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Feeding Value of Peas for Backgrounding Beef Heifers

by

Jinqiang Chen ©

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陈金强

Jinqiang Chen

11 NongZhanGuan Nanli
Beijing 100026, P. R. China

August 29. 2002

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled ***Feeding Value of Peas for Backgrounding Beef Heifers*** submitted by ***Jinqiang Chen*** in partial fulfillment of the requirements for the degree of ***Master of Science*** in ***Animal Science.***

Dr. Mick A. Price, Co-supervisor

Dr. Erasmus K. Okine, Co-supervisor

Dr. Reza Khorasani

Dr. Scott R. Jeffrey

August 28. 2002

Abstract

Two experiments were conducted to study the biological and economic viability of feeding peas to backgrounding heifers.

Five diets (0, 30, 50, 100% peas, and canola meal) were tested in the feeding trial. It was found the cost of per unit gain of the 100% pea diet was higher or tended to be higher than all other diets, but that of the 30% and 50% pea diet was not different from the 0% pea and canola meal diet.

The rumen undegradable protein (RUP) supplied by all five diets met the requirements of backgrounding cattle with an ADG of 0.80 kg d^{-1}. The low RUP content of peas was not a limiting factor for backgrounding cattle. The RUP content of peas ground through a 1mm screen was lower than that of peas ground through 2 or 4mm screens ($P < 0.01$), which were themselves not significantly different ($P = 0.67$).

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Table of Contents

List of Tables

List of Figures

I. Introduction

Canada is one of the main pea growing areas in the world, and one of the main pea exporters to the European Union (EU) market. Worldwide, the harvested area of dry peas was between about 5.7 and 6.5 million ha annually with annual production ranging between 10 and 12 million tonnes from 1996 to 2000 (FAO 2001). The opening up of the European feed pea market in 1985, brought about a rapid increase in pea production in western Canada. The seeded area increased from about 74,400 ha in 1985 to 1.24 million ha in 2000, and production increased from 168,800 tonnes to 2.86 million tonnes over the same period in Canada (Statistics Canada 2001).

Field peas *(Pisum sativum)* were traditionally grown for human use, and only downgraded peas were used as animal feed. With more new cultivars available and increased production, more and more peas are being used in animal feeds. Animal feed accounted for 90% of the total pea production in the European Union in the early 1990's, the remainder being destined for seed and human use. Peas are mainly being used to feed pigs and poultry. It was estimated that mean incorporation levels of peas were 22% in pig diets, 10% in poultry diets and 2% in cattle diets (UNIP-ITCF 1995). Western Canada (Manitoba, Saskatchewan and Alberta) produces almost all of Canada's dry peas. This region also is the main cattle producing region. The population of all cattle and calves (dairy and beef) in this region, as of July 1, 2001, accounted for 70% of the total in Canada (Statistics Canada 2001). Many pea growers in this region also raise cattle. Feeding peas to cattle could be an outlet and a way of value-adding for pea growers, and could also be a new feed resource for both dairy and beef industry.

The purpose of the experiments presented in the following chapters was to determine the biological and economic viability of feeding peas to backgrounding cattle. The feeding trial was designed to compare diets with different inclusion levels of peas with an all barley diet (the 0% peas) and a canola meal diet. The in situ experiment was designed to investigate the kinetic digestion characteristics of ground peas and of the five diets used in the feeding trial. The effects of particle size of peas on the digestion characteristics of peas were also determined.

II. A Review of the Use of Peas in Feeding Ruminants

2.1 Nutritive Characteristics of Peas for Ruminants

Peas are high in both protein and energy content. The composition of field peas in comparison with the commonly used ruminant feeds (barley grain, canola meal, and soybean meal) and rumen microbes is shown in Table 2.1.

Field peas contain about 20-25% crude protein (CP), which is twice as much as barley grain and about two-thirds of the protein content of canola meal; it is also half of the protein content of soybean meal and about 40% of that found in rumen microbes. As for all natural materials, the total crude protein content is variable. Evaluations conducted by UNIP (Interprofessional National Union for Protein Rich Crop, France) and ITCF (Technical Institute for Cereals and Forages, France) on 729 stored samples between 1987 and 1994 indicated a mean CP level of 24.1 ± 1.2% of DM. Analysis of several pea cultivars is shown in Table 2.2 (Christensen and Mustafa 2000). Some low starch peas tend to have higher crude protein content. Annual averages between 1987 and 1994 varied between 22.9 and 25.6% with the maximum range in one year approaching 7 percentage points (for example 19.2% and 26.1% of DM in 1992) (UNIP-ITCF 1995). Pea proteins are predominantly water-soluble (over 85%), which may not be beneficial for feeding ruminants because of excessive rumen degradable protein. Pea protein contains a very high level of lysine (7.4% of CP) compared to cereal grains and most oilseed meals; for example, lysine content of soybean is approximately 6.4% of CP; on the other hand, peas as with most legume seeds, have relatively low amounts of the sulphur containing amino acids, methionine and cystine (UNIP-ITCF 1995).

Table 2.1. Chemical composition of field peas, barley grain, canola meal, soybean meal, and rumen microbes (DM basis, g kg^{-1})[z]

	Peas[y]	Barley[x] Grain	Canola[w] Meal	Soybean[x] Meal	Rumen[v] Microbes
Crude protein	251	118	378	534	625
Ether extract	15	19	42	34	120
Ash	37	26	53	65	44
ADF	91	72	191	61	-
NDF	185	199	236	100	-
Lignin	9.4	22	57	8	-
Starch	520	640	25	-	-
Lysine (g kg^{-1} CP)	74	36.6	55.9	63.5	79.0
Methionine (g kg^{-1} CP)	11.9	18.0	20.9	14.1	26.0
Isoleucine (g kg^{-1} CP)	48.7	35.0	38.8	45.5	57.0
Undegraded Protein (g kg^{-1} CP)	220	270	280	350	-
Calcium	1.2	0.6	7.0	3.8	-
Phosphorus	4.6	3.8	11.2	7.8	-
ME, Mcal kg^{-1}	3.42	3.29	2.94	3.42	3.42
NEL, Mcal kg^{-1}	2.01	1.94	1.74	2.01	2.20

[z] Compiled by Christensen and Mustafa (2000).

[y] Hickling, D. 1997. Canadian Peas, Feed Industry Guide.

[x] US-NRC Swine, Dairy and Tables of Feed Composition Publications and CPM Dairy Model.

[w] Hickling, D. 1997. Canola Meal, Feed Industry Guide.

[v] CPM Dairy Model, Version 1, and CNCPS, Version 3.

Table 2.2. Protein and carbohydrate composition of peas (DM basis, g kg^{-1})^{z}

	Pea Cultivars				
	Scout	Express	Marrowfat	Polo M19	Radley
Ash	36.8	30.1	30.2	37.4	31.8
Ether extract	19.7	11.2	13.0	20.9	10.4
Crude protein	272.3	228.6	233.8	251.4	273.8
Starch	272.1	496.2	464.0	322.1	436.0
NSC	478.3	556.1	573.0	488.4	526.5
NPN (% of SCP)	12.88	7.40	18.49	9.77	19.24
ADL (% of NDF)	1.65	1.63	3.41	1.41	2.56
SCP (% of CP)	79.05	84.97	85.52	76.91	89.01
NDICP (% of CP)	0.51	2.41	2.19	0.63	1.51
ADICP (% of CP)	0.40	0.57	0.36	0.63	0.25
Starch (% of NSC)	56.89	89.23	80.98	65.95	82.81

^{z} Compiled by Christensen and Mustafa (2000).

ADF = Acid Detergent Fiber; NDF = Neutral Detergent Fiber; NPN (% of SCP) = Non Protein Nitrogen as % of Soluble Crude Protein; ADL (% of NDF) = Acid Detergent Lignin as % of NDF); SCP (% of CP) = Soluble Crude Protein as % of Crude Protein; NDICP = Neutral Detergent Insoluble Crude Protein; ADICP = Acid Detergent Insoluble Crude Protein; NSC = Non Structural Carbohydrate.

Pea seeds have a relatively variable starch content (27-50% of DM), as shown in Table 2.2. Some varieties have less than 30% starch in the dry matter, while other varieties contain closer to 50% starch. A starch value of 51.4 ± 1.5% was reported by UNIP (1995). Variation in starch content may be partly explained by the level of crude protein, but the substitution is only partial since the correlation between these two criteria ($r^2 = 0.4$) is low (UNIP-ITCF 1995). The starch content of peas is about 80% of the starch level found in barley grain while other protein supplements such as canola meal and soybean meal contain little or no starch. The metabolizable energy (ME) of peas is about

3.4 Mcal kg^{-1}, which is higher than barley and is close to that of corn and wheat. Fiber content is similar to that of other protein supplements with a crude fiber content of between 6.7% and 8.9% of DM compared to 5.8% for SBM and 5% for barley grain (Khorasani and Kennelly 1997). The majority of the fiber in peas exists in the form of hemicellulose and cellulose with very little lignin, the fiber is highly digestible (Tables 2.1 and 2.2). So peas are a good source of both protein and energy.

Anti-nutritional factors (ANFs) are those secondary metabolites that are known or suspected to have adverse effects on monogastric animals following ingestion (Dixon and Hosking 1992); these include protease inhibitor, lectins, antigenic proteins, polyphenol, oligosaccharides, and phytates. Peas contain relatively low levels of ANFs. Rumen fermentation can modify ingested anti-nutritional factors to a form that is not toxic to mammals, effectively reducing the susceptibility of ruminants to those specific anti-nutrient factors. Therefore, ANFs in peas only affect their application in non-ruminants, including calves.

Fermentation characteristics of the rumen have a significant impact on animal performance and are particularly important when determining the suitability of a novel feedstuff (Khorasani and Kennelly 1997). Peas, like other legume seeds are characterized by having highly degradable protein and relatively slowly degradable starch. Ruminal undegradable protein for peas is reportedly 22%, compared to 35 and 28% for soybean meal and canola meal, respectively [National Research Council (NRC) 1989]. In the study of Goelema et al. (1998), the rumen undegraded protein was found to be 25%. Cerneau and Michale-Doreau (1991) compared the starch degradation of barley, maize,

Table 2.3. Effect of substituting pea protein for soybean meal on rumen metabolites and performance of late-lactating dairy cow[z]

	Pea protein replacing soybean meal protein				
	0	33	67	100	SEM
Rumen pH	6.11	6.07	6.03	6.00	0.12
Rumen Ammonia (mg $100ml^{-1}$)	12.4	13.1	16.2	15.9	0.57
Rumen total VFA (mM)	94.0	99.8	94.7	100.3	6.60
Dietary residual N at duodenum (% intake)	31.1	23.3	27.5	25.9	3.8
Rumen bacterial N yield (g kg^{-1} ADOM[y])	21.9	23.8	23.4	25.1	2.3
Protein captured (% of protein intake)	62.9	58.5	58.9	59.9	3.5
Dry matter intake (kg d^{-1})	21.2	21.5	21.9	21.6	0.68
Crude protein intake (kg d^{-1})	3.28	3.42	3.65	3.56	0.11
Milk yield (kg d^{-1})	20.7	22.0	21.4	21.7	0.53
4% fat corrected milk (kg d^{-1})	20.2	21.8	21.5	20.7	0.58
Milk protein (%)	3.53	3.58	3.63	3.51	0.03

[z] Khorasani and Kennelly 1997.

