C were 35.9, 52.5, and 11.6%, respectively; the Kd and effective degradability were 48% h^{-1} and 82.6%, respectively. Compared with the results of Michalet-Doreau and Cerneau (1991), in which the barley was ground through a 0.8-mm screen, the fraction A found in the present study was lower (35.9 vs. 62.5%), and fraction B was higher (52.5 vs. 25.2%), but fraction C (11.6 vs. 12.3%) and effective degradability (82.6 vs. 82.5%) were similar to those of Michalet-Doreau and Cerneau (1991). In the present study, the degradation rate of the DM of barley was 48.0%, and 81% of the DM had disappeared in the first 4 h.

Values of fractions A, B, and C of the DM of canola meal were 27.7, 58.3, and 14.0%; the Kd and effective degradability were 8.1% h^{-1} and 66.5% (Table 7). Fraction A in the present study was higher than the value of 18.8% reported by Mustafa (1996), and lower than the 31.4% reported by Seoane et al. (1992). Correspondingly, fraction B was lower and the insoluble fraction of DM of CM was higher than

Table 6. Dry matter and crude protein disappearance (%) of barley grain (BG), canola meal (CM), peas of three different particle sizes[z], and barley straw (BS) incubated in the rumen

Time	Dry matter						Crude protein					
(h)	BG	CM	P1[z]	P2[z]	P4[z]	BS	BG	CM	P1[z]	P2[z]	P4[z]	BS
0	38.2	29.1	63.7	49.5	44.8	20.2	32.0	14.8	71.8	57.2	55.7	46.7
4	81.4	42.3	68.3	56.6	53.0	25.2	81.2	39.1	78.3	69.0	64.6	58.5
8	85.2	53.7	71.7	64.1	62.2		90.1	52.2	83.4	76.3	73.4	
12	85.5	66.5	75.4	66.6	70.4	32.6	91.4	69.0	85.7	78.4	80.6	61.7
16	85.9	68.9	81.6	73.9	78.1		92.9	72.0	91.3	84.6	85.8	
24	86.8	77.5	92.2	88.3	90.8	44.4	94.9	83.0	98.6	95.3	96.4	61.6
36	89.9	82.8	97.4	97.3	98.3		97.5	90.3	99.8	99.8	99.9	
48	90.7	84.6	99.7	99.1	99.2	59.0	97.7	93.2	–	–	–	62.5
72	92.4	85.1	–	–	–	64.7	98.0	94.1	–	–	–	65.9
120						70.3						68.0
240						75.2						73.6

[z]Peas ground through 1-mm (P1), 2-mm (P2) or 4-mm (P4) screen.

Table 7. Parameters of ruminal degradation of feeds, estimated by fitting to the equation of Ørskov and McDonald (1979), and their effective degradability (ED) of CP and DM, calculated by the method of Marquardt (1963)

	DM			CP					ED of DM[y]			ED of CP[y]		
	A	B	Kd	A	B	Kd	RUP[z]	RDP[z]	Kp = 2%	Kp = 4%	Kp = 6%	Kp = 2%	Kp = 4%	Kp = 6%
P1[x]	60.7*a*	39.3*a*	0.053	71.8*a*	21.2*a*	0.075	12.7*a*	87.3	89.3	83.1	79.2*a*	94.0	90.1	87.3*a*
P2[x]	46.1*b*	53.9*b*	0.055	57.9*b*	42.1*b*	0.069	19.7*b*	80.3	85.4	77.1	71.7*b*	90.4	84.4	80.3*b*
P4[x]	41.4*c*	58.6*c*	0.064	55.7*b*	44.3*c*	0.072	20.2*b*	79.8	86.1	77.5	71.7*b*	90.3	84.2	79.8*b*
BG	35.9	52.5	0.48	30.0	65.5	0.36	13.9	86.1	86.3	84.4	82.6	92.0	88.9	86.1
CM	27.7	58.3	0.081	14.6	79.6	0.087	38.6	61.4	74.2	66.5	61.0	79.0	68.8	61.4
BS	19.8	54.6	0.025	46.7	19.7	0.19	35.8	64.2	50.0	40.6	35.7	64.2	62.2	61.1

