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King Crab Meal in Concentrates for Lactating Cows[1,2]

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ABSTRACT

King crab (*Paralithodes camtschatica*) meal was compared with soybean meal at two percents of concentrate supplementation for lactating cows in a 2^2 factorial feeding experiment with an unsupplemented negative control. All cows were fed the high soybean concentrate wk 5 through 7. Milk production and live weight from this positive control were independent continuous variables for covariance analysis of wk 8 through 16. Silage and concentrates were fed independently. Cows rejected .5 and .2 kg/day of high and low crab concentrates. Milk production was lowest for cows receiving the unsupplemented control and next low for those receiving concentrates supplemented with the smaller amounts of either soybean or crab meal. The linear regression of milk production on time was significant for all concentrates and of weight on time for soybean meal. With certain qualifications king crab meal can be a potential source of supplemental protein in concentrates for lactating cows.

INTRODUCTION

Waste from king crab (*Paralithodes camtschatica*) processing is 75% of the initial catch, and 30% of this can be recovered in processed crab meal (1). Even if environmental constraints permitted continued disposal of this material as point sources of pollution into the tidal waters of Alaska, salvage as a potential source of protein for use in livestock rations would be an alternative.

Limited palatability and large quantities of chitinous material could be serious limitations to crab meal in livestock rations. Richards (15) describes the molecular structure of chitin as similar to that for cellulose, differing only in the substitution of an acetylamine group for the hydroxyl group on carbon-two of the glucose units. Therefore, at least part of the chitinous material in crab meal may be subject to degradation by rumen microorganisms. Chitin digestibility by calves fed blue crab meal varied from 26 to 87% and averaged 66% (13). Patton and Chandler (12) reported 35.7% digestibility for blue crab meal by in vivo rumen fermentation techniques. They concluded (12, 13) that the chitin molecule is a potential energy source and that crab meal could supply some of the crude protein for ruminants when marginal rations were supplemented.

Brundage et al. (2) reported 75, 58, and 62% in vitro disappearance of dry matter, organic matter, and nitrogen from king and tanner crab meals.

EXPERIMENTAL PROCEDURE

Five pelleted concentrates (Table 1) were fed in a 2^2 factorial experimental design with two sources of protein – soybean meal and king crab meal – at two percents of supplementation. An unsupplemented negative control was adjunct to the factorial design to assess the response to protein irrespective of source or percent. Supplemented rations were formulated by replacing a portion of corn in the negative control with either soybean meal or king crab meal. Failure of response to supplementation would imply that the negative control was

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TABLE 1. Ingredient composition of concentrate mixtures.

Ingredients	Mixtures[1] 1	2	3	4	5
	(%)				
Corn	51.4	33.4	42.4	29.7	41.2
Barley	15.0	15.0	15.0	15.0	15.0
Mixed feed oats	10.0	10.0	10.0	10.0	10.0
Beet pulp	15.0	15.0	15.0	15.0	15.0
Molasses	7.0	7.0	7.0	7.0	7.0
Soybean meal	.0	18.0	9.0	.0	.0
Crab meal	.0	.0	.0	22.5	11.0
Monocalcium phosphate	.4	.4	.4	.0	.0
Dicalcium phosphate	.4	.4	.4	.0	.0
Trace mineral salt	.8	.8	.8	.8	.8
Vitamin A	(4400 IU/kg)				
Vitamin D_2	(13200 IU/kg)				

[1] 1)Negative control, 2) high soybean meal, 3) low soybean meal, 4) high crab meal, and 5) low crab meal.

adequate in protein content or that the number of animals in the experiment was inadequate to compare protein sources, percents, and interaction of source with percent.

Thirty multiparous Holstein cows from the University herd were assigned randomly to five concentrates in six complete blocks of five animals at wk 5 of lactation. All were fed high soybean meal during wk 5 through 7 of lactation and one of the five concentrates during the succeeding 9 wk. Milk production or live weight from the 3-wk control were independent continuous variables in the covariance analysis of corresponding data from the 9-wk experimental period.