[y] ADOM: Apparently digested organic matter.

peas, oats and wheat bran, and reported that peas have the highest degradability of dry matter; the degradability of pea starch is 90.0%, lower than that of barley (98.3%), oats (97.4%) and wheat bran (96.4%) and higher than that of maize (57.8%). Based on a compilation of research on site of digestion of starch in various feedstuffs, Nocek (1996) showed that approximately 76% of the starch in peas is rumen degradable with the remaining 24% escaping to the small intestine. By comparison, barley had about 87.5% rumen degradable and 12.5% rumen escape starch.

Table 2.3 shows the effect of substitution of pea protein for soybean protein on rumen pH and metabolites (Khorasani and Kennelly 1997). Rumen pH decreased and rumen ammonia concentration increased linearly with increasing level of peas in the diet compared to those of SBM diet. Valentine and Bartsch (1987) compared the fermentation of hammer-milled barley, lupin and pea and faba bean grain in the rumen of dairy cows. They found that when the cows were given hammer milled barley grain, rumen pH declined to a minimum value of 5.4, and from 3 to 6 h after the grain was given, rumen pH was significantly ($P < 0.05$) lower than when the cows were given legume grains. Rumen pH was maintained above 6.0 when the cows were given hammer milled lupin or faba bean grain. Rumen pH value was between barley and lupin and faba bean grain when pea was fed. Rumen ammonia-nitrogen concentration was significantly ($P < 0.05$) higher at 0, 3, 4, 5, 6, and 8 h after legume grains were given than after barley grain.

The Cornell Net Carbohydrate and Protein System (CNCPS) is a system developed to better predict nutrient requirement of cattle. In the CNCPS, carbohydrate and protein can be classified into five fractions according to their degradation rates in the rumen. The analyses shown in Table 2.4 are the main laboratory analyses required for ration formulation using the CPM Dairy Model (Cornell-Penn-Minor Institute Dairy Model). Peas contain a relatively high proportion of B1 protein (soluble, see Table 2.4) which represents soluble cell content protein which is fermented at the rapid rate of 200 to 300% h^{-1} (a degradation rate of 200% h^{-1} would indicate that all of the protein is degraded

Table 2.4. Protein fractions and their degradation rates of peas used in CPM dairy model[z]

CPM Dairy Model Fractions	Description	Rumen Degradation Rate (% h^{-1})	Composition (% of crude protein)			
			Barley	Peas	Canola	SBM
A	soluble non protein nitrogen & peptides	instantaneous	1	7	11	11
B1	soluble proteins, cell contents	200 - 300	16	68	21	9
B2	insoluble, cell contents	5 - 15	75	23	57	77
B3	insoluble, cell wall	0.1 - 1.5	3	0	4	1
C	cell wall, unavailable, N bound to lignin	0	5	1	6	2

[z] Christensen and Mustafa (2000) adapted from the CPM Dairy Model.

Table 2.5. Carbohydrate fractions and their degradation rates of peas used in CPM dairy model [z]

CPM Dairy Model Fractions	Description	Rumen Degradation Rate (% h^{-1})	Composition (% of carbohydrate)			
			Barley	Peas	Canola	SBM
A	soluble sugars	200 - 350	3	15	9	3
B1	starch, pectin, beta glucans	20 - 40	76	54	40	80
B2	insoluble available cell wall	2 - 10	15	29	32	16
C	unavailable cell wall (ADF lignin)	0	6	1	18	1

[z] Christensen and Mustafa (2000) adapted from the CPM Dairy Model.

in 30 min.). These analyses allow for the calculation of protein and carbohydrate fractions (Tables 2.4 and 2.5) that are used in the CPM Dairy Model to predict microbial growth and microbial protein synthesis.

2.2 Utilization of Peas in Ruminants

The following are the findings regarding the utilization of peas by various classes of beef and dairy cattle.

2.2.1 Milk replacer for calves

Interest has been maintained in the replacement of costly milk protein in the diets of pre-ruminant calves with alternative sources of protein. Important factors for assessing alternative proteins include chemical composition, anti-nutritional factors, digestibility, amino acid content, physical and microbiological properties, economics, and commercial availability. Attempts to incorporate pea protein into milk replacers have only been partially successful for utilization by pre-ruminant calves, due to their relative inability to digest such proteins and the anti-nutritional factors present in peas (Mbugi et al. 1989; Bell et al. 1974). Pea protein products are variable in protein content and experimental products have poor suspension properties. The anti-nutritional factors in the pea are significant for pre-ruminant calves and processes have not been developed on a commercial scale to eliminate them. So acceptable pea protein ingredients with high protein content and low anti-nutritional factors are not available.

The results of Christison (1980) indicated that untreated pea protein was virtually indigestible by young calves, but various treatments to pea protein concentrates markedly improved CP digestibility. The digestibility of the pea protein concentrate increased with the age of the calf. Mbugi et al. (1989) found that pea protein concentrates (with 80% CP) could supply at least 30% of the protein in milk replacer diets of Holstein calves without markedly affecting the utilization of nutrients or growth performance of the pre-ruminant calves. Substitution of milk protein with 60% of protein from pea protein sources appears to depress the digestibility of nutrients and the growth of young calves. Bush et al. (1991) fed dehulled raw pea flour (34% CP) to 2-month-old pre-ruminant calves for four weeks. During the first week, the apparent ileal digestibility was lower with the pea diet than with the control diet ($P < 0.01$). Four out of five calves exhibited intolerance to the pea diet, resulting in much lower digestibility during the fourth week. The calves developed high titres of systemic antibodies against the main two globulins of peas (legumin and vivilin). Legumin was found to survive digestion in the small intestine, in amounts generally equivalent to 1-3% of intake.

2.2.2 Feeding calves

Field peas have been successfully fed to calves. Field peas are very palatable and can be used effectively in creep rations. Young calves possess mature ruminal function within 2-3 weeks after dry feeds are first offered (Lalles and Poncet 1990). In a two-year study with 128 cow/calf pairs, wheat midds and field peas were offered in four different combinations as creep feeds (Anderson 1999a). Treatments were reciprocal amounts of dry rolled peas and pelleted wheat midds at 0-100 percent, 33-67 percent, 67-33 percent, and 100-0 percent, respectively. It was found that the feed intake increased ($P < 0.01$), and the feed efficiency (liveweight gain per unit feed) decreased ($P = 0.02$) with increasing pea levels. No reason was given why feed efficiency decreased. It could be because young cattle cannot use peas as well as older cattle. Taking account of feed cost kg^{-1} liveweight gain, 67% inclusion level of peas in creep ration was recommended.

In another study Anderson (1998b) showed that the ADG of calves increased with increasing peas in the diet ($P < 0.05$). The improvement in gain, however, was not proportional to the increase in creep feed intake with more peas in the diet. The reduction ($P < 0.05$) in feed efficiency with increasing peas suggests that higher levels of peas would incur greater feed costs kg^{-1} of gain. Landblom et al. (2000) did a similar feeding trial. Their 67% peas group had higher daily creep feed intake, and better average daily gain, and feed efficiency than the 37% and 100% peas group, but were not significantly different. Economic analysis revealed a net return for creep feeding of $US13.33, $US24.91 and -$US4.65 for the 33, 67 and 100% pea test diets, respectively. They concluded that the inclusion level of peas should not be over 67%.

In a University of Alberta study (de Boer et al. 1991), ten female Holstein calves were fed a 20% CP concentrate containing 50% peas as a replacement for barley, canola meal and soybean meal. The calves were one to four weeks post weaning at the beginning of the experiment. Both concentrates were consumed readily by the calves. Average daily gain (ADG), daily dry matter intake (DMI) of concentrate, daily hay consumption and feed conversion efficiency were not affected by diet.

2.2.3 Feeding dairy cows

Dairy cows need high levels of both protein and energy for lactation. High performance dairy cattle need both microbial synthesized protein (MCP) and rumen undegradable protein (RUP) to supply amino acids needed for milk production. In their study Khasan et al. (as cited by Ellwood 1998), attributed reduction in milk production to the greater degradation of pea protein in the rumen. However peas have been successfully substituted for soybean meal in situations where the need for undegradable protein has been modest, for example in late-lactation cows (Khorasani et al. 1992) and in a commercial dairy herd with modest milk production (23 kg d^{-1}) (Ward et al. 1989). Valentine and Bartsch (1990) compared the effects of feeding legume grains and barley grain with or without 1.5% urea as supplements to dairy cows fed cereal hay based diets. They found that daily yields of milk, fat and protein were significantly ($P < 0.05$) higher for cows fed lupin, pea and faba bean grains compared with those of cows fed barley grain with or without urea. Yields of milk, fat, protein and milk protein content were significantly ($P < 0.05$) higher when 7.0 kg DM compared with 3.5 kg DM of grain (legume or barley) was fed. A significantly ($P < 0.05$) higher milk fat production per unit DM intake was recorded for cows fed legume grains compared with barley grain. Valentine and Bartsch (1990) found that there were generally higher returns above grain cost for cows fed legumes than those fed barley grain and for cows fed 4 kg compared to 8 kg daily of grain. Khorasani and Kennelly (1997) used peas to replace soybean meal at the level of 0, 33, 67, and 100% to feed four late-lactation (200 ± 23 DIM) Holstein cows. The dry matter intake and milk yield were not affected by the substitution of peas for SBM.

Petit et al. (1997) used peas (raw peas and extruded peas) to substitute for most of soybean meal; the diets were formulated for early lactation cows (week 4 to 15), with average milk yield of 37 kg d^{-1}. There are no differences between the soybean and peas groups (raw peas and extruded peas) in terms of milk production and 4% fat corrected milk production. A similar experiment feeding peas to high yield cows was reported by Corbett et al. (1995). The inclusion rate of peas was 25% of the diet, replacing most part of soybean meal, and the diets were balanced with similar levels of undegradable protein. For cows in early lactation, 4% fat-corrected milk was higher ($P < 0.05$) for cows fed pea based concentrates (31.3 kg d^{-1}) than for cows fed soybean and canola supplement (29.7 kg d^{-1}). Fat-corrected milk was not affected by source of protein in mid- and late-lactation cows. Fat-corrected milk production was not different ($P > 0.05$) for cows fed soybean/canola meal compared with cows fed the pea supplement when cows across all stages of lactation were included in the analyses. The results of these studies suggest that peas can be used in rations for high producing dairy cows fed properly balanced rations. In high producing dairy cows the use of untreated peas should be limited only by the cost of providing adequate bypass protein. Peas give a lower level of bypass protein than soybean meal, but the rate of nitrogen degradation of peas can be improved by heat treatment.

