Milk Production and Intake of Lactating Cows Fed Raw or Extruded Peas[1]

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ABSTRACT

Primiparous (n = 9) and multiparous (n = 18) Holstein cows averaging 584 ± 15 kg of body weight ($\overline{X}$ ± SE) were allotted at 2 wk postpartum to nine groups (3 primiparous and 6 multiparous) of 3 cows each to determine the effects of pea extrusion on ruminal degradability and milk production. Cows were fed a total mixed diet based on timothy silage and concentrate for ad libitum intake. The experiment was carried out between wk 4 and 15 of lactation. Cows within each group were assigned randomly to isonitrogenous and isoenergetic concentrates based on corn plus soybean meal, raw peas, or extruded peas. Extrusion of peas increased the ruminal degradability of starch but had no effect on the ruminal degradability of crude protein. Cows fed extruded peas had higher dry matter intakes and plasma urea N concentrations than did those fed soybean meal; no differences were detected between cows fed extruded and raw peas. Production of 4% fat-corrected milk and milk composition generally were similar for cows fed the various diets. Digestibilities of dry matter and N were higher for cows fed extruded peas than for cows fed soybean meal or raw peas. These data suggest that peas can substitute for soybean meal as the protein source in diets of early lactation cows without adverse effects on production and that, in this study, the extrusion of peas had no beneficial effect on milk production.
(**Key words**: dairy, extrusion, pea, protein)

Abbreviation key: **EDCP** = effective degradability of CP, **EDDM** = effective degradability of DM, **EDST** = effective degradability of starch, **EXT** = extruded, **SBM** = soybean meal.

INTRODUCTION

Peas (*Pisum sativum*) appear to be a good feed for lactating cows because of their relatively high protein (24%) and starch (48%) contents. Soybean meal (**SBM**) was substituted completely by peas in the diets of late lactation dairy cows averaging 22 kg/d of milk (13), and SBM was replaced by 25% peas in the diets of early lactation cows averaging 34 kg/d of milk (6). Moreover, Valentine and Bartsch (29) found that milk production was higher for early lactation cows fed peas than for those same cows fed barley (18.9 vs. 18.0 kg/d). Degradability of protein from peas is about 78% (16), suggesting that peas should not replace all of the supplemental protein and may not adequately meet RUP requirements of high producing lactating cows.

Extrusion of peas decreases RDP and ruminal NH_3 N concentrations and increases the amount of microbial N that reaches the small intestine (31), thus increasing microbial protein synthesis (8). Extrusion of lupin seeds has no effect on total tract digestibility of CP and fiber but shifts the digestion of those nutrients from the rumen to the lower gastrointestinal tract (14). No information was found on the use of extruded peas in the diets of high producing cows. Therefore, the objectives of this experiment were to determine the effects of the extrusion of peas on ruminal degradability of CP and starch, milk production and composition, feed intake, digestion, and blood parameters of early lactation cows fed a total mixed diet based on grass silage.

MATERIALS AND METHODS

Cows

At 2 wk postpartum, 27 Holstein cows from the Dairy and Swine Research and Development Centre (Lennoxville, QC, Canada), averaging 584 ± 15 kg of

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TABLE 1. Chemical composition of feed ingredients.[1]

Item	Grass silage	Corn	Soybean meal	Extruded peas	Raw peas
pH	5.2	. . .	. . .	. . .	. . .
DM, %	23.2	86.3	91.1	93.0	89.0
ADF, % of DM	40.7	3.0	5.2	5.9	7.2
NDF, % of DM	63.2	11.3	8.4	9.1	14.2
Gross energy, kcal/g of DM	4.19	4.46	4.67	4.52	4.59
CP, % of DM	15.5	9.5	51.9	28.1	28.1
Protein N, % of N	57.8	86.0	96.1	92.7	89.1
NH_3 N, % of N	17.0	. . .	. . .	. . .	. . .
Lactic acid, % of DM	0.97	. . .	. . .	. . .	. . .
Acetic acid, % of DM	0.34	. . .	. . .	. . .	. . .
Propionic acid, % of DM	0.06	. . .	. . .	. . .	. . .
Isobutyric acid, % of DM	0.02	. . .	. . .	. . .	. . .
Butyric acid, % of DM	0.17	. . .	. . .	. . .	. . .
Valeric acid, % of DM	0.03	. . .	. . .	. . .	. . .

