Corn Steep Liquor and Fermented Ammoniated Condensed Whey as Protein Sources for Lactating Cows and Yearling Heifers Grazing Winter Native Range

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Story in Brief

Corn steep liquor (CSL) and fermented ammoniated condensed whey (FACW) were compared to cottonseed meal (CSM) as protein sources for wintering 61 lactating first-calf Hereford heifers and 32 yearling Hereford heifers on native range. Cattle were allotted by weight and individually fed 6 days per week for 12 weeks one of four protein treatments: negative control (NC), positive control (PC), CSL and FACW to provide .7, 1.5, 1.5 and 1.5 lb crude protein (CP) per day, respectively, to the lacating heifers and .2, .4, .4 and .4 lb CP per day, respectively, to the yearling heifers. CSM was supplied in the CSL and FACW treatments at the same level as in the negative control. Lactating heifers fed the NC lost more ($P<.005$) weight and body condition (120 lb and 1.6 units) than those fed the PC (45.8 lb and .9 units). Weight and condition losses were similar ($P>.05$) for lactating heifers fed PC, CSL and FACW. Yearling heifers fed the NC lost more ($P<.005$) weight than those fed the PC (49.4 vs 10.6 lb). Yearling heifers fed CSL and FACW gained more ($P<.005$) weight than those fed the PC (17.6 and 9.3 vs −10.6 lb). Feeding CSL resulted in significantly lower rumen pH, lower ruminal acetate and higher ruminal butyrate, isovalerate and caproate levels than did feeding either control. Supplementing with FACW produced significantly lower rumen pH, higher rumen ammonia and soluble carbohydrate levels, lower ruminal acetate, and higher ruminal propionate and butyrate concentrations than did either control supplement. In vitro ammonia concentrations for FACW were similar at 1, 2, 4 and 8 hours incubation and were higher ($P < .05$) than the CSL ammonia concentrations. Ammonia nitrogen, amino acid nitrogen and long chain polypeptide and protein nitrogen accounted for 13.3, 17.0 and 29.6 percent of total nitrogen, respectively, in CSL and 60.0, 7.0 and 13.2 percent of total nitrogen, respectively, in FACW. Corn steep liquor and FACW appear to be effective protein sources for cows and heifers grazing winter native range.

Introduction

Modern liquid supplements contain a variety of by-product ingredients from the sugar, paper or fermentation industries. Corn steep liquor (CSL) is obtained during the wet milling of corn and contains most of the soluble proteins of corn. Fermented ammoniated condensed whey (FACW) is manufactured from liquid whey, a by-product of the cheese industry, and contains ammonium lactate as its primary nitrogen source.

Data comparing CSL and FACW-based liquid supplements to dry, processed oil meal protein supplements for cattle consuming low quality roughages is limited although previous research has shown that CSL and FACW are effective sources of crude protein for feedlot cattle fed corn silage-based rations. The objective of this study was to compare CSL and FACW to cottonseed meal as protein sources for lactating first-calf heifers and yearling heifers grazing winter native range.

Materials and Methods

Sixty-one lactating first-calf Hereford heifers and 32 yearling Hereford heifers were allotted by weight to four supplemental protein treatments. During the 84-day trial lasting from mid-November to mid-February all cattle grazed together in two pastures (220 acres) of native tallgrass range in north central Oklahoma. The predominant forage species were little bluestem, switchgrass, big bluestem and Indian grass.

Cattle were gathered from the pastures at 8:00 a.m. six days each week and fed their supplements individually in covered stalls. Supplement treatments were: negative control (NC), positive control (PC), CSL and FACW to supply .7, 1.5, 1.5 and 1.5 lb CP per day, respectively, to the lactating heifers and .2, .4, .4 and .4 lb CP per day, respectively, to the yearling heifers. Cattle fed the liquid supplements received cottonseed meal to supply equal CP as the negative control. Corn steep liquor or FACW was then fed to make up the difference between the NC and PC. All supplements were formulated to be approximately isocaloric and to provide equal amounts of calcium, phosphorus and potassium. The composition of each supplement is shown in Table 1.

Cattle were weighed after an overnight shrink (16 hr) at 28-day intervals and visually scored for body condition (1 = very thin, 9 = very fat) at the beginning and end of the trial.

Table 1. Percent composition of protein supplements fed to lactating first-calf heifers and yearling heifers

Ingredient	Treatment			
	NC	PC	CSL	FACW
Cottonseed meal	11.5	66.7		
Corn, ground	41.8	30.6		
Sorghum, grain	41.8			
Dicalcium phosphate	3.2	.6		
Limestone	.7	2.2		
Potassium chloride	1.2			
Vitamin A (30,000 Iu/g)	.1	.1	.3	.3
Trace mineral premix[a]	.1	.1	.1	.1
CSL			69.9	
FACW				37.2
Cane molasses			27.4	60.3
Sulfuric acid			1.1	1.0
Analysis (as-fed)				
Dry matter, %	89.8	91.0	53.7	69.0
Crude protein, %	12.9	29.0	16.8	16.0
Total digestible nutrient, %	72.0	72.6	55.0	62.0
pH			4.2	5.0

[a]Ingredients in trace mineral premix, %: Zn, 16.0; Fe, 12.0; Mg, 3.0; Mn, 6.0; Cu, 1.0; Co, .3; I, .6; K, 1.0.