Table 2.6 summarizes the results from five experiments in Europe (UNIP-ITCF 1995), based on maize silage. On average there was very little difference between experiments in terms of overall milk production. Peas may therefore provide the complementary nitrogen to diets based upon good quality maize silage fed to lactating cows producing between 25 and 30 kg of milk daily. Beyond this level of production, utilization of another more concentrated source of nitrogen is essential. In circumstances where diets are already high in soluble nitrogen (grass silage), materials such as soybean meal with high bypass protein must be used.

Table 2.6. Relative performance of dairy cows fed maize silage supplemented with soybean meals or peas[z]

Trial	% Pea	DM Intake	Total Milk Production	Protein Content	Fat Corrected Milk
Trial 1	25	101	95	99	94
Trial 2	27	103	103	98	105
Trial 3	27	101	99	94	99
Trial 4	25	106	103	100	103
Trial 5	26	99	99	101	97
Mean		102	100	98	100

[z] UNIP-ITCF 1995; control diet with soybean meal =100.

2.2.4 Feeding beef cattle

In Europe, it has been shown that peas may, without any difficulties, provide supplementary nitrogen for a diet based on maize silage for fattening beef cattle. Peas were well accepted by beef cattle. In addition, quantities consumed, growth rate and feed conversion ratio were not altered. Finally no digestive disorder or health problems were observed (UNIP-ITCF 1995).

In some preliminary research reported by Anderson (1998a), field peas were evaluated in diets for growing heifer calves, and backgrounding and finishing steers. For growing replacement heifer calves fed wheat midds and field peas during early winter, the average daily gain for the peas group was 0.84 kg d^{-1} and for wheat midds was 0.79 kg d^{-1}. The feed cost kg^{-1} gain was $US0.687 for the peas group, and $US0.623 for the wheat midds group. For backgrounding steer calves with barley, barley plus canola meal and field peas, the average daily gain was 1.31 kg d^{-1} for the peas group, 1.17 kg for the control (barley) group, and 1.27 kg d^{-1} for the barley plus canola meal group. The feed cost for the peas group was $US0.46 kg^{-1} gain, for the barley group $US0.44 kg^{-1} gain and $US0.37 kg^{-1} gain for barley plus canola meal group. For the finishing steers fed field peas, the ADG was 1.68 kg d^{-1} for the peas group, and 1.66 kg d^{-1} for the barley group; the cost was $US0.71 kg^{-1} gain for the peas group, and $US0.62 kg^{-1} gain for barley group. Field peas appear to be a very useful feed for growing and finishing calves. Feed intake and liveweight gains were equal to or better than other feeds used (wheat midds, barley).

Poland and Landblom (1998) compared the feeding value of field pea and hull-less oats in growing calf diets to conventional diets (soybean meal plus barley grain). In the first study, dietary treatments included a control diet and two diets where a portion of the barley and soybean meal (SBM) of the control diet was replaced by either oats or peas. Average daily gain ($P = 0.66$) was not affected by dietary treatment. However, calves fed the control and pea diets had higher dry matter intakes ($P < 0.05$) than calves fed the oat diet. Consequently, feed efficiency ($P = 0.1$) was improved in the calves that were fed the oat diet. In the second experiment, dietary treatments included a control diet, two diets where a portion of the control diet was replaced by either peas or oats and one diet where peas and oats were combined as a replacement. Average daily gain ($P = 0.84$) was not affected by dietary treatment. Calves consuming the control diet had higher DMI ($P < 0.01$) than diets containing either peas or oats, while the DMI of the combined diet was intermediate. Although differences were detected in intake and not in gain measurements, there was only a tendency toward differences in feed efficiency ($P = 0.17$) due to dietary treatments. Field peas and hull-less oats are suitable substitutes for barley and soybean meal, when replacement is on an equivalent protein basis in backgrounding calf diets.

2.3 Processing of Peas to Improve the Feed Efficiency

The purpose of processing is to improve the digestion and utilization efficiency of both starch and protein.

2.3.1 Reducing particle size of peas

Particle size of cereal or legume seeds may affect availability of protein or starch in the rumen (Cerneau and Michale-Doreau 1991; Bayourthe et al. 2000). The conclusions are not in agreement whether it is necessary to process peas to reduce their size. According to Valentine et al. (1983), it is necessary to hammermill lupins to maximize their digestibility by dairy cows. When whole lupin seeds were fed to dairy cows as a supplement to roughage diets, about 22% of the grain dry matter intake was excreted in the feces. Dry matter digestibility of whole lupin seeds was 64.5% compared to 78.9% for hammer milled lupin seeds. The cost of whole lupin grain excreted in the feces was enough to offset the cost of hammermilling.

Some studies (Cerneau and Michale-Doreau 1991; Bayourthe et al. 2000) concluded that particle size strongly influenced protein and starch degradation. Cerneau and Michale-Doreau (1991) found that when the particle size of peas increased (screen size 0.8 mm, 3.0 mm and 6.0 mm) the in situ degradability of starch decreased 10.4 percentage unit points. Bayourthe et al. (2000) tried seven different particle sizes from 112 μm to 2025 μm diameter. They found that OM (organic matter), CP and starch degradation increased as particle size decreased. They speculated the difference between CP degradation for the different pea particle size may be due to increased area to mass ratio. However, by 16 h, particles of different sizes were degraded to a similar extent. However, Bock (2000) fed ground, rolled and whole peas to steers (with mean particle size of 1.59, 3.18, and 6.35 mm, respectively), and concluded that processing did not appear to improve their utilization when fed in grower diet. Steers fed whole and ground peas had higher ($P = 0.04$; quadratic) average daily gains and no difference was detected in daily dry matter intake ($P > 0.38$). The fecal matter appeared to have very few pieces of whole or cracked field peas.

2.3.2 Heat treatment

Heat is the most used treatment method in feed industry. It has been shown that heat treatment can decrease degradation of protein in the rumen. Heat processing decreases rumen protein degradability by denaturation of protein and by the formation of protein-carbohydrate (Maillard reactions) and protein-protein cross-links (NRC 2001). The main processing methods include: extrusion, roasting, pressure toasting, expander, flaking, micronization and moist heat treatment.

Studies of ruminal degradation in protein of heat processed feedstuffs using the in situ approach indicate reductions in soluble fraction (fraction A), increases in slowly degradable fraction (fraction B) and undegradable fraction (fraction C), and decreases in the fractional rates of degradation of the B fraction (Goelema et al. 1999; Prestlokken 1999; Khorasani and Kennelly 1997). Khorasani and Kennelly (1997) demonstrated that peas subjected to 5 min of heat treatment exhibited a reduction of the soluble dry matter fraction from 47.2 to 33.5%.

The intensity of the heat processing effect is a function of the temperature reached, the time of exposure and the moisture content during processing (Stern et al. 1985; Cleale IV et al. 1987). Aguilera et al. (1992) demonstrated that heat treatment strongly reduced the effective degradability of peas and lupin seeds, by autoclaving peas at 120°C for 30 min. The dry matter and nitrogen disappearance (%) of peas for treated and untreated was significant. Autoclaving decreased the rate of degradation ($P < 0.001$ and $P < 0.01$ for dry matter and nitrogen, respectively) but had a minor influence on the extent of degradation. Walhain et al. (1992) found that extrusion of peas did not significantly affect dry matter effective degradability, but dramatically reduced crude protein effective degradability (88.3 vs. 65.5% at an outflow rate of 6% h^{-1}). Extrusion of peas diminished rumen protein solubility to give a decrease of more than 20 percentage units. In addition, extrusion greatly increased the rate of disappearance of starch in the rumen because of the starch gelatinization. Focant et al. (1990) tried steam flaking and extrusion. They found that steam flaking failed to significantly affect any of the parameters. Extrusion of peas decreased protein solubility and gelatinized starch. Goelema et al. (1998) investigated the rumen degradability of pressure toasted whole peas and broken peas, lupins and faba beans. They found that pressure toasting broken pea seeds increased rumen undegradable protein ($P = 0.013$).

Many studies have been tried to determine the optimal combination of temperature and time. Optimal conditions are generally defined as those which decrease rumen degradability without negatively altering postruminal digestion (Stern et al. 1985; Satter

1986). Walhain et al. (1992) studied three different extrusion temperatures: 140, 180 and 220°C. Increase of temperatures above 140°C failed to improve the protection of proteins. Extrusion markedly increased the disappearance of starch from the rumen. Compensation between ruminal and intestinal disappearance was observed. They concluded that the best extrusion temperature was 140°C. Protein protection was not significantly improved above this temperature. Mustafa et al. (1998) tried moist heat treatment. Ground peas were autoclaved at 127°C with a steam pressure of 117 kPa for 10, 20 and 30 min. In situ soluble crude protein fraction (A) was lower while potentially degradable crude protein was higher ($P < 0.05$) in heated relative to unheated peas with both fractions responding in a cubic relationship to heating time. These results indicated that heating peas for up to 30 min could change the site of crude protein digestion from the rumen to the small intestine without affecting the total crude protein available for digestion. Goelema et al. (1999) studied the effect of pressure toasting, expander treatment and pelleting. They tried pressure toasting for 3 min at 132°C, expander treatment (115°C, 8s) and pelleting (80°C, 10s). Toasting was the most effective treatment in altering rumen protein degradability. Expander treatment and pelleting both increased that soluble fraction, whereas pelleting also increased degradation rate (k_d) resulting in a decreased amount of rumen undegradable protein.

2.4 Further Investigation

From the above review, we may conclude that technically and biologically, peas can be used for weaned calves, backgrounding cattle, dairy cows, feedlot cattle, and as a protein supplement for grazing ruminants. The main constraint is economic viability. Pea utilization in backgrounding and feedlot cattle diets, especially the optimal inclusion rate and processing technique of peas to improve feed efficiency needs further investigation. In order to investigate the economic viability of feeding peas to backgrounding cattle, two experiments were conducted. The first was a feeding trial, and the second used the nylon bag technique to explain the results of the feeding trial.

III. Feeding Peas to Backgrounding Heifers

Abstract

Ninety crossbred heifers (215.8 ± 13.8 kg) were used to study the biological and economic viability of feeding peas to backgrounding cattle. Five diets were formulated: (1) 100% barley grain + barley straw (0% peas group); (2) 30% peas + 70 % barley grain + barley straw (30% peas group); (3) 50% peas + 50% barley grain + barley straw (50% peas group); (4) 100% peas + barley straw (100% peas group); and (5) canola meal + barley grain + barley straw, formulated to be iso-nitrogenous with the 30% peas group, as a positive control (canola meal group). The amount to be fed was calculated to achieve a gain of 0.8 kg d^{-1}, with concentrates and straw fed separately. The total dry matter intakes (DMI) were very similar: 5.5, 5.5, 5.5, 5.6, and 5.7 kg d^{-1} for the 0, 30, 50, 100% peas, and canola meal group, respectively. Straw consumption was lower than expected: 2.0, 1.9, 2.0, 2.2, and 2.0 kg d^{-1} for the 0, 30, 50, 100% peas, and canola meal group, respectively. Average daily gains (ADG) were 0.72, 0.80, 0.79, 0.83, and 0.76 kg d^{-1} for the 0, 30, 50, 100% peas, and canola meal group, respectively; the difference in ADG between the 0% peas group and the 100% peas group was significant ($P = 0.028$), and between the 30% peas group and the 0% peas group approached significance ($P = 0.092$). The feed conversion efficiency (FCE, kg feed kg^{-1} gained) of concentrates was 4.8, 4.5, 4.4, 4.1, and 4.8, and the FCEs of total dry matter were 7.6, 6.9, 7.0, 6.8, and 7.4 for the 0, 30, 50, 100% peas, and canola meal group, respectively. The total feed cost of gain was $0.786, 0.779, 0.799, 0.860, and 0.817 kg^{-1} gain for the 0, 30, 50, 100% peas, and canola meal group, respectively; with dietary treatment having a significant effect on cost

(P = 0.035). Statistical analysis showed that the cost of gain was significantly greater for the 100% peas group than for the 0, 30 or 50% peas groups. Feeding the 100% pea diet also tended to be more expensive than the canola diet (P = 0.090). There were no significant differences among the 0, 30 and 50% peas groups.