[1]Mean of seven monthly samples that were prepared by compositing weekly samples.

BW ($\overline{X} \pm SE$), were assigned to nine groups (three primiparous and six multiparous) of 3 cows each. Cows were blocked within parity for similar calving dates. Cows within groups were assigned randomly to one of three diets. The experiment was carried out from wk 4 to 15 of lactation. Cows were housed in tie stalls, fed individually, and milked twice daily at 0545 and 1645 h. Milk production was recorded at every milking. Milk samples were obtained weekly from each cow for two consecutive milkings and were analyzed separately to determine milk composition. Cows were weighed weekly.

Diets

All cows were treated and fed similarly before calving. After parturition and prior to the start of the experiment, all cows received for ad libitum intake a total mixed diet based on grass silage, cracked corn, SBM, vitamins, and minerals to meet NRC (16) requirements. The diet was formulated for cows at a mean of 600 kg of BW producing 37 kg/d of milk with 3.6% fat. Milk production and composition during wk 2 of lactation were used as covariants.

Cows were introduced gradually to the experimental diets over a 7-d period starting at wk 3 postpartum. All cows received a total mixed diet based on grass silage and concentrate for ad libitum intake (Table 1). The grass was harvested at the boot stage with a cylinder-type forage harvester (New Holland 782; New Holland Corp., New Holland, PA) at a theoretical length of cut of 10 mm from the primary growth of a stand of mostly timothy (>80% *Phleum pratense*). The chopped material was wilted to approximately 24% DM and ensiled for 1 d as a long stack without preservative and without compaction. The entire mass of forage was completely sealed with two 40- × 9.5-m polyethelene sheets on a concrete pad. The three experimental diets (Table 2) consisted of concentrate based on cracked corn and SBM, cracked corn and raw peas, or cracked corn and extruded (**EXT**) peas. Peas (*Pisum sativum*) were ground

TABLE 2. Ingredient and nutrient composition of the three total mixed diets.

	Diet		
Composition	Soybean meal	Raw peas	Extruded peas
Ingredient, % of DM			
Grass silage	43.0	40.2	40.2
Corn	46.4	33.6	33.6
Soybean meal	8.2	3.5	3.5
Peas	. . .	20.2	. . .
Extruded peas	. . .	. . .	20.2
$CaCO_3$	1.0	1.1	1.1
Mineral and vitamin mixture[1]	1.3	1.3	1.3
MgO	0.1	0.1	0.1
Nutrient[2]			
DM, %	35.0	36.5	37.9
CP, % of DM	16.4	16.9	14.9
Protein N, % of N	73.1	72.2	84.3
NDF, % of DM	42.1	40.3	36.7
ADF, % of DM	25.0	23.4	21.8
Gross energy, kcal/g of DM	4.12	3.98	3.94
Ca, % of DM	0.73	0.74	0.66
P, % of DM	0.57	0.57	0.57
Mg, % of DM	0.36	0.35	0.32

[1]Contained 3.0% Ca, 9.0% P, 6.0% Mg, 16.0% Na, 1.8% S, 1.5% K, 40.0% NaCl, 3400 mg/kg of Zn, 125 mg/kg of I, 50 mg/kg of Co, 3200 mg/kg of Mn, 620 mg/kg of Cu, 4000 mg/kg of Fe, 25 mg/kg of Se, 300,000 IU/kg of vitamin A, 100,000 IU/kg of vitamin D, and 3000 IU/kg of vitamin E.