Milk production during wk 5 through 7 of lactation was extrapolated through wk 8 through 16 according to a hypothetical lactation curve (8). Silage intake was assumed to be 1.5 kg dry matter/100 kg live weight and its energy value to be 2 Mcal of metabolizable energy/kg dry matter. Grain allowances were set to meet National Research Council (NRC) (9) energy requirements for weight maintenance and theoretical milk production in excess of energy supplied by the silage portion of the ration. Feeding according to expectation and not actual performance reduced the possibility of establishing a negative feedback whereby adverse effects of a ration would reduce concentrate allowances and further exacerbate progressive decline in animal performance. All rations should have been adequate in energy, permitting full expression of protein amounts and availability.

Silage, fed ad libitum, and concentrates were weighed and fed twice daily in separate containers to individual animals. Rejected silage and concentrates were weighed once daily and discarded. Feeding silage and concentrates independently permitted maximum selectivity of silage and concentrates by individual animals and provided objective assessments of palatability.

Silage and concentrates were sampled each week for laboratory analysis. Milk production was recorded twice daily, and animals were weighed at the start, on 2 consecutive days each week, and at completion of the 12-wk period.

Silage pH was on fresh samples. Dry matter was Toluene distillation for silage and oven-drying at 110°C for concentrates. Samples were oven-dried at 60°C for all chemical analyses with aliquots oven-dried at 110°C to convert all data to moisture free basis. Cell wall, acid detergent fiber (ADF), lignin, and cellulose measures were according to the procedures of Goering and Van Soest (4). In vitro dry matter disappearance (IVDMD) was measured by two-stage IVDMD of Tilley and Terry (17) as modified by Kansas State University with the use of a phosphate buffer and direct acidification before the second stage (11). Total nitrogen (N) and phosphorus (P) were determined simultaneously by automated continuous flow methodology in an auto analyzer II system (7, 16). Crude protein was total N × 6.25. Calcium (Ca) was determined on acid digest by atomic absorption spectroscopy with lanthanum oxide background. Metabolizable energy (Mcal) was calculated as $[(.99 \times \%\ \text{IVDMD} - 1.01) \times 34.2 + 45.0] \div 1000$ (17, 14).

Mean daily milk production and weight across the 9-wk experimental period were analyzed by Harvey's least-squares and maximum likelihood general purpose (LSMLGP) program (5, 6) with the model:

$$y_{ij} = \mu + b_i + c_j + \beta(s_{ij}) + \epsilon_{ij}$$

where

y_{ij} = datum for the ijth cow receiving the jth concentrate in the ith block
μ = common mean
b_i = effect of the ith block, i = 1 to 6
c_j = effect of the jth concentrate, j = 1 to 5
s_{ij} = datum for the ijth cow during the 3-wk control period, covariable to y_{ij}
ϵ_{ij} = random residual component

Feed intake and nutrient intake and requirement were analyzed by the same model without the $\beta(s_{ij})$ component. The 4 df for concentrate were divided into four orthogonal comparisons: a) negative control, supplemented concentrates; b) soybean meal based concentrates, king crab meal based concentrates; c) high protein, low protein (supplemented concentrates); and d) interaction of protein source with protein percent, b × c.

The linear relationship of milk production and weight with time was analyzed statistically by Harvey's LSMLGP program (5, 6) with the model:

$$y_{ijk} = \mu + b_i + c_j + (bc)_{ij} + (w{:}c)_{kj} + \epsilon_{ijk}$$

where

y_{ijk} = datum for ijth cow receiving the jth concentrate in the ith block during the kth week
μ = common mean
b_i = effect of the ith block, i = 1 to 6
c_j = effect of the jth concentrate, j = 1 to 5
$(bk)_{ij}$ = block by concentrate interaction
$(w{:}c)_{kj}$ = effect of the kth week nested in the jth diet, k = 1 to 9
ϵ_{ijk} = random residual component

Linearity of either milk production or weight over time within the five concentrates was tested by variances attributable to the linear relationship and the residual ($F_{1,207}$). Residual variances were from the least-squares analyses as sums of pure error and lack of fit (linear), by appropriate sums of squares, and degrees of freedom (3).

RESULTS AND DISCUSSION

Chemical analyses for king crab meal, silage, and concentrates are summarized in Table 2.

Data for feed intake and rejection are in Table 3. The concentrates did not affect ($P<.05$) intake of either silage or concentrate or rejection of silage. The rejection of concentrate was affected ($P<.05$) by inclusion of king crab meal. Cows rejected .5 and .2 kg/day of the high and low crab meal concentrates and essentially none of the negative control or soybean meal concentrates.