3.1 Introduction

Field peas (*Pisum sativum*) were traditionally grown for human use; their use in animal feeding is a comparatively recent phenomenon. However, the nutritive value of peas for non-ruminants is well documented (Castell et al. 1996; Stefanyshyn-Cote et al. 1998) and animal feed accounted for 90% of the total pea production in the European Union in the early 1990's, the remainder being destined for seed and human use (UNIP-ITCF 1995). It was estimated that the mean levels of incorporation were 22% in pig diets, 10% in poultry diets and 2% in cattle diets (UNIP-ITCF 1995).

Peas have not been widely used in diets for cattle partly because of cost and partly because of lack of information on the nutritive attributes of peas in ruminant digestion and metabolism. Even though peas are high in both protein and starch content, containing 20-25% CP (Ellwood 1998) and 41-54% starch of dry matter (Corbett 1997), they are usually thought of as a protein supplement, because of their relatively high price. The beef and dairy industries have not been major pea users. However, with more feed pea cultivars becoming available, and the unusual combination of high protein and high energy found in peas, these industries could be potential users.

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). Against this background, and considering that many pea growers in Alberta are also cattle backgrounders, the Alberta Pulse Growers expressed an interest in testing peas in backgrounding diets for beef cattle. This experiment was designed to explore the feasibility of feeding peas to backgrounding cattle, both as a source of protein and energy, and a replacement for the more traditional canola and soybean meal. Since soybean meal is relatively expensive in Alberta, locally produced canola meal is more commonly used in western Canada, and was selected as the comparative protein source.

3.2 Materials and Methods

This project was conducted at the University of Alberta's Kinsella Research Station in compliance with the Canadian Council on Animal Care (CCAC) policies for welfare in animal research. The experimental protocol was approved by the Faculty of Agriculture, Forestry and Home Economics (AFHE) Animal Policy and Welfare Committee at the University of Alberta, Edmonton.

3.2.1 Animal selection

Ninety crossbred heifers were selected for this study on the basis of body weight (215.8 ± 13.8 kg). They were born between April 7 and May 20, 2000 and were weaned on September 15, 2000. Heifers were assigned by a method of stratified randomization on live weight basis to 15 pens, 3 pens for each of the five diets. Experimental diets were gradually fed to the animals (from 0 to 2 kg concentrates d^{-1}, with ad lib straw) during a period of about two weeks starting November 8, 2000.

3.2.2 Experimental treatments

To study the effect of feeding peas to backgrounding cattle, five different types of diets were formulated:

- 100% barley grain + barley straw (0% pea diet);

- 30% peas + 70 % barley grain + barley straw (30% pea diet);
- 50% peas + 50% barley grain + barley straw (50% pea diet);
- 100% peas + barley straw (100% pea diet);
- canola meal + barley grain + barley straw (canola meal diet).

Canola meal diet was formulated to be iso-nitrogenous with the 30% pea diet. The formulation of these diets is shown in detail in Table 3.1. The diets were formulated by using the COWBYTE ration balancing program (Alberta Agriculture 1999) with the goal of achieving about 0.8 kg (1.75 lb) gain d^{-1} for each diet.

Table 3.1. Diet formulation of five diets for pea-feeding study (g kg^{-1}, as-fed basis)

Ingredient Composition	0% Peas	30% Peas	50% Peas	100% Peas	Canola Meal
Barley straw	412	413	411	412	413
Barley grain	573	403	286		516
Pea		170	287	572	
Canola meal					57
Premix[z]	15	15	16	16	15

[z] Premix containing Monensin: 440 g ton^{-1}; Ca: 5%, P: 0.14%, K: 0.66%, Mg: 0.33%, lysine: 0.49%, methionine: 0.23%, Co: 4.25 mg kg^{-1}.

The variety of peas used in this experiment was Espace, and peas were purchased directly from a nearby grower. Barley and peas were coarsely rolled. The concentrate and straw were fed separately, the concentrate being fed once a day around 9:00 a.m. except on weigh days, and the straw fed after the concentrates in a separate bin. On weigh days feeding was delayed until after the cattle have been weighed.

3.2.3 Measurement and management

Animals were weighed on two consecutive days at the beginning (November 20 and 21) and again at the end (February 27 and 28) of the experiment, and weighed once every two weeks during the course of the experiment. Animals were weighed between 9:00 a.m. and 10:00 a.m. before feeding but had continuous free access to water. The amount of feed offered to each pen was adjusted after each weighing to maintain the target rate of gain.

3.2.4 Feed cost calculation

The prices of ingredients used to calculate costs were the actual locally available purchase price, plus a processing fee for the peas and barley.

3.2.5 Animal health

Health was continually monitored by the herdsmen; sick animals were treated appropriately and the treatments recorded.

3.2.6 Feed sampling and chemical analysis

The individual feed ingredients 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 according to the Association of Official Analytical

Chemists (AOAC, 1990). Crude protein (CP, N x 6.25) was determined with Leco FP-428 Nitrogen Analyzer (Leco Corporation, St. Joseph, MI). Analyses of neutral detergent fiber (NDF) and acid detergent fiber (ADF) and lignin were carried out using the filter bag technique (ANKOM Company, Fairport, NY).

3.2.7 Statistical analyses

Analysis of variance was used to test the effects of diets using the General Linear Model procedure of the SAS Institute, Inc. (1996). The effects of diets on average daily gain (ADG), feed conversion efficiency (FCE, feed/gain), straw consumption d^{-1}, and feed costs kg^{-1} gain were analyzed. The effects of diets on ADG were analyzed using individual cattle as the experimental unit. The effects on FCE, straw consumption d^{-1}, feed cost kg^{-1} gain, were analyzed using the pen as the experiment unit. The Fisher's (protected) LSD procedure (Steel and Torrie 1980) was used for means separation. Differences among means were declared significant when the calculated probability was $P < 0.05$.

3.3 Results and Discussion

The outlier data of one heifer were excluded for reasons unrelated to the experiment.

3.3.1 Chemical composition of main ingredients used

The chemical composition of the main ingredients is shown in Table 3.2. They were similar to those reported in the literature (Christensen and Mustafa 2000). The fat content (ether extract) of peas was only 0.87%, which is lower than that of the five different cultivars (1.0-2.1%) reported by Christensen and Mustafa (2000). Canola meal contained 39.6% crude protein, and high NDF and ADF values (37.6 and 20.3%, respectively). The NDF and ADF contents of canola meal were higher than those reported by Bell and Keith (1991), but close to that reported by Khorasani et al. (1994).

Table 3.2. Chemical composition of dietary ingredients used in the feeding trial (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

Table 3.3 shows the nutritive contents of the five diets as consumed, calculated from the ingredients in Table 3.2. 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 3.3). According to NRC (1996), for diets with 22% RUP from CP (peas), CP requirements are 13.8 and 10.6% for cattle at 200 and 300 kg growing at 0.8 kg d^{-1}; for diets with 32% RUP from CP (barley diets), the requirements are 12.2 and 10.4% respectively; for diets with 30 and 50% peas, the protein requirements would be between the level of 22% RUP and 33% RUP diet. It is evident that the 9.36% CP of the

0% pea diet was insufficient to meet the requirements of growing cattle; the 100% pea diet had a higher protein content than required. However, backgrounding cattle are not expected to grow quickly.

Table 3.3. Actual diet composition fed to backgrounding heifers (as-fed basis)[z]

Ingredients (g kg^{-1})	0% Peas	30% Peas	50% Peas	100% Peas	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 [y]					
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] Actual feed fed to heifers.

[y] Calculated from ingredient chemical composition.

3.3.2 Dry matter intake (DMI)

The diets were formulated as the totally mixed rations (TMR) shown in Table 3.1, and were calculated to give daily gains of about 0.8 kg d^{-1}. However, since concentrate consumption was controlled, and the concentrates and straw were fed separately, cattle did not actually eat the amount of straw that was anticipated (Table 3.3). The actual DM consumption is shown in Table 3.4. There was no significant difference in total dry matter intake (DMI) among the five diets ($P = 0.35$). The straw consumed was lower than designed in all five diets. Only the straw consumed by the 100% peas group (38%, on as-fed basis) came close to the designed intake level (41.2%). The 100% peas group had significantly higher straw consumption than the 0, 30% peas and canola meal group, and also tended to be higher than the 50% peas group. This may be because the 100% peas group had a higher CP content, which enabled the rumen microbes to digest the straw and so the cattle could consume more of it. It has been demonstrated by many studies that feeding high protein diets increases straw consumption (Church and Santos 1981; Nelson 1985). However, in the 0% peas group which had the lowest protein intake, the straw consumption was very close to that of the canola meal and 30% peas group.

3.3.3 Average daily gain (ADG)

Figure 3.1 shows the average live weights of the five groups during the course of the study. The target weight gain was 0.8 kg d^{-1} (1.75 lb d^{-1}) for all treatments, and with the exception of the 0% peas group (0.72 kg d^{-1}) this was achieved (Table 3.4). Cattle fed the 100% peas diet gained 15.3% ($P = 0.028$) more than the 0% peas group, but there were no other statistically significant differences in gain among the diet groups. Cattle fed the

0% peas diet grew 10% more slowly than expected, possibly because of the low CP content of the diet. Thus, although energy was not limiting, the low dietary protein intake may have affected the growth potential of the rumen microbes and hence microbial protein synthesis. Similar results to these had been reported by Anderson (1998a), who fed peas and wheat middlings as the only grain sources to heifers, from 222 kg to 294 kg live weight over 84 d. He reported an average daily gain of 0.84 kg d^{-1} for the peas group and 0.78 kg $d^{-1}$for the wheat middlings group, a little bit lower than the projected 0.91 kg d^{-1} (2 lb d^{-1}).

3.3.4 Feed conversion efficiency (FCE, feed /gain) and economic analysis

Feed conversion efficiency values of the concentrate portion [FCE, concentrates consumed per unit weight gain, DM basis] of these five diets are shown in Table 3.5. Feed needed per unit of gain decreased with inclusion level of peas, the differences among the treatments being significant (P = 0.003). The 0% peas group had significantly poorer concentrate FCE than either the 100% or the 50% peas group. In terms of total dry matter FCE, the 100%, 50% and 30% peas group had better FCE than the 0% peas and canola meal group. However, Anderson (1998a) found that FCE were 5.52, 5.78, 5.43 for peas, barley only, and barley plus canola group, respectively, with no significant differences among the treatment groups.