[2]Mean of seven monthly samples that were prepared by compositing weekly samples.

through a 6.3-mm screen and processed in a single-screw extruder (model 2000R; Instapro International Ltd., Des Moines, IA) without an external source of heat or humidity at an exit temperature of 140°C. Screw speed was 550 rpm, and the die diameter was 9.5 mm. Residence time and extrusion rate averaged 30 s and 800 kg/h, respectively. The SBM was added at 15% of the total pea mixture during the extrusion process to ease product passage in the extruder. The same percentage of EXT SBM was added to raw peas. The SBM added to the pea diet was extruded under conditions that were similar to those described for the pea mixture. The three experimental diets were designed to yield similar CP and NE_L concentrations and were formulated to meet requirements for cows that were a mean of 600 kg of BW and produced 37 kg/d of milk with 3.6% fat. Feed consumption was recorded daily. Diets were fed twice daily to yield 10% orts. Composition of the orts was considered to be the same as that of the total mixed diet offered. Silage DM was analyzed weekly to adjust the total mixed diets. Feed ingredients were sampled weekly, frozen, and composited on a 4-wk basis. Composited samples were mixed thoroughly and subsampled for chemical analyses.

Blood Sampling

Blood was collected from all cows at wk 8 and 12 postpartum at 1 h before the morning feeding to give a basal value and at 3 h postfeeding. The postfeeding sampling time of 3 h was chosen because ruminal NH_3 N concentrations usually peaked 2 to 3 h after feeding (4) and because there is no interaction between sampling time and treatment for blood urea of cows fed diets based on silage (18). Blood was withdrawn from the coccygeal vein into vacutainer tubes (Becton Dickinson and Cie, Rutherford, NJ) that contained no preservative to determine total protein and urea concentrations in serum and into vacutainer tubes containing EDTA to determine VFA and NEFA concentrations in plasma. Serum and plasma were separated and frozen at –20°C for subsequent analysis.

Digestibility, N Balance, and Ruminal Degradability

Total feces, urine, and milk were collected from each of the 27 cows during wk 11 of lactation for 6 d. Feces were collected from a rubber mat placed behind the cows and were stored in plastic containers. Daily feces were weighed and mixed thoroughly. A 10% subsample was taken and stored at –15°C for subsequent drying at 55°C. Total urine was collected in stainless steel containers via a Gooch tube (BF Goodrich Co., Kitchener, ON, Canada) attached to the cow with a nylon netting covered with neoprene (Spall Bowan Ltd., Guelph, ON, Canada) affixed to the vulva. A 1% daily subsample was taken and kept frozen until analysis. Urine was acidified daily with 100 ml of 10*N* H_2SO_4. Milk samples were obtained from each cow for 12 consecutive milkings and were analyzed for N to calculate N balance.

Ruminal degradability of DM, CP, and starch of raw and EXT peas was determined according to the procedure described by Petit and Tremblay (19), except that times of incubation were 0, 2, 4, 6, 8, 12, 24, 48, 72, and 96 h. Two dry multiparous cows, which were not part of the experimental group of cows, were fed timothy hay twice daily (0700 and 1300 h) for ad libitum intake. The hay was supplemented once daily with 1 kg of rolled corn and minerals. Duplicate bags of each test feed were incubated in each cow at each time period. Peas were cracked (as fed) or ground through a 1-mm Wiley mill and incubated in the nylon bags to determine the effect of particle size on degradability. Degradation of DM, CP, and starch was calculated using the equation of Ørskov and McDonald (17):

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

where p = percentage of disappearance at time t; a = intercept representing the portion of DM, CP, or starch solubilized at time 0; b = fraction of DM, CP, or starch that is potentially degradable in the rumen; c = rate constant of disappearance of fraction b; and t = time of incubation. The nonlinear parameters a, b, and c were estimated by an iterative least squares procedure (25), and best fit values were chosen with the Secant method (DUD) using the convergence criterion (10^{-8}) of SAS (25). The effective degradability of DM (**EDDM**), CP (**EDCP**), or starch (**EDST**) was calculated using the following equation (17):

$$\text{EDDM, EDCP, or EDST} = a + [bc/(c + k)]$$

where k = estimated rate of outflow from the rumen, and a, b, and c = parameters described previously. The EDDM, EDCP, and EDST were estimated for each ingredient assuming outflow rates of 8%/h.

