INFLUENCE OF CORN CONDENSED DISTILLERS SOLUBLES (CCDS) ON RATION DIGESTIBILITY, NITROGEN/ENERGY UTILIZATION AND RUMEN FLUID CHARACTERISTICS OF LACTATING DAIRY COWS

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SUMMARY

Digestion and Balance trials were conducted with 18 lactating dairy cows in their 7—8 weeks of lactation, using 7 day total collection to determine nitrogen and energy balance and digestibility of ration nutrients by lactating dairy cows fed three levels (0, 8 and 16%) of corn condensed distillers solubles (CCDS). Cows were fed treatment rations for 4 weeks before collection. Following digestion and balance trials, rumen fluid samples were collected esophagially before feeding and 3 hours after feeding to determine the influence of CCDS on rumen pH, ammonia nitrogen and volatile fatty acids. Corn condensed distilers solubles significantly ($P \angle 0.05$) improved the digestibility of the neutral detergent fiber and ether extract but depressed the digestibility of the ash. Apparent nitrogen retention was significantly ($P \angle 0.05$) lower for animals on 8% CCDS ration. There were no significant differences in energy utilization among groups. Corn condensed distilers soluble did not significantly affect rumen pH, but depressed rumen ammonia nitrogen. On molar percentage basis, animals on the 8% CCDS ration had significantly ($P \angle 0.05$) higher acetate in the rumen 3 hours after feeding. Other VFA remained relatively unaffected by treatments.

INTRODUCTION

The nutritive value of any feedstuff cannot truely be assessed unless that feedstuff is directly fed to animals and its utilization by the animals monitored through digestion and balance trials. With the results of such trials, one would be able to explain the improvement in performance or lack of it of animals fed the feedstuff. For ruminants, especially the diary cows, the study of the rumen fluid constituents has in addition become important as the performance of the animals in terms of growth and milk production is heavily dependent upon the proportions of the various constituents of the rumen fluid.

Condensed distillers solubles (CDS) are one of the primary by-products resulting from the fermentation of cereals for production of whisky or spirit. The whole spent stillage is fractionated into the coarser fraction, the distillers grains, and the soluble and finely suspended fraction, the distillers solubles. The distillers solubles which are about 5 — 10% solids at the time of production are then dewatered to a semi-solid containing 25 — 40% solids to give the condensed distillers solubles (CDS). The predominant grain in the mash-bill is designated as the first word in the name of the by-product, e.g. corn condensed distillers solubles (CCDS), sorghum condensed distillers solubles (SCDS).

Because only the starch portion of the grains is removed during fermentation, there is approximately a 3-fold concentration of the remaining nutrients. Corn condensed distillers solubles (CCDS) have been shown to be high in protein and energy (Carpenter, 1970; Udedibies, 1981) and the main protein in corn, zein, has been shown to be more resistan to rumen degradation than soybean or casein (McDonald, 1954; Little *et al.* (1968). In vitro studies by Burroughs *et al.* (1950), Little *et al.* (1964), Beeson and Chen (1976) have demonstrated an increased cellulose digestion with CDS at levels up to 5% in the rations. The by-product has also been shown to be a good source of protein and energy for beef cattle (Horn and Beeson, 1969; Hatch *et al.* (1981). We recently reported improvement in milk production with CCDS (Chase and Udedibie, 1983). Hills (1903), Loosli *et al.* (1952) and Loosli *et al.* (1960) had earlier established a similar value for dried distillers solubles. Improvement in urea utilization by beef cattle fed CDS has also been reported by Beeson (1975). However, no information is available on the effect of this by-product on digestion of nutrients, rumen NH_3 and volatile fatty acids of dairy cows. The trials reported here were therefore conducted to investigate its influence on nutrient digestion, nitrogen and energy utilization and rumen fluid constituents of lactating dairy cows.