Because of the relatively high price of peas, the unit price of both concentrate and total diet increased with the inclusion level of peas (Table 3.5). The unit price of the feed consumed, ranged from \$0.090 kg^{-1} for the 0% pea diet to \$0.112 kg^{-1} for the 100% pea

Table 3.4. Average daily gain and dry matter intake of the heifers on the five diets during the100 d experiment

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

[z] See Table 3.3 for details.

[ab] Numbers in the same column bearing different superscripts are significantly different ($P < 0.05$).

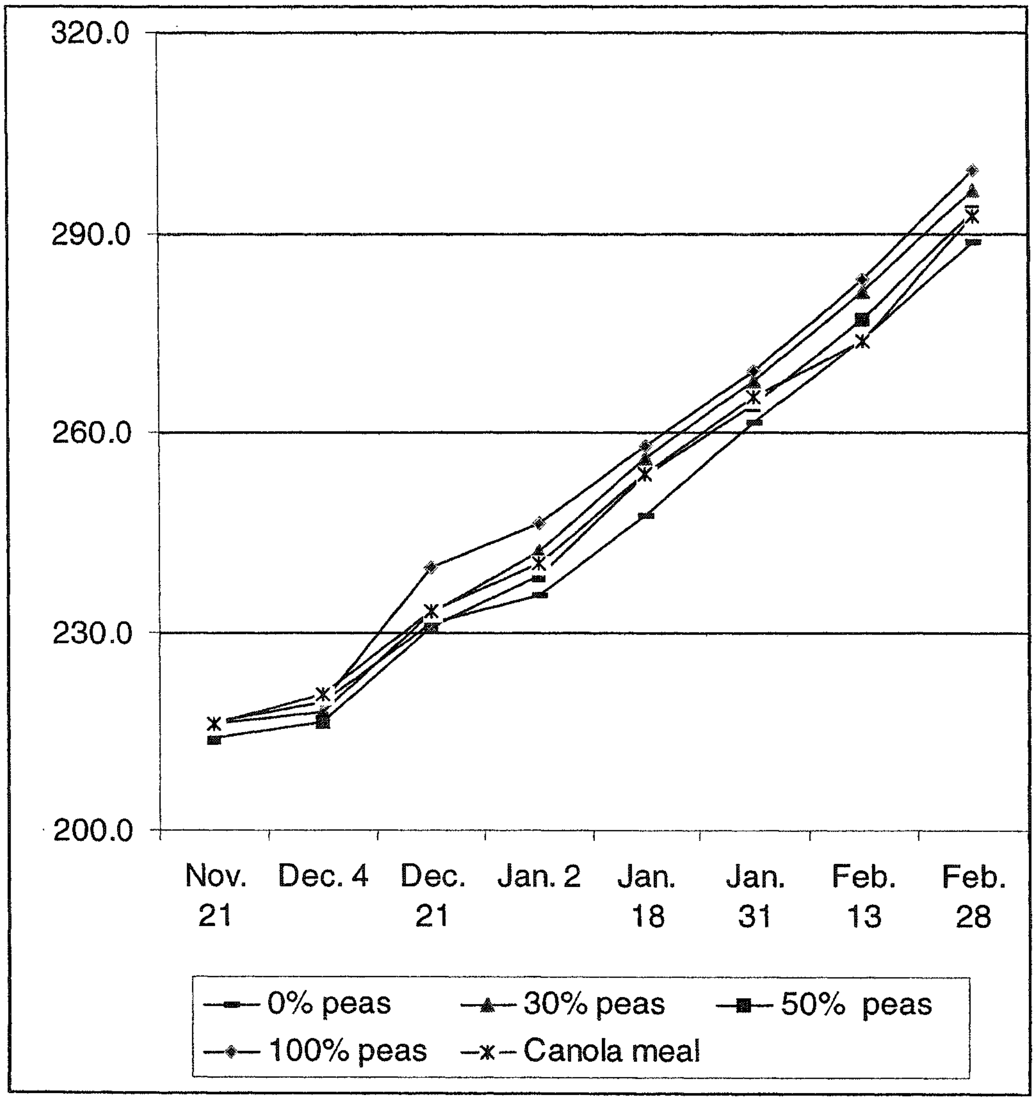

Fig. 3.1 Mean live weights (kg) of the heifers fed five different diets (see Table 3.3) during the experiment period (100 days).

diet, reflecting the high unit cost of peas. The price of the 100% pea diet was only 24.4% higher than 0% pea diet, because more straw was consumed by cattle fed 100% pea concentrates. The difference of feed cost kg^{-1} gained (Table 3.5 and Figure 3.2) between the 0% and 100% pea group reduced to 9.4%, because of the improved FCE with the higher peas content. The 100% pea group had significantly higher feed cost kg^{-1} gained than the 0, 30 or 50% pea group ($P = 0.009$, 0.005, and 0.024, respectively), and tended to be significantly higher than that of the canola meal group ($P = 0.090$). The 30% peas group had the lowest cost kg^{-1} gain. Similarly, in the Anderson (1998a) experiment, the feed cost kg^{-1} gain was $US0.45, 0.44, and 0.37, for peas, barley only, and barley plus canola, respectively.

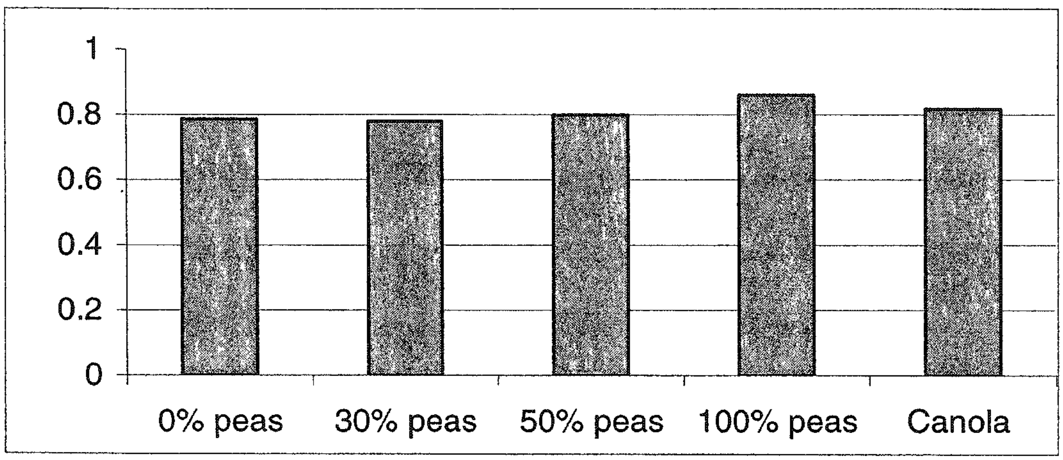

Fig.3.2 Feed cost kg^{-1} gain ($ kg^{-1}) of heifers fed five diets during the experiment period.

3.3.5 Animal health

There was no evidence of digestive disorders. Four heifers in the 0% peas group suffered pneumonia in the first week of this study. They were treated with biomycin and recovered soon after.

Table 3.5. Feed conversion efficiency and feed cost kg^{-1} weight gain of heifers fed the five diets during the study[z]

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

[z] Price used were as follows: barley: $112.5 ton^{-1} (2.45$ $bushel^{-1}$, 48 lb $bushel^{-1}$), and $7 ton^{-1} for processing; peas $140 ton^{-1}, and processing fee $12 ton^{-1}; straw $45 ton^{-1} ; canola meal $212 ton^{-1}; mineral (premix) $180 ton^{-1}.

[y] Concentrates: grains plus premix.

[x] Total feed = concentrates plus straw.

[w] See Table 3.3 for details.

[v] SEM = 0.101.

[u] SEM = 0.127.

[abc] Numbers in the same column bearing different superscripts are significantly different ($P<0.05$).

3.4 Conclusions

Peas are acceptable for backgrounding beef cattle. There were no significant differences in daily gain and feed cost, compared to more traditional diets (barley grain plus barley straw; or barley grain plus barley straw and canola meal). Apparent cost kg^{-1} of gain was higher for the 100% peas group, and the 30% and 50% pea diet have a comparable cost with canola meal diet. Many factors could affect the inclusion level of peas in livestock feed, including animal species, supply and relative price of peas compared to other protein sources. Processing technique may improve the feed efficiency of peas. In addition, economic returns of feeding peas to livestock should not be the only criterion; agronomic benefits of using peas as a rotation crop should not be neglected and also the economic advantage for raw materials produced locally, which would reduce the cost of transportation.

IV. Rumen Digestion Characteristics of Five Diets Fed to Backgrounding Cattle

Abstract

An in situ digestion trial was conducted to determine whether the rumen degradable (RDP) and undegradable (RUP) fractions of the proteins of the five diets used in the previous feeding trial (see Chapter III) were sufficient to meet the requirement of heifers with an average daily gain of 0.8 kg. Rumen digestion characteristics of peas, especially the effects of particle sizes of ground peas on degradability of the soluble and slowly degradable fractions of the crude protein of peas were also determined. Barley grain (BG), canola meal (CM), and peas of three particle sizes (ground through 1, 2, and 4 mm screen, named P1, P2, and P4, respectively) were incubated in the rumens of three steers for 0, 4, 8, 12, 16, 24, 36, 48, and 72 h. Barley straw (BSW) was similarly incubated for 0, 4, 12, 24, 48, 72, 120, and 240 h.

The actual ADGs of the heifers used in the previous trial were 0.72, 0.80, 0.79, 0.83, and 0.76 kg $d^{-1}$for the 0, 30, 50, 100% peas, and canola meal group, respectively. The ADG of the 30 and 100% peas group was 11.1 and 15.3% higher than that of the 0% peas group (P = 0.092 and 0.028, respectively). The RUP supplied by the five diets was 17.5, 19.0, 19.9, 21.5, and 22.5% of CP for the 0, 30, 50, 100% peas, and canola meal diets, respectively. The RUP content of all five diets met the requirements of backgrounding cattle with the target ADG of 0.80 kg d^{-1} as determined by NRC (1996). However, the total protein of the 0% pea diet (9.5%) was lower than required (10.7%). In addition, the RDP contents of the 0, 30% peas, and canola meal diets were 12.9, 0.7 and 16.0% lower

than the requirements, respectively. The 50 and 100% peas diet had 40.2 and 77.7% higher RUP, 5.2 and 20.5% higher RDP than the requirement.

The soluble fraction of the DM of peas was high (60.7%), intermediate (46.1%), and low (41.4%) for P1, P2, and P4 ($P < 0.05$), respectively. The slowly degradable fraction of the DM of P1, P2, and P4 tended to be inversely related to the soluble fraction of P1, P2, and P4 ($P < 0.05$). The effective degradability of DM for P1 ($Kp = 6\% \ h^{-1}$) was significantly higher than that of P2 and P4 ($P < 0.05$). The soluble fraction of CP of P1 was 24.0% and 28.9% higher than that of P2 and P4 ($P < 0.05$), respectively. The slowly degradable fractions of CP were 28.2, 42.1, and 44.3%, for P1, P2, and P4, respectively, and were different from each other ($P < 0.001$). The slowly degradable fraction increased with increased screen size. The RUP content increased with the screen size increase, with the RUP content of P1 being 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 ($P = 0.67$).