Chemical Analyses

Dry matter and pH of grass silages were determined according to the methods of Dewar and

McDonald (7) and Playne and McDonald (21), respectively. Dry matter of other feed ingredients was obtained by drying at 100°C for 48 h. Concentrations of D- and L-lactate in silages were determined according to the methods of Gawehn and Bergmeyer (9) and Gutmann and Wahlefeld (10), respectively, with the following modifications: 3 ml of hydrazine-glycine buffer with NAD were mixed with 60 μl of silage extract (2 g of fresh silage mixed with 20 ml of 0.1*N* HCl kept at 21°C overnight). Readings were taken at 340 nm (blank); then, 25 μl of D-L lactate dehydrogenase solution were added, and samples were sealed and left at 21°C for 1 h before reading at the same wavelength. Silage VFA were determined by gas chromatography (Varian model 3400; Varian Canada, Inc., Ville St-Laurent, QC, Canada) on an aliquot of the deproteinized extract using 2-ethylbutyric acid as the internal standard. Silage and ingredient samples were digested with sulfuric acid and selenous acid (12). Phosphorus was determined with inductively coupled plasma spectroscopy (model 6500 XR; Perkins Elmer, Norwalk, CT), and Ca and Mg were determined by atomic absorption (Varian model spectrAA-30; Varian Canada, Inc.). Protein N of silage was analyzed using an acidified extract (20 g of fresh sample in 200 ml of 0.01*N* HCl agitated at 21°C for 22 h) and deproteinized with TCA (27). Determinations of N (N, protein N, and NH_3 N) were done by the Kjeldahl method (1). Concentrations of NDF and ADF were measured according to the nonsequential procedures of Van Soest et al. (30). Gross energy of wet silages, wet feces, and wet urine was measured with an adiabatic bomb calorimeter (model 1241; Parr Instrument Co., Moline, IL). Starch in ingredients (kit 207748; Boehringer Manheim, Dorval, QC, Canada), total protein in serum (kit 690, Sigma, Toronto, ON, Canada), and plasma NEFA (kit 99075401; Wako Pure Chemical Industries, Osaka, Japan) were analyzed by colorimetric methods. Nitrogen, fat, and lactose in milk were determined by infrared spectroscopy (Bentley 2000; Bentley Instrument, Inc., Chaska, MN). Milk urea N was analyzed according to the methods of Broderick (3).

Statistical Analysis

All results were subjected to ANOVA using the general linear models procedure of SAS (25). Milk production and composition measured during wk 2 of lactation were used as covariants. Data on production were analyzed as a randomized block design: covariant, treatment, block, and the interaction of treatment and block were sources of variation in the model. Data on blood composition were analyzed as repeated measurements across time (23). Main effect and interaction included in the model were the same as those for production data except that covariant was not a source of variation. Sums of squares for treatments were partitioned to provide contrasts that compared the diet containing SBM with the diet containing EXT peas and the diet containing raw peas with the diet containing EXT peas. Data for predicted a, b, and c values and data for EDDM, EDCP, and EDST were analyzed by the general linear models procedure of SAS (25) as a 2 × 2 factorial design; cows served as replicates. Sums of squares for treatments were partitioned to provide contrasts that compared 1) EXT peas versus raw peas, 2) ground peas versus cracked peas, and 3) the interaction of extrusion and particle size. Significance was declared at $P < 0.05$ unless otherwise stated.

RESULTS AND DISCUSSION

An interaction between extrusion and particle size for the readily soluble fractions and the potentially degradable fractions of DM, CP, and starch was detected (Table 3). Extrusion increased the readily soluble fractions, and the increase was greater for ground peas than for cracked peas. This result was paralleled by a decrease in the potentially degradable fractions, which were greater for ground peas than for cracked peas. Particle size had no effect ($P > 0.10$) on the rate of disappearance of DM, CP, and starch. The EDDM and EDCP were not affected by particle size, but starch of ground peas tended ($P = 0.08$) to be more degraded than starch of cracked peas. In general, the response to extrusion was similar for ground and cracked peas, although the response was greater for ground peas in some cases.