MATERIALS AND METHODS

Digestion and Balance Trials

Eighteen cows were assigned to a basal ration for 25 days post-partum after which they were arranged in threes according to date of calving, age and milk production and randomly assigned to three treatment rations in a randomized complete blook design. Treatment rations contained 0, 8 and 16% CCDS, dry matter basis. Complete mixed rations were prepared daily and cows were fed ad libitum once daily. Rations were iso-nitrogenous and iso-caloric. To get used to the rations, animals were placed on the treatment rations for at least 4 weeks before collection. During this preliminary period, they were housed in individual tie stalls with rubber mats and individual water cups. Wood shavings were used on the mats. Ingredient composition of the basal and treatment rations is in table 1.

On Monday of the week of collection, feed intakes of the cows to go on trial the following Thursday were averaged for the previous five days and the amount entered on the feed sheets to indicate the exact amount to be fed during the trials so as to control consumption during the trial.

Cows were moved to the metabolism stalls on Tuesday after the afternoon milking. Assignment of cows to metabolism stalls was random. Urinary catheters were placed in the cows on Wednesday morning. A 48 hour lag period was allowed between the first feed sampling and the first fecal, urine and milk collection. All feeds were sampled daily from Tuesday through the next Tuesday. Orts were sampled Wednesday through Tuesday. Milk was sampled Thursday afternoon through the following Thursday morning.

Urine was collected in 20 litre plastic jars to which 100ml of 6N HCL was added to acidify the urine and prevent N losses. The total urine production of each cow was weighed at 9.00 h, totally mixed by shaking and then sampled. One percent of the total daily production was saved in 4 litre glass jars and frozen. At the end of the 7 day collection period, the composite samples for each cow were thawed, thouroughly mixed, subsampled in 100ml plastic containers and taken to the laboratory for N analysis.

Fecal collections were also at 9.00 h and were weighed and mixed in a mortar mixer for about 5 minutes before subsampling. One 2% aliquot was taken and dried in a forced air oven at 55°C. Another 1% aliquot was frozen. At the end of the collection period, a compsotive sample was prepared for each cow.

TABLE 1

Ingredient Content of the Basal and Treatment Rations[a]

Ingredient	Rations			
	Basal Ration	*0% CCDS*	*8% CCDS*	*16% CCDS*
	(% of DM)			
Corn silage	44.41	23.00	23.00	23.00
Haylage	6.65	12.00	12.71	13.00
Corn meal	33.23	—	—	—
Ear corn	—	40.95	36.50	32.45
Soybean meal — 48%	12.84	17.50	13.50	9.50
Wet brewers grain	—	4.00	4.00	4.00
Condensed distillers solubles	—	—	8.00	16.00
TM salt	0.47	0.42	0.39	0.34
Hical Min	—	0.25	0.54	1.03
Phos. Min	0.86	0.42	0.24	—
Bicarb	—	0.10	0.13	0.09
Dynamate	—	0.32	0.19	0.16
Limestone	0.82	1.04	0.80	0.43
Calcium sulfate	0.72	—	—	—

[a]All values expressed on dm basis

Feeds, feces, ortsand urine were analysed for nitrogen by Kjeldahl method. Gross energy of feeds, orts and wet feces was determined with an adiabatic bomb calorimeter. Gross energy of urine was estimated using the method of Elliot (1958) and the energy of the milk by the method of Tryreell and Reid (1965). Acid Detergent fiber, neutral detergent fiber, cellulose and lignin of feed, orts and feces were determined according to Georing and Van Soest (1970) and either extract according to AOAC (1080). Protein solubility and estimated rumen escape proteins of treatment rations were determined according to Krishnamoorthy (1982).

Rumen Fluid Studies

Following the digestion and balance trials, rumen fluid samples were collected from the cows via esophageal tube at 0 and 3 hours post-feeding into 100ml bottles containing 0.5ml saturated mercuric chloride to stop bacterial action. Rumen samples were analysed for pH, ammonia nitrogen according to AOAC (1980) and for volatile fatty acids (VFA) by gas-liquid chromatography as described by Baumgardt (1964).