[z]RUP and RDP were calculated at Kp = 6% h^{-1} for concentrates, and 2% h^{-1} for straw.
[y]Multiple comparisons were made at Kp = 6% h^{-1} only.
[x]Peas ground through 1-mm (P1), 2-mm (P2) or 4-mm (P4) screen.
a–c Numbers in the same column bearing different letters are significantly different ($P < 0.05$).

those reported by Mustafa (1996) and Seoane et al. (1992). These differences could be due to the processing methods of canola meal in the various studies, for example, the processing temperature; or perhaps to other factors such as basal diet or intake level.

In the present study, fractions A, B, Kd and EDCP of barley grain were 30.0%, 65.5%, 0.36, and 86.1%, respectively (Table 7), which are very close to the values reported by other researchers (Michalet-Doreau and Cermeau 1991).

The soluble fraction (14.6%) of canola meal CP in the present study was lower than the reported values of around 20% with a range of 18.6 to 26.5% (Ellwood 1998). The potentially degradable fraction (79.6%) was within the range of 56.7 to 84.9% for fraction B (Ha and Kennelly 1984; Kirkpatrick and Kennelly 1987; Seoane et al. 1992). Assuming a fractional passage rate (Kp) of 6% h^{-1}, the effective degradability of canola meal was 61.0% in the present study, which is in the middle of the reported range of 38.9 to 81.3% cited by Ellwood (1998). Variability in effective degradability of canola meal is related to the diet, the processing conditions and the turnover rate of the rumen contents (Ellwood 1998). In addition, the RUP of the CM in the present study was 38.6%, higher than the 28% reported by NRC (1989), which may be due to higher fraction B and C.

No lag time was found for the degradation of barley straw (BS) in the present study. However, in a similar experiment by Mathison et al. (1999), the lag time was about 2.8 h. Although the straw was ground through a 2-mm screen in the present study as was done by Mathison et al. (1999), the soluble fraction (A) and the slowly degradable fraction (B) of barley straw were higher in the present study (19.8 vs. 12.6% for fraction A, and 54.6 vs. 47.3% for fraction B) than that reported by Mathison et al. (1999). The higher fraction A of DM in this study could be indicative of finer particles.

RUP and RDP Contents of the Five Diets

As shown in Table 8, the average daily gains of the heifers in exp. 1 were 0.72, 0.80, 0.79, 0.83, and 0.76 kg d^{-1} for the 0P, 30P, 50P, 100P and CM diet group, respectively, and thus generally close to the target of 0.80 kg d^{-1}. The protein requirements and protein supplied shown in Table 8 were based on diets for cattle with average body weight of 280 kg (starting from 260 kg, ending at 300 kg).

The recommended RUP contents were 15.5, 17.6, 15.5, 15.7, and 16.9%, respectively, for the five diets. The actual RUP contents of the five diets were 17.5, 19.0, 19.9, 21.5 and 22.5%, respectively, and all met the requirements as determined by NRC (1996). The RUP contents were not a limiting factor for the backgrounding cattle (moderate ADG) in the present study. However, the recommended RDP contents were 84.5, 82.4, 84.3, 84.3 and 83.1% of CP for the five diets, respectively, while the actual RDP supplied were 82.5, 81.0, 80.1, 78.5, and 77.5% of CP. Three of the five diets had lower RDP contents than recommended. In particular, in the 0P and CM diets the amounts of RDP

Table 8. The NRC (1996) recommended (R), and actually supplied (S) crude protein (CP), rumen undegradable protein (RUP) and rumen degradable protein (RUP) contents of the five diets, for cattle with average body weight of 280 kg