It is concluded that the low RUP content of peas was not a limiting factor in feeding peas to backgrounding heifers, the RUP supplied by all five diets used in the previous diets met the requirements, but the 0, 30% peas, and canola meal diets had lower RDP than required. It was also concluded that the substantial differences in the soluble and slowly degradable fractions of DM and CP of peas ground through 1mm and 2 mm screen indicated the need to use standardized screen size in the in situ procedure.

4.1 Introduction

In the previous trial (Chapter III), five diets were used to determine the economic viability of feeding peas to backgrounding cattle. The five diets were

- 100% barley grain + barley straw (0% peas group, as negative control);
- 30% peas + 70 % barley grain + barley straw (30% peas group);
- 50% peas + 50% barley grain + barley straw (50% peas group);
- 100% peas + barley straw (100% peas group);
- canola meal + barley grain + barley straw (canola meal group, iso-nitrogenous with 30% peas group, as positive control).

They were formulated to enable heifers (215.8 ± 13.8 kg) to gain 0.80 kg d^{-1} (ADG). The actual ADGs achieved were 0.72, 0.80, 0.79, 0.83, and 0.76 kg d^{-1} for the 0, 30, 50, 100% peas, and canola meal group, respectively. The ADG of the 100% peas group was 15.3% higher than that of the 0% peas group ($P = 0.028$), and the ADG of the 30% peas group tended to be higher (11.1%) than the 0% peas group ($P = 0.092$). The total feed cost of live weight gain of the 100% peas group was 9.4, 10.4, and 7.6% higher than the 0, 30, and 50% peas diet ($P = 0.035$). Feed conversion efficiency increased with inclusion level of peas, the differences among the treatments being significant ($P = 0.003$). The feeding trial results suggested that peas could be used to replace canola meal and part of barley grain in backgrounding diets for cattle. From an economic point of view, there were no significant differences between the 0, 30, 50% peas, and canola meal diets. However, the goal of ruminant protein nutrition is to provide adequate amounts of rumen-degradable protein (RDP) for optimal rumen efficiency and to obtain the desired animal productivity with a minimum amount of dietary CP. Peas, like other legume seeds, are characterized by having highly degradable protein, but low rumen undegradable protein. Ruminal undegradable protein for peas is 22%, compared to 35 and 28% for soybean meal and canola meal, respectively [National Research Council (NRC) 1989]. Comparing RUP and RDP contents of the five tested diets with the requirement, may help to make a decision of which diet was better.

In addition, the in situ procedure has emerged as the most widely used approach for estimating rumen degradation characteristics of feeds (Stern et al. 1997). Standardized procedures have been recommended (Michalet-Doreau and Ould-Bah 1992; Nocek 1988; Stern et al. 1997). The major factors influencing variation include basal diet, bag characteristics, sample characteristics, rinsing techniques, and microbial correction. A 2 mm screen size was recommended for concentrates and has been used in many in situ experiments (Michalet-Doreau and Ould-Bah 1992; Nocek 1988; Stern et al. 1997). However, when studying peas, many researchers have tended to use a 1 mm screen instead of a 2 mm screen, and this has caused a significant variation in the results reported.

The objectives of the present study were to (1) determine whether the RDP and RUP contents of the five diets met the requirements for heifers predicted to gain 0.8 kg d^{-1}; and in terms of RUP and RDP contents relative to the requirements, which diet had more economical RUP and RDP composition; and (2) investigate the rumen digestion characteristics of pea grains, including the effects of particle size on degradability of DM and CP of peas, using three different screen sizes (1, 2, and 4 mm).

4.2 Materials and Methods

All animal procedures used in this study were approved by the AFHE Animal Policy and Welfare Committee at the University of Alberta, Edmonton. Animals were housed at the University of Alberta Metabolic Research Unit at Edmonton Research Station.

4.2.1 Animals and treatments

Three rumen cannulated steers (575 ± 56.3 kg) were used to estimate the degradability of the DM and N in barley straw (BSW), canola meal (CM), barley grain (BG) and peas 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 and provided 4 kg concentrates and 6 kg hay d^{-1} (as fed basis) and free access to water. All concentrates were fed in the morning, and hay was fed twice a day. The composition of the concentrate was: 89.9% barley grain, 7.8% canola meal, and 2.3% canola oil. Minerals were added at the level of 0.2% calcium phosphate, 1.3% calcium carbonate, 0.4% fortified salt and 0.3% dynamate (DM basis).

Barley straw (BSW), canola meal (CM), barley grain (BG), and pea grain (P2) were ground through a 2 mm screen, to determine the RDP and RUP contents of the five diets. In addition two more portions of peas were ground through 1 and 4 mm screen (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 of 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. Standard (alfalfa) hay was incubated with samples to monitor the rumen condition. Upon removal from the rumen, bags were immediately rinsed with cold water for a few minutes to arrest fermentation, and frozen at -15°C 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 75°C for 72 h and weighed and equilibrated in the air for 24 h. Subsamples of residue were then taken from the bags for chemical analyses.

4.2.2 Laboratory analyses

Ground samples and their residues after incubation were analyzed for DM and CP contents. DM was determined by drying at 105°C to a constant weight. Crude protein was determined using a nitrogen analyzer (LECO, model FP-428, St. Joseph, MI). Approximately 100 mg sample was weighed into a tin foil cup, and wrapped and compressed then completely combusted. Nitrogen content was determined from the nitrogen concentration in the combustion gases. Crude protein content of the sample was calculated as N × 6.25 (AOAC 1990).

4.2.3 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 = fraction A (soluble, % of total);

B = fraction B (potentially degradable, % of total);

t = time of rumen incubation (h);

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 rumen degradable protein (RDP) and rumen undegradable protein (RUP) fraction were calculated for each feedstuff using the following two equations (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});

C = fraction 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). Briefly, all data points (other than zero time) were used to fit the equation of Ørskov and McDonald (1979) to estimate the parameters A' and B' which were then used in the following equation to calculate the lag times:

$$t_0 = \frac{1}{Kd} \ln\left(B' / \left(A' + B' - A\right)\right)$$

Where: t_0 is lag time (h), A' (soluble fraction, %), B' (degradable fraction, %) and Kd (% h^{-1}) were the parameters estimated using the equation of Ørskov and McDonald (1979), A was soluble fraction (%) including data point of zero hours.

4.2.4 Statistical analyses

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 Statistical Analysis System (SAS 1996). The estimates of A and B were constrained so that (A+B) did not exceed 100. Effects (differences of fraction A, fraction B, degradation rate, effective degradability of protein, and rumen undegradable protein) of particle sizes on degradability were analyzed by analysis of variance using the GLM procedure of the SAS institute, Inc. (1996). The significance level was set at $P < 0.05$.

4.3 Results and Discussion

4.3.1 Rumen degradation characteristics of pea grain

After 24 h rumen incubation, more than 95% of CP of peas had disappeared, with almost 100% disappearance by 36 h (Table 4.1). 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, the results of Aguilera et al. (1992) indicated that CP residue was still detectable after 72 h incubation. Differences between the present results and those of Aguilera et al. (1992) could be due to 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%) of Aguilera et al. (1992). Similarly, about 90% of the DM of pea grain had disappeared by 36 h incubation, and had almost totally disappeared by 48 h in the rumen in the present study.

The rapid rate of disappearance of both DM and CP of 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 and B, and Kd. Use of the equation made the sum of fraction A and B greater than 100%, a physiological impossibility.

Results whereby $A + B > 100$ have been reported in the literature (Arieli et al. 1995, Petit et al. 1997), and even, in a particular study by Goelema et al. (1999), a negative value was reported for fraction A. A plausible explanation for $A + B > 100$ could be that some of materials (possibly microbial cells) were adsorbed onto the feed particles from rumen fluid; and or a greater analytical or statistical error with these low values for the B fraction after incubation in the rumen. As shown in Figures 4.1 and 4.2, the shape of the pea degradation curve was flat, and no clear asymptote was reached. To overcome the analytical difficulties, Marquardt's method (Marquardt 1963; Cerneau and Michalet-Doreau 1991) was used and the boundary of $A + B \leq 100$ was set. A new parameter D was used to replace (A+B), i.e. $D = A + B$, where $D \leq 100$. A and D were calculated by

SAS (A was determined by disappearance rate of zero h), and then fraction B was estimated as B = D – A. The estimated parameters of rumen degradation of feeds are shown in Table 4.2.

Particle size had a significant effect on the degradability of peas (Table 4.2). The difference between DM and CP degradation for different screen sizes (Table 4.2) may be due to increased area to mass ratio of the particle; 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. One explanation is that 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 suggest 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, and P4 ($P < 0.05$), respectively (Table 4.2). 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 4.2). 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 0.8 mm screen reported by Cerneau and Michalet-Doreau (1991). The fraction A of DM of

Table 4.1. Dry matter and crude protein disappearance (%) of barley grain (BG), canola meal (CM), Peas of the different particle sizes (P1, P2 and P4) and barley straw (BSW) incubated in the rumen

Time	Dry Matter						Crude Protein					
(h)	BG	CM	P1	P2	P4	BSW	BG	CM	P1	P2	P4	BSW
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

Table 4.2. 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	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	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	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
BSW	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, RDP was calculated at $Kp = 6\% \ h^{-1}$ for concentrates, and $2\% \ h^{-1}$ for straw.

[y] Multiple comparisons were done at $Kp = 6\% \ h^{-1}$ only.

[a-c] Numbers in the same column of the parameters of peas bearing different superscripts are significantly different ($P < 0.05$).

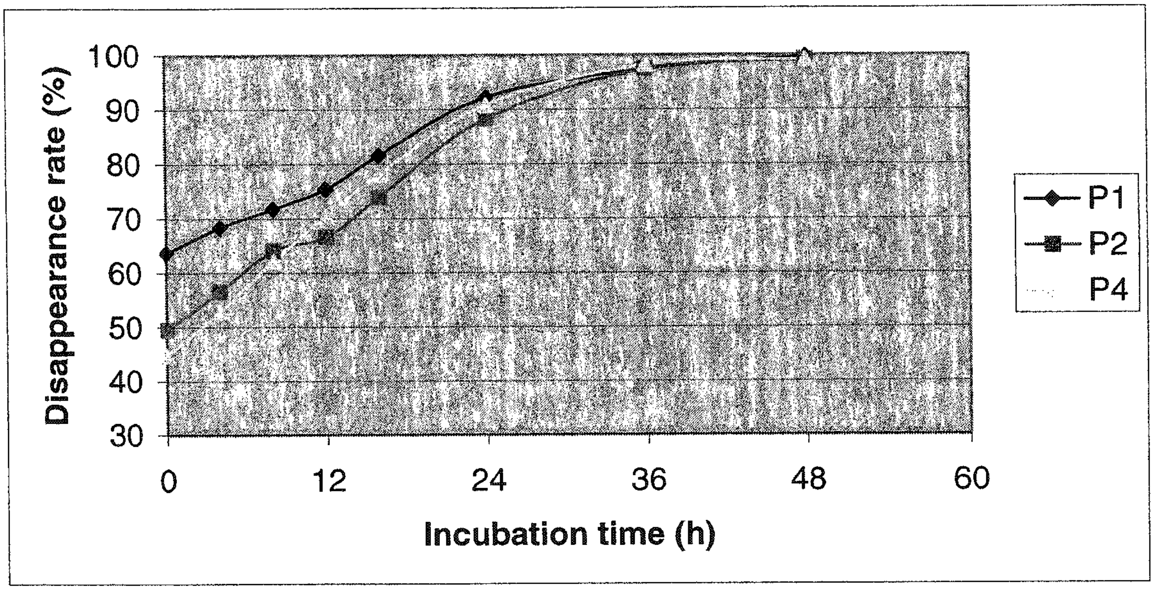

Fig. 4.1. Percentage disappearance of the DM of pea grains ground through 1, 2, and 4 mm screen and incubated in the rumen.