Statistical Analyses

Data on digestion and balance trials and rumen fluid were analysed using two-way analysis of variance (Snedecor and Cochran, 1978). Where significant treatment differences were detected from the analysis of variance, means were compared using Least Significant Difference (LSD) as also described by Snedecor and Cochran (1978).

RESULTS AND DISCUSSION

Digestion and Balance Trials

Chemical composition, protein solubility and estimated rumen escape proteins of the treatment rations are in Tables 2 and 3. Protein solubility of the treatment rations increased with increase in CCDS levels. This was due to the higher protein solubility of CCDS. The increase in bound protein of the treatment ration as CCDS was increased was also due to the bound proteins of CCDS resulting from heat damage during processing. These differences were insignificant as to constitute a major factor in animal performance. Apart from the neutral detergent fiber, the other major nutrients of the treatment rations did not differ.

Data on digestion trials are in table 4. CCDS did not significantly affect the disgestibilities of dry matter, crude pro-

TABLE 2

Chemical Composition of the Basal Ration and Average Chemical Composition of the Treatment Rations

Measurements	Basal	0% CCDS	8% CCDS	16% CCDS	SE[c]
Dry matter %	47.70	51.75	44.13	41.35	4.41
			(% of DM)		
Crude protein	18.50	18.58	18.42	18.72	0.19
Available protein	17.10	16.53	16.06	16.19	0.13
Acid detergent fiber	20.70	18.65	19.01	19.14	0.25
Neutral detergent fiber	42.36	40.17[a]	44.13[b]	46.95[b]	2.82
Cellulose	15.22	14.34	14.55	15.29	0.15
Lignin	—	2.53	2.92	2.83	0.26
Ether extract	3.01	3.57	4.07	5.55	0.84
Ash	7.89	8.45	6.59	6.59	0.14
Gross energy, Koal/gm	4.14	4.07	4.25	4.33	0.22
Calcium	0.80	0.9	0.83	0.94	0.12
Phosphorus	0.48	0.47	0.51	0.52	0.04
Magnesium	0.33	0.26	0.26	0.28	0.02
Potassium	1.07	0.85	0.97	0.98	0.07
Sodium	0.43	0.14	0.16	0.17	0.02
Sulfur	—	0.31	0.31	0.42	0.06
Iron, ppm	261	268	321	292	33.0
Zinc, ppm	96	74	153	221	28.4
Copper, ppm	23	10	22	25	7.8
Manganess, ppm	102	46	50	55	5.2

[a,b]Means within lines with different superscripts are different (P .05)

[c]Standard errors apply to treatment rations only.

TABLE 3

Soluble and Estimated Rumen Escape Proteins of the Treatment Rations

Ration	*CP*	*Sol. CP*	*Insol. CP*	*Bound CP*	*Rumen Escape CP*
	—% of DM—		—% of CP—		
0% CCDS..	18.58	26.20	73.80	11.02	26.94
8% CCDS..	18.42	28.78	71.22	12.80	28.70
16% CCDS..	18.72	30.06	69.94	13.50	30.44

TABLE 4

Apparent Digestibility of Diet Dry Matter and Nutrients by Cows Fed Rations Containing 0,8, and 16% CCDS

Components	*Rations* 0% CCDS	8% CCDS	16& CCDS	*SE*
		(%)		
Dry matter	66.38	64.83	66.37	1.26
Protein	72.24	70.04	72.35	3.31
EnergY	65.40	65.33	67.19	1.15
Ether extract	71.46[ac]	77.37[abd]	81.63[bd]	2.86
Acid detergent fiber	55.74	54.15	53.88	2.45
Nuetral detergent fiber	58.99[a]	63.69[ab]	67.02[b]	2.98
Cellulose	59.98	59.19	61.18	2.26
Lignin	25.04	25.91	28.56	3.12
Ash	54.34[c]	47.76[d]	47.77[d]	3.56

[a,b]Means within lines with different superscripts are different (P .05)

[c,d]Means within lines with different superscripts are different (P .10).

tein, energy, acid detergent fiber, cellulose and lignin. The digestibility of crude protein was slightly depressed with 8% CCDS. CCDS, however, significantly improved the digestibilities of the neutral detergent fiber (NDF) and ether extract but depressed the digestibility of ash. The increased cellulose digestibility due to CCDS which Beeson and Chen (1976) reported in an *in vitro* study was not confirmed in this study. Perhaps levels over 5% CCDS depress the activity of cellulolytic micro-organisms.