Rumen liquor samples were obtained at 1 and 4 hours postfeeding via stomach tubes on day 49 of the trial from 10 randomly selected first-calf heifers from each treatment. Rumen pH was determined immediately at sampling time. Ruminal fluid was analyzed for ammonia, soluble carbohydrate and volatile fatty acid (VFA) concentrations.

Fermentation in vitro was used to compare the rate of ammonia release from CSL and FACW to the rate of ammonia release from soybean meal (SBM), urea and ammonium lactate (AL).

Corn steep liquor and FACW were analyzed for total nitrogen, ammonia nitrogen, amino acid nitrogen and long chain polypeptide and protein nitrogen. Dry matter and lactic acid concentrations were also determined.

Results and Discussion

The performance of lactating first-calf heifers is shown in Table 2. Heifers fed the NC supplement lost more ($P < .005$) weight and body condition (120 lb and 1.6 units) than those fed the PC (45.8 lb and .9 units). Differences in weight and condition losses between heifers fed the PC, CSL (55.1 lb and .8 units) and FACW (49.6 lb and .7 units) were not significant. Calves of the NC supplemented cattle tended to gain less weight than calves whose dams received PC, CSL or FACW. Differences in conception rates between treatments were not significant. Poorer conception rates for the positive control cattle in both trials were probably a function of low animal numbers per treatment.

Table 2. Performance of lactating first-calf heifers and their calves

Item	Treatment			
	NC	PC	CSL	FACW
Number of pairs	15	15	15	16
Initial cow weight, lb	890.6	884.2	884.2	889.5
Cow weight change, lb	-120.0^a	-45.8^b	-55.1^b	-49.6^b
Initial body condition	6.5	6.4	6.4	6.4
Body condition change	-1.6^a	$-.9^b$	$-.8^b$	$-.7^b$
Initial calf weight, lb	110.2	110.2	118.8	126.7
Calf weight gain, lb	69.9	83.1	76.9	79.3
Conception rate, %	86	60	80	81

[ab]Means with different superscript letters differ ($P < .05$).

The performance of yearling heifers is shown in Table 3. Yearling heifers receiving the NC supplement lost more ($P < .005$) weight than those consuming the PC (49.4 vs 10.6 lb). Weight gains by yearling heifers supplemented with CSL and FACW were similar (17.6 and 9.3 lb, respectively) and greater ($P < .005$) than weight gains of heifers fed the PC (− 10.6 lb). Differences in body condition and conception rates between treatments were not statistically significant.

Lower ruminal pH was observed in cattle fed CSL and FACW than in cattle fed NC and PC (Table 4). Rumen ammonia and soluble carbohydrate levels are also presented in Table 4. At 1 and 4 hours postfeeding, rumen ammonia and soluble carbohydrate levels were highest ($P < .05$) in FACW fed cattle. Rumen ammonia

Table 3. Performance of yearling heifers

Item	Treatment			
	NC	PC	CSL	FACW
Number	8	8	8	8
Initial weight,lb	779.3	768.1	768.3	770.5
Weight change, lb	-49.4^a	-10.6^b	$+17.6^c$	$+9.3^c$
Initial body condition	7.2	7.0	7.2	7.1
Body condition change	−.9	−.7	−.7	−.8
Conception rate, %	83	67	100	100

[abc]Means with different superscript letters differ (P< .05).

Table 4. Ruminal pH and the concentration of ammonia and soluble carbohydrate in rumen fluid collected 1 and 4 hours postfeeding

Item	Treatment			
	NC	PC	CSL	FACW
Number	10	10	10	10
Rumen pH				
1 hr postfeeding	7.07^a	7.24^a	6.73^b	6.79^b
4 hr postfeeding	6.83^b	7.06^a	6.89^b	6.79^b
Rumen ammonia, mg/d1				
1 hr postfeeding	8.4^c	10.5^c	18.9^b	26.2^a
4 hr postfeeding	3.8^c	11.3^b	14.8^b	23.1^a
Rumen soluble				
Carbohydrates, u moles/1				
1 hr postfeeding	1865.6^b	2268.9^b	5016.1^b	17271.1^a
4 hr postfeeding	2144.4^b	1705.0^b	2169.9^b	3703.9^a

[abc]Means in same row with different superscripts differ (P < .05).

concentrations were higher (P < .05) in CSL supplemented cattle than in the NC or PC cattle at 1 hour postfeeding and similar (P > .05) to the ammonia level in the PC cattle at 4 hours postfeeding.

Ruminal VFA concentrations are shown in Table 5. Total VFA concentrations were similar (P > .05) for cattle fed NC, PC, CSL and FACW. Feeding FACW resulted in a lower (P < .05) acetate to propionate ratio than feeding NC, PC or CSL. Rumen fluid from FACW supplemented cattle contained lower (P < .05) acetate and higher (P < .05) propionate and butyrate levels than rumen fluid from NC or PC supplemented cattle. Feeding CSL resulted in higher (P < .05) butyrate and lower (P < .05) acetate levels than did feeding NC and PC. The molar concentrations of isovalerate and coproate were higher (P < .05) in rumen fluid from the CSL treatment.