Metabolizable energy, crude protein, calcium, and phosphorus requirements for maintenance and change of weight and for milk production were estimated from milk production and weight changes and NRC parameters (10). Specific nutrient intakes were calculated from feed intake and laboratory data. Requirements and intakes are in Table 4. Protein, calcium, and phosphorus requirements were not affected ($P<.05$) by concentrates. Protein intake was lower on the negative control ration ($P<.01$) than on the supplemented rations as was predicated by the experimental design. Calcium intake was higher on king crab meal, and all four orthogonal comparisons were significant ($P<.01$). Phosphorus intake was highest on the high king crab meal, and orthogonal comparisons were significant for a) negative control, supplemented concentrates and d) interaction of protein source with protein percent ($P<.05$).

Milk production and weight are summarized in Table 5. Differences in milk production for concentrates were significant; differences in weight were not ($P<.05$). Production was lowest for animals receiving the negative control ($P<.01$) and next low for those receiving

TABLE 2. Chemical analyses of king crab meal, silage, and five concentrates.

Feed	Dry matter	pH	Cell[1] wall	ADF[1]	Lignin[1]	Cellulose[1]	IVDMD	Protein	Ca	P	ME[2]
	(%)		(% Oven dry basis)								(Mcal/kg)
King crab meal	92.8		26.6	19.2	.9	17.9	73.6	40.5	10.40	1.80	2.56
Silage	36.4	4.5	57.3	33.5	5.4	26.0	58.0	10.7	.35	.27	1.99
Concentrates											
Negative control	88.2		21.2	8.5	1.4	5.7	87.8	9.7	.35	.46	2.97
Soybean meal											
High	86.5		21.4	8.7	1.5	6.0	88.3	16.5	.48	.51	3.00
Low	86.3		19.6	7.8	1.7	5.4	88.0	14.9	.46	.54	2.99
Crab meal											
High	88.3		27.2	12.1	1.5	9.8	82.4	17.0	2.81	.65	2.79
Low	88.6		23.5	10.0	1.4	7.8	88.3	13.5	1.98	.51	2.98

[1] Reporting analytical results as cell walls, ADF, lignin, and cellulose does not imply that these specific plant entities are present in King crab meal.

[2] Metabolizable energy was calculated from IVDMD.

TABLE 3. Dry matter intake and refusals.

	Silage		Concentrate	
	Intake	Refused	Intake	Refused*
	(kg)			
Negative control	10.3	1.6	7.6	.03
Soybean meal				
High	10.9	1.5	7.3	.03
Low	11.8	1.5	7.6	.00
Crab meal				
High	10.3	1.5	8.0	.48
Low	11.7	1.5	7.3	.20

	Concentrate refused	
	$\overline{X}$	SE
Linear functions		
a) Negative control, supplemented	−.15	.12
b) Soybean meal, crab	−.32	.11**
c) High, low N	.15	.11
d) Interaction	−.12	.11

*$P<.05$.

**$P<.01$.

concentrates supplemented with the smaller amounts of soybean meal or king crab meal ($P<.10$). The effect of source of protein and interaction of protein source with percent did not approach significance.

The linear relationship of milk production and weight changes within the five concentrates over time are in Table 6 as variances from linearity, and residual variances from departure from linearity and pure error. The linear regression of milk production on time was significant for each of the five concentrates ($P<.01$). Also significant ($P<.01$) was the linear regression of weight on time within groups fed soybean meal. Large variations between cows within groups receiving the negative control and king crab meal relative to the linearity of liveweight changes over time precluded establishment of a significant linear relationship between weight and time on these diets. The groups fed high king crab meal and unsupplemented diets had relatively large quadratic components of regression, 62.1 and 148.5, respectively; those fed low king crab meal had a relatively large cubic component, 124.4.

Regressions of milk production and weight adjusted for production and weight, respectively, during the positive control period are plotted in Figures 1 and 2. For the significant linear relationship between milk production and time within all five diets, Figure 1 provides an approximation of the expected decline in milk production during wk 8 through 16 of lactation when cows are fed under conditions of this experiment. There was a positive response to supplementation of the negative control diet with protein. Although the rate of decline on low king crab was similar to rates for other supplemented rations, milk production was lower. Lower milk production was determined primarily during the 1st wk of the experimental period when mean milk production declined from 28.8 to 24.1 kg/day.