Data on nitrogen balance are in Table 5. Cows on 8% CCDS ration apparently retained significantly ($P < 0.05$) less nitrogen than the control or the group on 16% CCDS. Since 16 CCDS ration contained more bound protein (Table 3), one would have expected higher fecal N from the animals on 16% CCDS ration. A possible explanation, through speculative, for the higher fecal N from 8% CCDS ration would be that 8% CCDS ration resulted in higher bacterial protein synthesis. As a result, a good percentage of the fecal N came from bacterial N as nucleic acid. This argument is supported in part by the fact that 8% CCDS ration also significantly depressed rumen ammonia as will be discussed later and by the fact that 5% CCDS has been demonstrated *in vitro* to enhance microbial protein synthesis (Beeson and Chen, 1976). It appears therefore that 16% CCDS is not optimal for maximum microbial activity.

Data on energy balance are in Table 6. There were no significant differences in energy utilization among treatments. Improvement in milk yield and composition of cows fed CCDS could be due to differences in nitrogen utilization and kind of volatile fatty acids produced.

Rumen Fluid Studies

Data on rumen fluid pH, ammonia nitrogen and volatile fatty acids (VFA) are in Table 7. Rumen pH was not affected by treatments. Rumen NH_3-N was significantly ($P < 0.05$) depressed with 8% CCDS both before and 3 hours after feedings. One would have expected further depression in rumen NH_3-N with 16% CCDS. This did not happen. Since low rumen ammonia may be found if the feed material is not easily degradable but the protein of 16% CCDS ration was more soluble in this case, it might be that around 8% CCDS level, microbial activity was maximized resulting in maximal

AABLE 5

Nitrogen Balance of Lactating Dairy Cows Fed Rations Containing 0,8 and 16% CCDS

	Rations			
Components	*0% CCDS*	*8% CCDS*	*16% CCDS*	*SE*
Nitrogen intake, g/day	622.96	623.33	608.96	39.20
Nitrogen in feces, g/day	172.56	186.64	168.28	12.83
Nitrogen absorbed, g/day	450.40	436.69	440.68	—
Nitrogen losses, g/day				
Urine	235.28	248.43	240.08	14.07
Milk	146.77	153.33	143.28	18.11
Nitrogen retained, g/day	58.35[c]	34.93[d]	57.15[c]	6.89
Nitrogen retained, % of intake	10.99	5.60	9.38	—
Productive nitrogen, g/day[a]	215.12	188.27	200.43	—
Nitrogen, as % of absorbed[a]				
Urine	52.23	56.89	54.48	—
Milk	32.59	35.11	32.51	—
Productive nitrogen	47.76	43.11	45.48	—

[a]Productive nitrogen = nitrogen in milk + nitrogen retained

[b]Absorbed nitrogen = nitrogen intake — nitrogen in feces.

[c,d]Means within lines with different superscripts are different (P 0.5)