Extrusion had no effect on the rate of DM disappearance but tended ($P = 0.07$) to increase EDDM (Table 3). This result agrees with results of Focant et al. (8) who reported that in vitro DM degradability of peas after 6 h of incubation with ruminal fluid was increased by extrusion. However, Walhain et al. (31) found that extrusion at 140°C had no effect on the rapidly soluble fraction of DM of peas but decreased the slowly degradable fraction and increased the rate of DM disappearance with no effect on EDDM. Discrepancies between the responses to extrusion could be the result of different temperatures; Focant et al. (8) did not specify what temperature was used.

Extrusion tended ($P = 0.06$) to increase the rate of CP disappearance but had no effect on EDCP. This result is in agreement with results of Clinquart et al. (5) who reported no effect of extrusion on the EDCP of peas mixed with 20% rapeseed. However, Focant et al. (8) and Walhain et al. (31) reported that extrusion significantly reduced the EDCP of peas. Extrusion increased the rate of disappearance of starch and EDST as reported by Walhain et al. (31), suggesting that extrusion was effective in gelatinizing the starch of peas. The increase in EDDM (P = 0.07), therefore, reflected the increase in EDST because extrusion had no effect on EDCP. The EDST tended (P = 0.08) to be greater for ground peas than for cracked peas, probably as a result of the greater surface area availability for microbial attachment to particles.

Cows fed diets containing EXT peas tended (P = 0.11) to have higher DMI, expressed in kilograms per day, than did cows fed diets containing SBM, and the difference was significant when DMI was expressed as a percentage of BW (Table 4). The percentage of NDF in the total mixed diet was higher for diets containing SBM than for diets containing EXT peas (Table 2), which could partly explain the decrease in DMI for cows fed SBM compared with those fed EXT peas. Dry matter intake can be inversely related to NDF content of the diet (26). However, DMI of cows fed raw or EXT peas were similar, although the percentage of NDF was higher for the diet containing raw peas because of the higher NDF content in raw peas than in EXT peas (Table 1), which could result in a difference in the partitioning of fiber components following extrusion. According to Walhain et al. (31), extrusion decreases the fiber content of peas by increasing the proportion of soluble dietary fiber by solubilization or by destroying pectic substances and hemicelluloses.

The lack of difference in DMI between cows fed raw or EXT peas agrees with the fact that extrusion of canola seeds or full fat soybeans had no effect on the DMI of beef steers (24). Diet had no effect on BW at wk 4 and 15 or on BW change (Table 4). However, cows fed EXT peas tended (P = 0.15) to gain more BW than did cows fed SBM because of higher DMI.

Production of milk and 4% FCM was similar among cows fed the various diets (Table 5), and response to the experimental diets was similar for primiparous and multiparous cows (data not shown). This result agrees with the results of Hoden et al. (11), although those researchers reported that cows (80% primiparous) producing >31.3 kg/d of milk had lower milk production when fed peas than when fed cereal grains, suggesting that peas were not suitable for high producing or primiparous cows. This relationship was not observed in the present experiment, and milk production was similar for cows fed the various experimental diets when the cows were producing >32 kg/d in early lactation (data not shown). Corbett et al. (6) found that early lactation cows fed a concentrate with 25% field peas had higher 4% FCM produc-

TABLE 3. Effect of extrusion and particle size on ruminal degradability of nutrients from peas.[1]

	Extruded peas		Raw peas			P<[2]		
Item[3]	Ground	Cracked	Ground	Cracked	SEM	EX	PS	EXPS
DM								
a	59.8[a]	55.0[b]	54.1[b]	42.0[c]	2.5	0.0001	0.0001	0.002
b	40.2[d]	44.8[c]	48.2[b]	59.0[a]	2.6	0.0001	0.0001	0.002
c	12.4	15.0	11.7	13.8	0.7	0.48	0.13	0.86
EDDM	88.5	88.6	87.8	85.2	0.6	0.07	0.21	0.18
CP								
a	59.9[a]	55.8[b]	59.4[a]	48.5[c]	1.7	0.003	0.0003	0.005
b	40.7[c]	44.9[b]	42.8[b]	55.4[a]	2.2	0.005	0.0018	0.02
c	16.4	16.4	14.3	13.4	0.6	0.06	0.65	0.67
EDCP	91.1	90.2	91.1	88.9	0.5	0.56	0.20	0.54
Starch								
a	66.1[a]	57.4[b]	54.9[c]	41.8[d]	3.3	0.0001	0.0001	0.01
b	33.9[d]	42.4[c]	48.3[b]	59.9[a]	3.6	0.0001	0.0001	0.04
c	29.7	36.1	13.6	15.3	3.7	0.002	0.22	0.45
EDST	95.1	94.6	90.3	86.7	1.3	0.002	0.08	0.15