Because of the significant regression of weight on time for cows fed soybean meal, Figure 2 provides an approximation of expected weight gains on these diets during wk 8 through 16 of lactation. Expectations for

TABLE 4. Estimated nutrient balance.

Ration	Energy (Mcal ME/day)		Crude protein (kg/day)		Calcium (g)		Phosphorus (g)	
	Required	Intake	Required	Intake**	Required	Intake**	Required	Intake*
Negative control	41.3	43.2	2.37	1.84	77.8	61.0	55.7	62.3
Soybean meal								
High	47.3	43.6	2.75	2.37	84.9	72.5	60.5	66.9
Low	46.2	46.3	2.69	2.39	85.9	77.1	61.2	73.4
Crab meal								
High	47.6	42.7	2.83	2.46	92.3	259.7	65.5	79.9
Low	44.6	44.9	2.54	2.23	81.1	184.8	58.0	69.5

	Intake					
	Protein		Calcium		Phosphorus	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Linear functions						
a) Negative control, supplemented	−.53	.13**	−87.54	10.97**	−10.11	4.12*
b) Soybean meal, crab	.04	.12	−147.46	9.81**	−4.58	3.69
c) High, low N	.11	.12	35.15	9.81**	1.97	3.69
d) Interaction	−.13	.12	−39.77	9.81**	−8.44	3.69*

*$P<.05$.

**$P<.01$.

TABLE 5. Daily milk production and mean liveweight of cows.

Ration	4% Fat corrected milk (FCM)*	Live weight
	(kg)	
Negative control	20.1	597.7
Soybean meal		
High	23.3	605.3
Low	22.7	605.3
Crab meal		
High	23.4	592.5
Low	21.0	611.6

	4% FCM	
Linear functions	$\overline{X}$	SE
a) Negative control, supplemented	−2.5	.8**
b) Soybean meal, crab	.8	.7
c) High, low N	1.5	.7⁺
d) Interaction	−.8	.7

⁺*P*<.10.

**P*<.05.

***P*<.01.

animals receiving the negative control and king crab meal are ambiguous because of the lack of significant relationships between live weight and time.

With certain qualifications, king crab meal can be a potential source of supplemental protein in concentrates for lactating dairy cows. Although milk production was comparable on concentrates supplemented with either soybean meal or king crab meal and slightly higher at higher supplementation, weight maintenance and gains were inconsistent for cows receiving rations supplemented with the latter. Problems of palatability were evident when king crab meal was included in concentrates. Subjective evaluation of animals on the experiment suggests that milk production may have been maintained at least partially at the expense of weight maintenance and gain by individual cows.

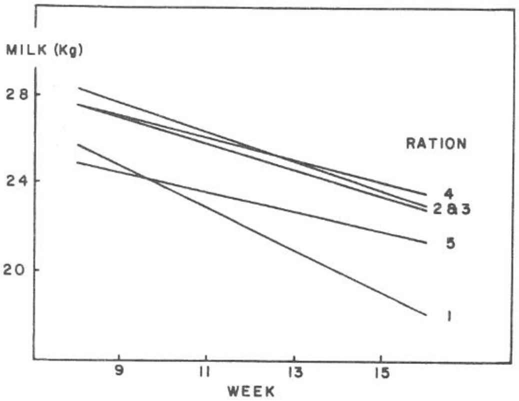

Figure 1. Linear regressions of milk production on week of lactation during wk 8 through 16, adjusted for production during the preliminary period. Rations: 1) unsupplemented negative control (β = −.968); 2) soybean meal, high (β = −.669); 3) soybean meal, low (β = −.586); 4) crab meal, high (β = −.482); and 5) crab meal, low (β = −.438).

TABLE 6. Linear relationship of milk production and live weight to time.

	Variance		Variance	
	Milk production		Live weight	
	Linear	Residual[1]	Linear	Residual[1]
Negative control	344.24**	3.315	216.16	145.24
Soybean meal				
High	121.46**	3.333	2482.1**	145.86
Low	117.85**	3.307	1360.7**	145.49
Crab meal				
High	143.51**	3.322	13.379	145.22
Low	51.92**	3.317	288.10	144.80

***P*<.01.

[1] Pure error and lack of fit (linear); df = 207.