TABLE 6

Energy Balance of Lactating Dairy Cows Fed Rations Containing 0, 8 and 16% CCDS

	Rattions			
Measurements	*0% CDDS*	*8% CCDS*	*16% CCDS*	*SE*
	(Meal/day)			
Energy intake	86.02	89.59	85.72	5.28
Energy in feces	29.69	40.92	28.16	2.09
Digestible energy	56.33	58.67	57.56	3.70
Energy losses				
Urine	3.58	4.55	4.43	0.44
Milk	21.08	23.29	21.41	3.02
Energy retained	34.43	34.40	35.17	0.64
Energy Loss as % of energy absorbed	31.67	30.83	31.72	1.53
Urine	6.36	7.76	7.70	—
Milk	37.42	39.70	37.20	—

utilization of available NH_3-N for microbial protein synthesis. And as the level of the CCDS increased, the stimulatory factor in CCDS responsible for the increased microbial activity started to exert inhibitory effect on the protein synthesizing system due to saturation. Although the blood urea of the animals was not examined in this study, the reduced rumen NH_3-N observed with 8% CCDS is in agreement with the observations of Chen *et al.* (1981) that CCDS reduced blood urea, and with those of Hawkins (1972) and Hatch *et al.* (1972) who reported higher urea utilization by steers when CCDS was added in rations contain-

TABLE 7

Rumen pH, Ammonia Nitrogen and Volatile Fatty Acids of Lactating Dairy Cows Fed Rations Containing 0, 8 and 16% CCDS

	0 hrs. (before feeding)				3 hrs. (after feeding)			
	Rations				Rations			
Rumen pH	6.99	7.04	6.99	0.19	6.47	6.89	6.72	0.28
Ammonia nitrogen, mg/ 100ml	10.02[a]	6.62[b]	9.56[a]	1.32	20.23[ac]	12.24[bd]	14.14[bd]	3.02
Acetate, molar %	63.66	62.82	61.17	2.37	58.37[a]	63.80[b]	59.05[ab]	2.45
Propionate, molar %	18.61	20.06	21.05	2.30	19.90	20.42	22.39	1.82
Iso-butyrate, molar %	1.26	1.30	1.29	0.11	1.31	1.32	1.32	0.14
Butyrate, molar %	13.20	12.25	12.71	1.35	14.15	11.26	13.69	1.76
Iso-volerate, molar %	1.85	1.90	1.78	0.25	1.97	1.66	1.67	0.27
Valerate, molar %	1.42	1.66	2.00	0.35	1.60	1.54	1.87	0.26
Total volatile fatty acid, mg/ml	4.57	3.81	3.80	0.64	5.82	4.65	4.82	0.88
C_2/C_3 ratio	2.84	2.56	2.48	0.34	2.42[cd]	2.55[d]	2.20[c]	0.16

[a,b] Means within lines and in same period with different superscripts are different (P .05)

[c,d] Means within lines and in same period with different superscripts are different (P .10)

ing urea. High rumen NH_3-N given rise to high blood urea (Lewis, 1957) and blood urea is an indication of nitrogen loss by the animal.

There were no statistical differences in total and individual rumen fatty acids among treatments prior to feeding. Total VFA, however, remained higher for the control group relative to 8% cr 16% CCDS group. Rumen acetate was significantly ($P < .05$) lower in the control group. That partially explains the increased fat content of milk of cows fed CCDS (Chase and Udedibie, 1983) or dried distillers solubles (Loosli *et al.,* 1952; Loodsli *et al.,* (1960). Armsby and Risser (1905) had earlier attributed the extra milk fat from distillers feeds to their high fat content. The relatively hith concentration of VFA and NH_3-N in the rumen of the control group was probably due to rapid solubilization of carbohydrate in corn and protein in soybean meal and the inability of the microganisms to match protein synthesis with NH_3 production. It has earlier been mentioned that the protein of soybean is more rapidly solubilized than that of corn (McDonald, 1954; Little *et al.,* 1968) because of the zein present. Likewise, the increase in the rumen total VFA and NH_3-H as the level of CCDS increased to 16% is an indication that 16% level is beyond the point of maximal microbial activity. It appears, therefore, that even through 16% CCDS level was not significantly different from 8% with regard to animal productivite performance (Chase and Udedibies, 1983), it is likely that levers beyond 16% may result in reduced performance.

It would appear from the foregoing results and discussion that levels of CCDSD close to 8% in rations for dairy cows are likely to produce the best results in terms of milk production and composition.

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