[a,b,c,d]Means within a row with no common superscripts differ (P < 0.05).

[1]Least squares means with pooled standard errors (n = 2 cows per treatment).

[2]EX = Extrusion main effect, PS = particle size main effect, and EXPS = interaction of EX and PS.

[3]a = Percentage of DM, CP, or starch solubilized at the initiation of the incubation; b = percentage of DM, CP, or starch potentially degradable in the rumen; c = rate constant (percentage per hour) of disappearance of fraction b; EDDM = effective degradability of DM; EDCP = effective degradability of CP; and EDST = effective degradability of starch, calculated at a solid outflow rate of 8%/h.

TABLE 4. Dry matter intake and BW of Holstein cows fed between wk 4 and 15 of lactation a total mixed diet containing a concentrate of cracked corn plus soybean meal (SBM), raw peas, or extruded (EXT) peas.[1]

	Diet				Contrast	
Item	SBM	Raw peas	EXT Peas	SE	SBM vs. EXT Peas	Raw peas vs. EXT Peas
					P	
DMI, kg/d	19.1	20.6	20.3	0.3	0.11	0.70
DMI, % of BW	3.19	3.51	3.55	0.07	0.04	0.82
ADF, % of DMI	25.0	23.4	22.6	0.1	0.001	0.0001
BW, kg						
wk 4	601	578	567	11	0.22	0.69
wk 15	606	592	590	10	0.49	0.92
BW Change, g/d	70	170	270	60	0.15	0.47

[1]Least squares means with pooled standard errors.

tion and higher milk fat percentage than did those fed SBM and canola meal as the primary protein sources (31.3 vs. 29.7 kg/d). However, Corbett et al. (6) found no difference in 4% FCM production for cows in mid or late lactation. According to Corbett et al. (6), the lower rate of degradation of the nonstructural carbohydrates in peas than in barley maintains a more stable ruminal pH and potentially increases the acetate to propionate ratio, thus increasing milk fat percentage. In the present experiment, concentrates were based on corn, which is less degradable than barley (15). Therefore, the difference in ruminal degradability of the nonstructural carbohydrates in peas and corn would be less important than that between peas and barley. Khorasani et al. (13) reported a similar milk fat content for midlactation cows fed peas or SBM as protein sources.

Cows fed EXT peas tended to have higher protein percentages in milk than did cows fed SBM (P = 0.06) or raw peas (P = 0.07). Higher N digestibility (Table 6) also was observed for cows fed EXT peas than for those fed SBM or raw peas, which could have contributed to the increased amount of N available for milk protein secretion. Benchaar et al. (2) reported that extrusion of whole horse beans increased amino acid flow to the duodenum and increased disappearance in the small intestine, which increased the availability of amino acids for milk protein secretion. Milk

TABLE 5. Milk production and composition (adjusted for covariants) of Holstein cows fed between wk 4 and 15 of lactation a total mixed diet containing a concentrate of cracked corn plus soybean meal (SBM), raw peas, or extruded (EXT) peas.[1]