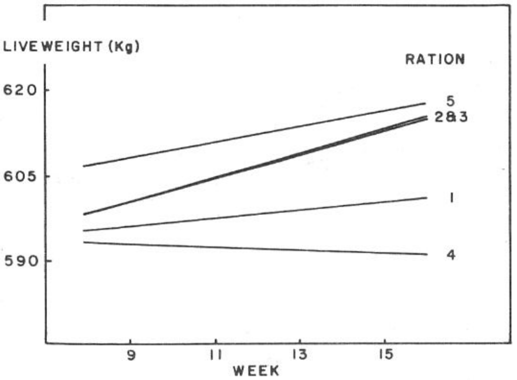

Figure 2. Linear regressions of weight on week of lactation during wk 8 through 16, adjusted for weight during the preliminary period. Rations: 1) unsupplemented negative control (β = .699); 2) soybean meal, high (β = 2.212); 3) soybean meal, low (β = 2.033); 4) crab meal, high (β = −.267); and 5) crab meal, low (β = 1.370).

Crab meals have not been protein supplements in concentrates in the University dairy herd. Results from this experiment reflect this lack of prior exposure to this material. Maximum stress was placed on the possibility of concentrate unpalatability by making no attempt to mask potential problems of palatability. Feeding silages and concentrates in separate receptacles provided optimum opportunities for independent selection and rejection of either silage or concentrate portions of total feed allowance. Qualified success in the use of crab meal suggests the possibility of more successful use in smaller amounts in conjunction with other sources of protein to obtain more acceptable, balanced rations.

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REFERENCES

1 Brundage, A. L., F. M. Husby, and G. L. Beardsley. 1978. King crab meal as a protein source for lactating dairy cows. 29th Alaska Sci. Conf., Univ. Alaska, Fairbanks.

2 Brundage, A. L., F. M. Husby, V. L. Burton, and J. L. Franklin. 1979. Dry matter and nitrogen solubility of Alaska marine waste. J. Dairy Sci. 62(Suppl. 1):135. (Abstr.)

3 Draper, N. R., and H. Smith, Jr. 1966. Applied regression analysis. John Wiley & Sons, Inc., New York, NY.

4 Goering, H. K., and P. J. Van Soest. 1970. Forage fiber analyses (apparatus, reagents, procedures, and some applications). Agric. Handbook No. 379, Agric. Res. Serv., US Dept. Agric.

5 Harvey, W. R. 1975. Least-squares analysis of data with unequal subclass numbers. ARS-H-4, Agric. Res. Serv., US Dept. Agric.

6 Harvey, W. R., and G. Thomson. 1969. Instructions for use of LSMLGP (Least-squares and maximum likelihood general purpose program). Ohio State University.

7 Isaac, R. A., and W. C. Johnson. 1976. Determination of total nitrogen in plant tissue using a block digester. J. Assoc. Off. Agric. Chem. 59:98.

8 Lucus, H. L. 1960. Critical features of good dairy feeding experiments. J. Dairy Sci. 43:193.

9 National Academy of Sciences – National Research Council. 1971. Nutrient requirements of dairy cattle, 4th ed. NAS-NRC Publ., Washington, DC.

10 National Academy of Sciences – National Research Council. 1978. Nutrient requirements of dairy cattle, 5th ed. NAS–NRC Publ., Washington, DC.

11 Meyer, R. M. 1971. Personal communication.

12 Patton, R. S., and P. T. Chandler. 1975. In vivo digestibility evaluation of chitinous materials. J. Dairy Sci. 58:397.

13 Patton, R. S., P. T. Chandler, and O. G. Gonzalez. 1975. Nutritive value of crab meal for young ruminating calves. J. Dairy Sci. 58:404.

14 Reid, J. T. 1969. Personal communication.

15 Richards, A. G. 1953. Chemical and physical properties of cuticle chitin, and its derivatives. K. D. Roeder, ed. Insect physiology. John Wiley & Sons, Inc., New York, NY.

16 Technicon Industrial Methodology. 1976. The simultaneous determination of nitrogen and phosphorus in BD acid digests. Meth. No. 334-74 A/A, Technicon Instr. Corp., Tarrytown, NY.

17 Tilley, J.M.A., and R. A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassl. Soc. 18:104.