Table 5. Volatile fatty acid concentration in rumen fluid collected at 1 and 4 hours postfeeding[a]

Item	Treatments			
	NC	PC	CSL	FACW
One hour postfeeding				
Total VFA, u moles/ml	92.42	95.53	93.60	93.88
Acetate	71.90[b]	71.48[b]	69.87[bc]	68.77[c]
Propionate	16.06[c]	16.21[c]	16.76[c]	19.83[b]
Isobutyrate	1.07[b]	1.19[b]	1.13[b]	.28[c]
Butyrate	9.24[c]	8.78[c]	10.74[b]	10.71[b]
Isovalerate	1.07[b]	1.99[b]	1.32[b]	.39[c]
Valerate	.59[b]	.72[b]	.68[b]	.44[c]
Caproate	.08	.07	.05	.02
Acetate/propionate	4.53[b]	4.32[b]	4.38[b]	3.62[c]
Four hours postfeeding				
Total VFA, u moles/ml	93.37	73.63	92.92	83.33
Acetate	71.13[b]	71.76[b]	65.90[c]	61.05[d]
Propionate	15.15[c]	15.85[c]	15.31[c]	17.93[b]
Isobutyrate	1.12[b]	1.23[b]	1.12[b]	.56[c]
Butyrate	10.26[d]	9.36[d]	14.42[c]	18.80[b]
Isovalerate	1.06[c]	.83[c]	1.52[b]	.42[d]
Valerate	1.02	.85	1.34	1.15
Caproate	.26[bc]	.12[cd]	.39[b]	.10[d]
Acetate/propionate	4.74[b]	4.65[b]	4.33[b]	3.54[c]

[a]Molar %.
[bcd]Means in same row with different superscripts differ ($P < .05$).

The in vitro ammonia concentrations are presented in Table 6. Ammonia was released gradually in vitro from SBM and CSL, presumably due to digestion by microbial proteases and the subsequent deamination of amino acids. The concentration of ammonia in the urea system was initially low but rapidly increased due to the hydrolysis of urea to ammonia. The ammonia in AL and FACW apparently established an immediate equilibrium between the disassociated free ammonium ion and the closely associated ammonium salt form.

Table 6. In vitro ammonia concentratiion from nitrogen sources[a]

Nitrogen source	Time of incubation (hr)			
	1	2	4	8
	mg NH_3 — N/dl			
SBM	13.83[b]	15.33[bc]	19.89[bc]	36.83[d]
CSL	23.58[c]	23.23[c]	22.71[bc]	36.00[d]
FACW	42.59[de]	44.51[def]	50.13[ef]	43.86[def]
AL	71.11[g]	71.47[g]	69.16[g]	62.92[g]
Urea	24.38[c]	53.00[f]	71.82[g]	85.33[h]

[a]Nitrogen source by incubation time interaction ($P < .005$).
[bcdefgh]Means with different superscripts differ ($P < .05$).

The percentage of dry matter, lactic acid, crude protein and the composition of crude protein in CSL and FACW is presented in Table 7. The CSL supplement contained 53.74 percent dry matter, 5.6 percent lactic acid and 16.85 percent CP (N×6.25). The nitrogen in CSL was composed of 13.3 percent ammonia nitrogen, 29.6 percent long chain polypeptide and protein nitrogen, and 17.0 percent amino acid nitrogen. The FACW supplement contained 68.95 percent dry matter, 10.2 percent lactic acid and 16.0 percent CP (N 6.25). The nitrogen in FACW was composed of 60.0 percent ammonia nitrogen, 13.2 percent long chain polypeptide and protein nitrogen and 7.0 percent amino acid nitrogen.

Table 7. Dry matter, lactic acid and crude protein composition of CSL and FACW

	Supplement	
Item	CSL	FACW
Dry matter[a]	53.74	68.95
Lactic acid[a]		
L(+) lactate	1.49	3.64
D(−) lactate	4.11	6.56
Total lactate	5.60	10.20
Crude protein (Nx6.25)[a]	16.85	16.00
Protein fractionation[b]		
NH_3 - N	13.3	60.0
Long chain polypeptide and protein N	29.6	13.2
Amino acid N	17.0	7.0
Undetermined N	40.1	20.0

[a]Percent composition, as fed basis.
[b]Percent of total nitrogen.

Greater weight and body condition losses by cattle fed the NC supplement indicated that a protein deficiency was established in the NC cattle. Improved performance by yearling heifers fed either liquid and similar weight and condition losses by lactating heifers fed the PC, CSL and FACW suggest that CSL and FACW are effective protein sources for cattle wintered on native range. Corn steep liquor appears to be a good source of amino acids and natural proteins. The high non-protein nitrogen (NPN) content of FACW is apparently well utilized by cattle grazing low quality forage.