	Diet				Contrast	
Item	SBM	Raw peas	EXT Peas	SE	SBM vs. EXT Peas	Raw peas vs. EXT peas
					P	
Milk production, kg/d	33.8	34.3	33.6	0.4	0.84	0.50
4% FCM, kg/d	31.1	30.6	30.0	0.5	0.42	0.68
Milk composition, %						
Fat	3.74	3.59	3.62	0.05	0.37	0.75
Protein	2.96	2.97	3.06	0.02	0.06	0.07
Lactose	4.74	4.70	4.68	0.02	0.24	0.71
Milk urea N, m*M*	3.1	3.7	3.9	0.1	0.006	0.41
Milk component production, kg/d						
Fat	1.24	1.23	1.19	0.02	0.34	0.55
Protein	0.98	1.01	1.02	0.01	0.27	0.73
Lactose	1.59	1.62	1.56	0.02	0.58	0.21
Milk efficiency, kg of FCM/kg of DMI	1.58	1.54	1.47	0.02	0.04	0.19

[1]Least squares means with pooled standard errors.

TABLE 6. Apparent total tract digestibility and N balance for lactating Holstein cows fed between wk 4 and 15 of lactation a total mixed diet containing a concentrate of cracked corn plus soybean meal (SBM), raw peas, or extruded (EXT) peas.[1]

	Diet				Contrast	
Item	SBM	Raw peas	EXT Peas	SE	SBM vs. EXT Peas	Raw peas vs. EXT peas
					P	
Apparent digestibility, %						
DM	65.3	67.2	70.0	0.4	0.0001	0.009
N	61.7	64.2	69.8	0.5	0.0001	0.0003
Energy	63.2	62.5	64.2	1.0	0.18	0.46
ADF	65.6	66.2	65.0	0.5	0.64	0.38
NDF	62.7	64.3	63.0	0.6	0.86	0.33
N Balance, g/d						
N Intake	515	559	597	16	0.003	0.118
Feces	196	201	181	4	0.12	0.04
Urine	148	194	180	5	0.02	0.24
Milk	162	181	166	5	0.75	0.26
N Retained	9	–17	70	13	0.004	0.002

[1]Least squares means with pooled standard errors.

urea N content, which gives an indication of the efficiency of microbial utilization of energy (3) and protein, was higher for cows fed EXT peas, indicating that microbial utilization of energy and protein was lower than that when cows were fed SBM. There was no difference in milk urea N content between cows fed EXT peas and those fed raw peas. Production of milk fat, protein, and lactose was not affected by diet. Milk efficiency, expressed as production of 4% FCM (kilograms per day)/DMI (kilograms per day), was higher for cows fed SBM than for cows fed EXT peas, and there was no difference between cows fed raw peas and those fed EXT peas. Differences in milk efficiency reflected differences in DMI because milk production was similar for cows fed all diets.

Digestibilities of DM and N were higher for cows fed EXT peas than for those fed SBM and raw peas (Table 6). Similar effects of extrusion were reported by Benchaar et al. (2) for whole horse beans. Moreover, Kibelolaud et al. (14) reported that extrusion of white lupin seeds shifted the digestion of CP and fiber from the rumen to the lower gastrointestinal tract, causing little effect on whole tract digestibility when using the mobile nylon bag technique. Excretion of N in feces was lower for cows fed EXT peas than for cows fed SBM and raw peas ($P = 0.12$ and 0.04, respectively).

Excretion of N in urine was higher for cows fed EXT peas than for those fed SBM but was not different from cows fed raw peas (Table 6). Similar differences among treatments were observed for mean values of plasma urea N concentrations (Table 7). Greater ruminal degradability of N for peas than for SBM (16) would result in higher intake of degradable CP, increased concentrations of ruminal NH_3 N and blood urea (18), and greater N excretion in urine for cows fed peas than for cows fed SBM. Plasma urea N concentration increased after feeding, and the increase was greater for cows fed SBM than for those fed EXT peas, which resulted in an interaction ($P = 0.05$) between treatment and time of blood sampling. Petit and Tremblay (20) reported that the rapidly soluble fraction of CP of a concentrate similar to the concentrate containing SBM was about 65%, which is greater than the 55.8% value observed for EXT peas (Table 3). Therefore, a greater rapidly soluble fraction of CP could result in greater increases in ruminal NH_3 concentration, which in turn could result in higher plasma urea concentration in the first fews hours postfeeding. Song and Kennelly (28) already reported a close relationship between blood urea N and ruminal NH_3 N concentrations.