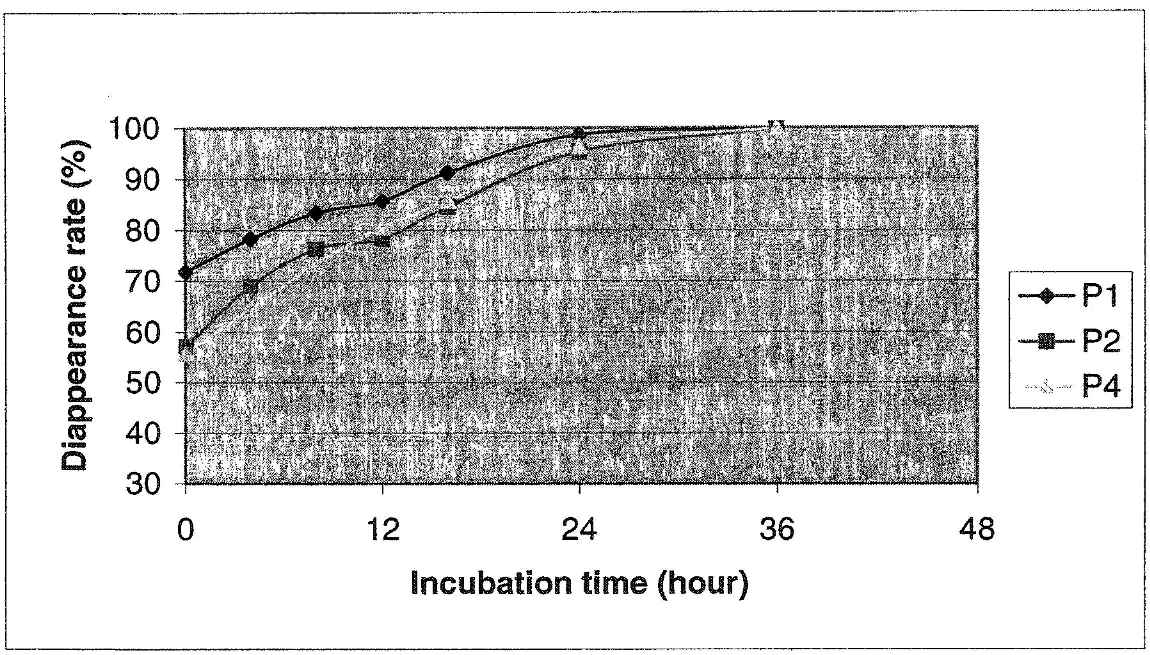

Fig. 4.2. Percentage disappearance of the CP of pea grains ground through 1, 2, and 4 mm screen and incubated in the rumen.

P2 in the present study was 66.4% higher than that reported by Aguilera et al (1992), even though their peas were 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 4.2), but there was no difference between P2 and P4. In the experiment of Petit et al. (1997), the fraction A of CP of peas ground through 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 of 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 in Petit et al. (1997) study), or difference in the washing method. Fraction B of CP was significantly less in P1 than in P2 and P4, respectively (Table 4.2), 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 4.1, 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 ($P < 0.01$). 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 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 4.2), but all considerably lower than the value (28.5%) reported by Mustafa et al. (1998).

The effective degradability of the CP of peas (Table 4.2) 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), and 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) from 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.

As discussed above, the values for the parameters of kinetics of peas have been quite variable in the published literature. Table 4.3 summarizes some of those studies. For example, fraction A of CP ranged from 39.29 to 73.0%, and RUP ranged from 5.2 to 28.7%. Fraction A of peas reported in NRC (2001) was 55.5 ± 11.5%, no RUP content was reported as in the NRC (1989), calculated corresponding RUP of peas is 11.8%. Possible reasons for these variations include variations in particle size, type of peas, washing method and feeding level in each study. According to the recommended procedures for the in situ technique (Michalet-Doreau and Ould-Bah 1992; Nocek 1988; Stern et al. 1997), samples should be ground through a 2 mm screen. However, in most cases, RUP contents of peas were determined by grinding the peas through 0.8 to1 mm screens. In the present experiment peas were ground through 1 mm and 2 mm, which resulted in significant differences between those kinetic degradation parameters such as fractions A and B, RUP, and RDP contents. Aufrere et al. (1994) ground peas through 0.8 mm screen, and reported 73% for fraction A, 26.9% for fraction B, and a degradation rate of 25.9%·h^{-1}. The RDP content of peas in the study of Aufrere et al. (1994) was 94.8%,

Table 4.3. Main kinetic parameters (fractions A and B, Kd, Kp, RDP, and RUP) of peas estimated by different investigators

Investigators	Screen Size (mm)	A	B	Kd	Kp	RDP[z]	RUP[z]
Michalet –Doreau and Cerneau (1991)	0.8	73.0	26.9	0.259	0.06	94.8*	5.2*
	3.0	57.7	42.2	0.194	0.06	89.9*	10.1*
	6.0	42.6	57.4	0.135	0.06	82.4*	17.6*
Aguilera et al. (1992)	2.0	39.29	60.71	0.086	0.0154	90.8*	9.2*
	2.0	39.29	60.71	0.086	0.022	87.5*	12.5*
Walhain et al. (1992)	1.0	48.6	51.2	0.20	0.06	88.0*	12.0*
Mustafa et al. (1998)	2.0	48.1	52.1	0.048	0.06	71.3**	28.7**
Goelema et al. (1998)	rolled	55.9	44.1	0.0452	0.06		25.2**

[z] RDP, RUP see text 4.2.3 Calculation of degradability, RDP and RUP content.

* Calculated according the reported values.

** Reported by the investigators.

and RUP was only 5.2%. Likewise the calculated value of RUP was 12.0% in the experiment of Walhain et al. (1992). In the two experiments by Goelema et al. (1998, 1999) with rolled peas, two significantly different values (64.7 and 25.2%) of RUP of peas were reported.

Feeding level of basal diets affects the passage rates of rumen contents. Higher passage rate results in lower retention time, allowing less time for rumen microbes to act on the particles, which allows to a higher percentage of protein to escape from the rumen. Aguilera et al. (1992) ground peas through a 2 mm screen, and the calculated values of

RUP were 9.2 and 12.5% at 0.7 times and 1.0 times maintenance level, respectively. To get comparable results, in situ procedure for peas study should be standardized and 2 mm screen size should be used. As indicated by the present and other studies (Walhain et al. 1992; Michalet-Doreau and Cerneau 1991; Aufrere et al. 1994), peas ground through 1mm or finer screen resulted in higher values for fraction A and lower values for RUP.

4.3.2 Ruminal degradation of other feeds

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 Cerneau and Michalet-Doreau (1991), in which the barley was ground through 0.8 mm screen, the fraction A found in the present study was much 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 Cerneau and Michalet-Doreau (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 CM were 27.7, 58.3, and 14.0%; the Kd and effective degradability were 8.1% h^{-1} and 66.5% (Table 4.2). Fraction A in the present study was higher than the reported value of 18.8% by Mustafa et al. (as cited by Ellwood 1998), and lower than the 31.4% reported by Seoane et al. (1992). Correspondingly, fraction B was lower than two values (77.9 and 62.6%) reported, and the insoluble fraction of DM of CM was correspondingly higher. These differences could be due to the processing methods of canola meal in the various studies, for example, the

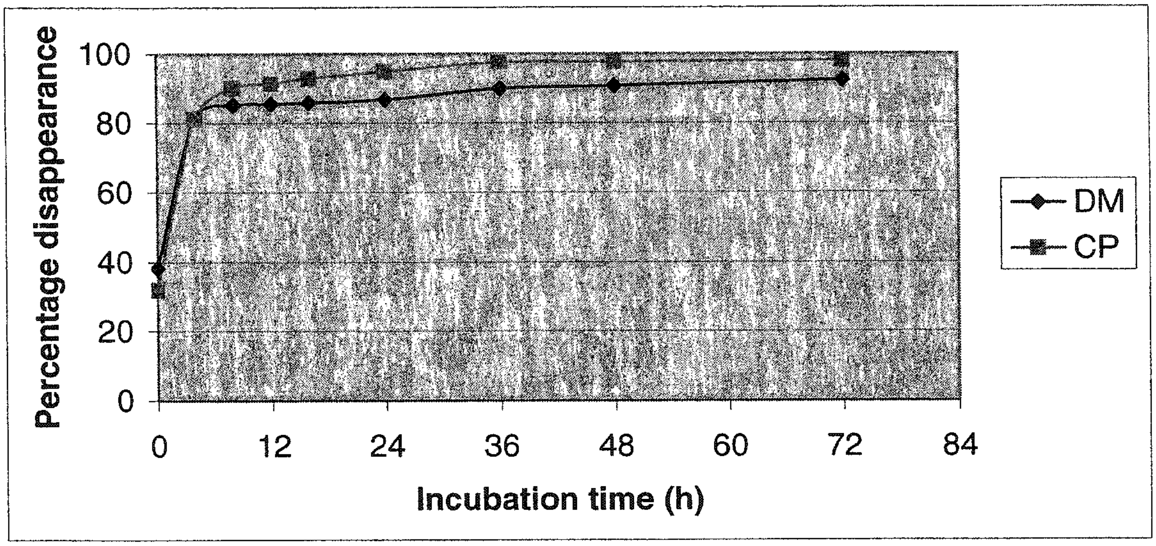

Fig. 4.3. Percentage disappearance of the DM and CP of barley grain ground through 2 mm screen and incubated in the rumen.