	ADG	DMI (kg d^{-1})		CP (g d^{-1})			RUP (g d^{-1})			RDP (g d^{-1})		
	(kg d^{-1})	R	S	R	S	CP%[z]	R	S	% of CP[y]	R	S	% of CP[x]
0P	0.72	6.99	6.99	746	666	9.5	116	117	17.5	630	549	82.5
30P	0.80	6.72	6.95	743	750	11.2	131	142	19.0	612	608	81.0
50P	0.79	6.90	6.95	746	826	12.0	117	164	19.9	629	662	80.1
100P	0.83	6.90	6.95	746	966	14.0	117	208	21.5	629	758	78.5
CM	0.76	6.95	6.99	744	783	11.2	126	176	22.5	618	519	77.5

[z]CP supplied expressed as a percentage of DMI.
[y]RUP expressed as a percentage of CP.
[x]RDP expressed as a percentage of CP.

supplied were 549 and 519 g d^{-1}, respectively, which is lower than the recommendation of 630 and 618 g d^{-1} (NRC 1996). Low RDP limits the ruminally synthesized microbial CP supply. This may explain why cattle fed these two diets had lower ADGs. The 50P and 100P diets supplied 40.2 and 77.7% higher RUP, 5.2 and 20.5% higher RDP than requirements. The excess of the RDP and RUP did not result in higher ADG by the heifers. The amount of RDP supplied by the 30P diet was slightly lower (0.7%), while the RUP of the 30P diet was slightly higher (8.4%) than the requirement.

CONCLUSION

Peas are characterized by low rumen undegradable protein. Pea proteins are predominantly water soluble (over 85%), and this characteristic may not be beneficial for feeding ruminants because of excessive rumen protein degradation of raw peas. However, backgrounding cattle, which are expected to have a moderate growth rate, do not have a very high RUP requirement.

This feeding trial showed that peas could be successfully fed to backgrounding cattle. The ADG of the 30P and 100P group was 11.1 and 15.3% higher than the 0P group (P = 0.092 and 0.028, respectively). The total feed cost of gain increased with increased inclusion level of peas in the diet from the 0P to 100P, with dietary treatment having a significant effect (P = 0.035) on cost. Statistical analysis showed that the cost of gain was significantly greater for the 100P group than for the 0P, 30P, and 50P groups. Feeding the 100P diet also tended to be more expensive than the canola diet, but it would be feasible to feed 30P or 50P in the backgrounding cattle concentrates.

According to the results of the in situ digestion trial, the low RUP content of peas was not a limiting factor in feeding backgrounder cattle. The RUP supplied by the 0P, 30P, 50P, 100P and CM diets, respectively, were 17.5, 19.0, 19.9, 21.5, and 22.5% of CP. The RUP content of the five diets was sufficient for backgrounding cattle with the target ADG of 0.80 kg d^{-1} NRC (1996). However, the total protein supplied by the 0P diet (9.5%) was lower than required (10.7%), and the amounts of RDP supplied by the 0P and CM diets were 12.9 and 16.0% lower than the requirements, respectively. The 50P and 100P diets supplied 40.2 and 77.7% higher RUP, and 5.2 and 20.5% higher RDP than requirements. The RDP supplied by the 30P diet was slightly lower than the requirement, while the RUP of the 30% diet was slightly higher than the requirement.

The particle size had effects on pea digestion in the rumen. The slowly degradable fraction increased with increased screen size. The RUP content increased with screen size, the RUP content of P1 was 35.5 and 37.1% lower than that of P2, and P4 (P < 0.01), but there was no significant difference between RUP content of P2 and P4 (P = 0.67). To offset the effect of low RUP of peas they should be processed in coarse particle size to feed cattle.

In addition, economic returns of feeding peas to livestock should not be the only criterion; the agronomic benefits of growing a pea crop should not be neglected. Peas are a very good rotation crop especially in the Black soil zone of Saskatchewan and Alberta, where peas are well adapted. Nitrogen fixing by this legume benefits both the peas themselves and the succeeding crop.

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