Serum urea concentration was not different between cows fed raw peas and those fed EXT peas, probably because there was little difference in EDCP between the diets (Table 3). Serum urea concentrations were higher for cows fed EXT peas than for those fed SBM. Differences in serum urea concentrations among cows fed the experimental diets were similar to those observed for milk urea concentrations. Serum urea concentration was higher during wk 8 than during wk 15. No effect of treatment was detected on serum total protein concentration (Table 7). During wk 8, serum total protein concentration decreased after feeding and increased during wk 15, resulting in an interaction of time of blood sampling and week.

Plasma NEFA concentrations decreased more rapidly after feeding for cows fed SBM than for cows fed EXT peas, which resulted in an interaction of treatment and time of blood sampling. Concentrations of NEFA in blood have been considered to be an index of body fat mobilization (22); higher NEFA for cows fed SBM than for those fed EXT peas could have resulted from the lower DMI of cows fed SBM (Table 4), which also resulted in better milk efficiency (Table 5). Cows fed EXT peas and raw peas had similar plasma NEFA concentrations, probably because there was no difference in DMI, BW change (Table 4), and milk production (Table 5).

CONCLUSIONS

The extrusion of peas increased ruminal degradability of starch but had no effect on RDP. Cows fed EXT peas had higher DMI than did those fed SBM, but there was no difference between EXT and raw peas. Production of 4% FCM and milk composition were similar for cows fed the various diets, although cows fed EXT peas tended ($P < 0.10$) to have greater milk protein percentages than did cows fed the other two diets. Digestibilities of DM and N were higher for

TABLE 7. Blood composition of Holstein cows fed between wk 4 and 15 of lactation a total mixed diet containing a concentrate of cracked corn plus soybean meal (SBM), raw peas, or extruded (EXT) peas.[1]

Lactation and sampling times	Total protein	Urea N	NEFA
	(mg/dl)		(μeq/L)
	SBM		
8 wk			
1 h Prefeeding	89.2	11.7	173.5
2 h Postfeeding	88.1	13.5	107.1
15 wk			
1 h Prefeeding	91.5	10.9	219.2
2 h Postfeeding	92.4	13.2	138.1
	Raw peas		
8 wk			
1 h Prefeeding	84.8	15.1	197.2
2 h Postfeeding	83.9	15.2	131.1
15 wk			
1 h Prefeeding	87.2	12.6	162.0
2 h Postfeeding	87.4	14.1	116.8
	EXT peas		
8 wk			
1 h Prefeeding	85.8	15.3	148.8
2 h Postfeeding	84.4	16.4	123.3
15 wk			
1 h Prefeeding	89.0	13.5	162.2
2 h Postfeeding	90.8	14.3	114.1
SE	0.8	0.4	8.7
	P		
Effect			
Treatment			
SBM vs. EXT Peas	0.81	0.0007	0.20
Raw peas vs. EXT peas	0.66	0.30	0.40
Week	0.0001	0.002	0.63
Treatment × week			
SBM vs. EXT Peas × week	0.35	0.18	0.18
Raw peas vs. EXT peas × week	0.26	0.86	0.32
Time of blood sampling (TBS)	0.85	0.0001	0.0001
Treatment × TBS			
SBM vs. EXT Peas × TBS	0.81	0.05	0.04
Raw peas vs. EXT peas × TBS	0.65	0.76	0.30
TBS × Week	0.03	0.21	0.71
Treatment × week × TBS	0.72	0.32	0.44

[1]Least squares means with pooled standard errors.

cows fed EXT peas than for cows fed SBM and raw peas. Serum urea concentrations were higher for cows fed EXT peas than for those fed SBM, which could reflect differences in the RDP content of the concentrates. Cows fed SBM had higher plasma NEFA concentrations than did cows fed EXT peas, which could have resulted from lower DMI for cows fed SBM and could have resulted in better milk efficiency. These data suggest that SBM can be completely substituted by peas as the protein source in the diet of early lactation cows without any adverse effect on production and that, in this study, extrusion of peas at 140°C had no beneficial effect on milk production.

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