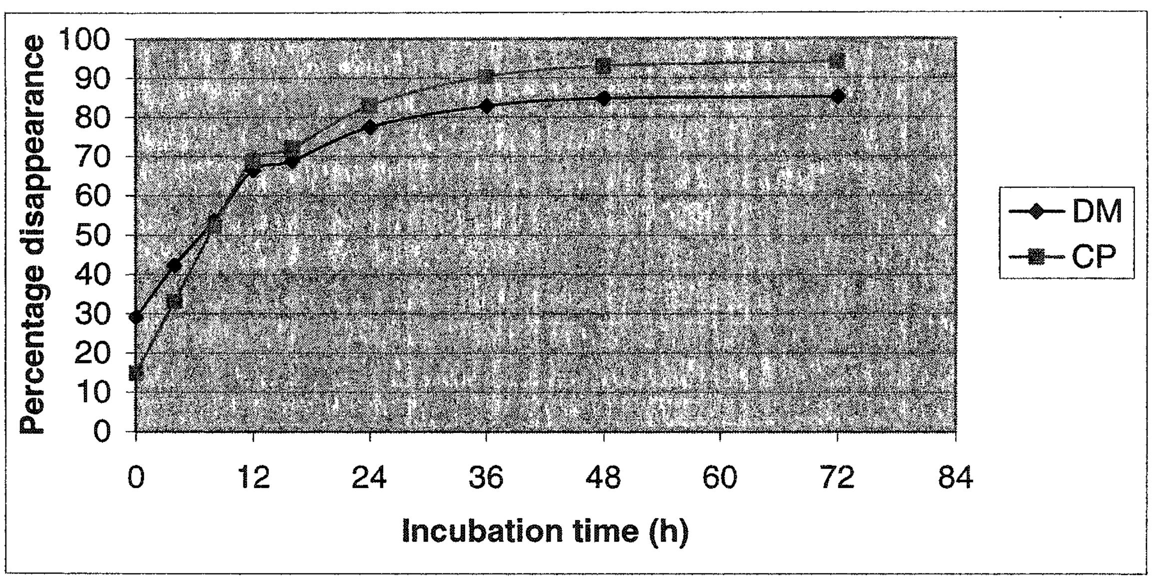

Fig. 4.4. Percentage disappearance of the DM and CP of canola meal and incubated in the rumen.

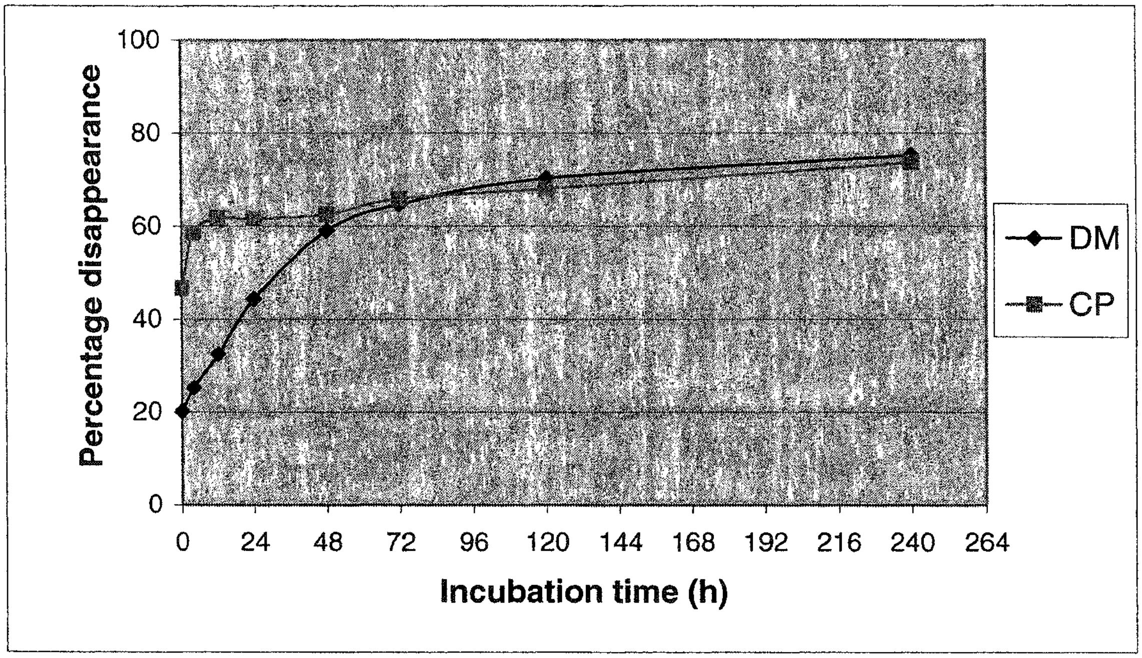

Fig. 4.5. Percentage disappearance of the DM and CP of barley straw ground through 2 mm screen and incubated in the rumen.

processing temperatures, also could be due to other parameters, for example, basal diet and intake level.

In the present study, fractions A, B, Kd and ED of CP of barley grain were 30.0%, 65.5%, 0.36, and 86.1%, respectively (Table 4.2), 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 reported values (Ellwood 1998). The reported values were between 18.6 and 26.5%, and most of them were around 20%. The potentially degradable fraction (79.6%) was within the range of 56.7 to 84.9% for fraction B (Seoane et al. 1992; Ha and Kennelly 1987; Kirpatrick and Kelley 1987). 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 within 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 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 barley straw (BSW) in the present study. However, in a similar experiment by Mathison (1999), the lag time was about 2.8 h. Lack of a lag time in the present study could be due to processing, as demonstrated by Singhal and Grant (1998). They reported that the lag time of chopped particles was longer than fine particles. Although the straw was ground through a 2 mm screen in present study as was done by Mathison et al. (1999), the soluble fraction (A) and 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 the values reported by Mathison et al. (1999). The higher fraction A of DM in this study could be indicative of finer particles.

The most fragile parts of the plant are the leaves, which are consequently ground most finely. Leaves are also the richest source of nitrogen in plants (Michalet-Doreau and Cermeau 1991). In the present study, the fraction A of CP (46.7%) of barley straw was higher than that (19.8%) of DM, which indicated that more leaves disappeared at the zero hour. The degradation rate of DM of barley straw was similar to that reported by Mathison et al. (1999), but the effective degradability was higher (54.6 vs 37.0%, Kp = 2% h^{-1}). This was because, as discussed above, in the present study both soluble and slowly degradable fractions of straw were higher than reported by Mathison et al. (1999).

4.3.3 RUP and RDP contents of five diets

As shown in Table 4.4, the actual ADGs of heifers achieved in the previous feeding trial were 0.72, 0.80, 0.79, 0.83, and 0.76 kg d^{-1} for the 0, 30, 50, 100% peas and canola meal diet group, respectively, and most of those ADGs were very close to the desired ADG 0.80 kg d^{-1}. The protein requirements and protein supplied shown in Table 4.4 were based on diets for cattle with average body weight of 280 kg (starting from 260 kg, ending at 300 kg). Total protein supplied by all diets except for the 0% peas group was higher than the recommended amount. Total protein supplied by the 0% peas group was 666 g d^{-1}, 10.7% lower than the recommended 746 g d^{-1} (NRC 1996). The actual protein concentrations supplied were 9.5, 11.2, 12.0, 14.0, and 11.2% for the 0, 30, 50, 100% peas and canola meal diets, respectively. The recommended concentration of CP for heifers with an ADG of 0.8 kg is 10.7%. The underfed protein may explain why the 0% peas group had the lowest ADG.

The recommended RUP contents were 15.5, 17.6, 15.5, 15.7, and 16.9% for the 0, 30, 50, 100% peas and canola meal diets, respectively. The actual RUP contents of the five diets were 17.5, 19.0, 19.9, 21.5%, and 22.5%, for the 0, 30, 50, 100% peas and canola meal diets, respectively. The RUP content of the five diets all met the requirements as determined by NRC (1996). The RUP contents were not a limiting factor for the backgrounding cattle with 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 0, 30, 50, 100% peas and canola meal diets, respectively, while the actual RDP supplied were 82.5, 81.0, 80.1, 78.5, and 77.5% of CP, for the 0, 30, 50, 100% peas and canola meal diets, respectively. Three out of the five diets had lower RDP contents than recommended. In particular, in the diet with 0% peas and the diet with canola meal, the amounts of RDP supplied were 549 and 519 g d^{-1}, lower than the requirement of 630 and 618 g d^{-1} (NRC 1996), which translated into 12.9% and 16.0% lower than the requirements, respectively. Low RDP limits the ruminally synthesized microbial CP supply. This may explain why cattle fed these two diets had lower ADGs. The 50 and 100% peas 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 of the heifers. The amount of RDP supplied by the 30% peas diet was slightly lower (0.7%), while the RUP of the 30% diet was slightly higher (8.4%) than the requirement.

4.4 Conclusions

The RUP contents of the five diets used in the previous feeding trial all met the requirements of backgrounding cattle with the target growth rate of 0.80 kg d^{-1}. The amount of RDP supplied by the 0% peas and canola meal diets was 12.9 and 16.0% lower than the requirements, respectively. This may explain why the 0% peas and canola meal groups had relatively lower ADGs. The 50 and 100% peas diets had 40.2 and 77.7% higher RUP, and 5.2 and 20.5% higher RDP than requirements; though this excess of the RDP and RUP did not lead to increased ADG in the heifers. The RDP supplied by the 30% peas diet was slightly lower (0.7%), while the RUP was slightly higher (8.4%) than the requirement.

Particle size affected the degradation pattern of peas. The slowly degradable fraction and RUP content increased with screen size, the RUP content of P1 was 35.5 and 37.1% lower than that of P2, and P4 ($P < 0.01$). However there was no difference in degradability of CP between P2 and P4 in the present study. Peas should be ground through a 2 mm screen in rumen digestion studies to be comparable with other concentrates study.

Table 4.4. The recommended (R) by NRC (1996), actually supplied (S) crude protein (CP), rumen undegradable protein (RUP) and rumen degradable protein (RUP) contents of five diets. All these were based on diets for cattle with average body weight of 280 kg (starting from 260 kg, ending 300 kg)[z]

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

[z] The starting weight in the previous trial was about 215 kg.

V. General Conclusions

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

This feeding trial showed that peas could be fed to backgrounding cattle. The ADG of the 30% and 100% peas group was 11.1 and 15.3% higher than the 0% peas 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 0, 30, 50, to 100% peas; 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 100% peas group than for the 0, 30, and 50% peas groups. Feeding the 100% peas diet also tended to be more expensive than the canola diet. It is feasible to feed 30 or 50% peas 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 backgrounding cattle feeding. The RUP supplied by the five diets was 17.5, 19.0, 19.9, 21.5, and 22.5% of CP for the 0, 30, 50, 100% peas and canola meal diets, respectively. The RUP content of all five diets met the requirements of backgrounding cattle with the target ADG of 0.80 kg d^{-1} as determined by NRC. However, the total protein supplied by the 0% pea diet (9.5%) was lower than required (10.7%), and the amounts of RDP supplied by the 0% peas and canola meal diets were 12.9 and 16.0% lower than the requirements, respectively. The 50 and 100% peas diets supplied 40.2 and 77.7% higher RUP, 5.2 and 20.5% higher RDP than requirements. The

RDP supplied by the 30% pea diet was slight lower than the requirement, while the RUP of the 30% pea diet was slightly higher than the requirement.

The particle size has 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, peas 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 best adapted; nitrogen fixing of peas as a legume crop benefits both the pea and succeeding crop; and also the economic advantage for raw materials produced locally, which could reduce the cost of transportation.

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