2009

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The Professional Animal Scientist 25 (2009):289–295

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ABSTRACT

Three experiments evaluated the influence of supplementation frequency of distillers dried grains plus solubles (DDGS) on forage digestibility (Exp. 1) and growth of yearling heifers (Exp. 2) and steers (Exp. 3). In Exp. 1, 6 steers (371 ± 30 kg) were used in a replicated 3 × 3 Latin square design with three 21-d periods. Treatments were DDGS fed at 16.7% of the diet (DM) either 1) daily, 2) every other day, or 3) every third day. In Exp. 2, 48 heifers (193 ± 20 kg) were fed hay and supplemented with the daily equivalent of 1.3 kg/heifer of DDGS, either 3 or 6 d/wk. In Exp. 3, 48 steers were assigned to replicated supplementation groups. Treatments were 1) hay and supplement fed 6 d/wk in a dry lot (control); 2) native winter range and supplement fed 6 d/wk; 3) native winter range and a DDGS supplement fed 6 d/wk; and 4) native winter range and the same DDGS supplement fed 3 d/wk. In Exp. 1, diet DM (P = 0.06), OM (P = 0.07), and hay NDF (P = 0.03) digestibility decreased linearly as DDGS supplementation frequency decreased. In Exp. 2, heifers fed DDGS 6 d/wk gained more BW (P = 0.01) than heifers fed 3 d/wk. In Exp. 3, steers fed the control diet, native winter range and supplement fed 6 d/wk, and native winter range and DDGS supplement fed 6 d/wk performed similarly, but performance was decreased when steers were fed native winter range and the DDGS supplement 3 d/wk. Improved animal growth may result from more frequent supplementation of DDGS when fed in excess of 15% of the diet.

Key words: supplementation frequency, distillers dried grains plus solubles, cattle

INTRODUCTION

In many forage-based production systems, supplemental protein is provided during periods of limited forage quality to maintain BCS (Hollingworth-Jenkins et al., 1996; Mathis et al., 1999) or increase animal BW gain (Judkins et al., 1987; Titgemeyer et al. 2004) and improve forage intake and digestibility (Hunt et al., 1989; Köster et al. 1996). Supplemental feeds may constitute a significant portion of variable costs of beef production, and providing protein supplements less frequently may reduce costs without negatively affecting performance (Huston et al., 1999; Farmer et al., 2001; Bohnert et al., 2002).

In situations in which forage energy content does not support the desired productivity, energy supplementation may be necessary (Caton and Dhuyvetter, 1997). Energy supplements containing nonstructural carbohydrates, such as cereal grains, can depress forage intake and digestibility (Sanson et al., 1990; Olson et al., 1999). However, supplements containing highly digestible fiber do not depress forage intake or digestibility (Bowman et al., 2004).

Distillers dried grains plus solubles (**DDGS**), a co-product of fuel ethanol production, is an excellent source of both protein and energy. Energy is supplied in the form of highly digestible fiber and fat and does not contain nonstructural carbohydrates (Stock et al., 2000). Additionally, DDGS is an ideal supplement for growing cattle consuming forage-based diets because of high RUP (Klopfenstein, 1996; Patterson et al., 2003) and phosphorous (McDowell, 1996) content.

Production of DDGS is increasing in the United States and represents

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an economical feed resource. We hypothesized animal performance could be maintained but cost reduced with less frequent supplementation of DDGS. Therefore, our objective was to determine the influence of DDGS supplementation frequency on forage intake and digestibility and on the growth performance of beef cattle consuming forage-based diets.

MATERIALS AND METHODS

Experimental protocols were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee for all 3 experiments.

Experiment 1: Digestion Trial

Six crossbred steers (371 ± 30 kg) were assigned randomly to treatment in a replicated 3 × 3 Latin square design with 3 periods. Replication of the Latin squares occurred simultaneously. Treatments were DDGS fed either daily, every other day, or every third day. Distillers dried grains plus solubles constituted 16.7% of the diet DM for all treatments, and over the course of a 3-d period, all cattle received the same amount of DDGS as a percentage of their diets. This level of DDGS was chosen because it is typical of the amount fed in applied feeding situations in geographic regions where DDGS is readily available. Steers were housed in individual pens (6 × 3 m) in a semi-enclosed barn and had unrestricted access to fresh water. Periods lasted 21 d, and total-tract diet digestion was assessed from d 16 to 21 of each period according to the procedures of Cochran and Galyean (1994). On d 1 through 9 of each period, cool-season grass hay, chopped to a 15-cm particle size, was provided ad libitum at 0730 h. Orts from the previous day were weighed before feeding. Beginning on d 10 of each period, the amount of hay fed was reduced to 90% of the average hay intake on d 1 through 9. Limiting the amount of hay offered resulted in elimination of orts during the fecal collection period. Subsamples of hay and DDGS were collected on d 14 through 19, weighed, dried in a forced-air oven (60°C; 72 h), reweighed for DM, composited by period, and ground to pass a 1-mm screen in a Wiley mill (Arthur H. Thomas, Philadelphia, PA).

Table 1. Digestion trial feedstuff nutrient content (Exp. 1)

Item	Grass hay	DDGS[1]
DM, %	95.9	92.1
OM, % DM	90.2	97.7
NDF, % DM	67.2	43.5
IVDMD, % DM	53.4	—
CP, % DM	6.7	34.1
Ether extract, % DM	—	10.2

[1]DDGS = distillers dried grains plus solubles.

Before hay feeding (0700 h), DDGS was provided to steers assigned to the daily treatment at 16.7% the DMI of the previous day. For steers assigned to the every other day and every third day treatments, DDGS was fed at 33.3% of the average DMI for the previous 2 d and 50.0% of the average DMI for the previous 3 d, respectively, on the appropriate supplementation day.

Steers were fitted with fecal bags at 0630 h on d 16, with bags changed once every 12 h for a total fecal collection period of 6 d. Fecal samples were weighed and hand mixed, and a 5% subsample (wet weight) was collected. Subsamples were weighed, dried in a forced-air oven (60°C; 72 h), reweighed for DM, composited by day within steer, and ground to pass a 1-mm screen in a Wiley mill. Digestibility of DDGS NDF was assumed to be 80% (Lodge et al., 1997).

Ground samples were analyzed for DM, OM, (AOAC, 1990), and NDF using an Ankom 200 fiber analyzer (Ankom Co., Fairport, NY). Ground hay and DDGS samples were analyzed for nitrogen content using a Leco FP-2000 nitrogen analyzer (Leco Corp., Henderson, NV). Hay samples were analyzed for IVDMD using the procedure of Tilley and Terry (1963), with the modification of addition of 1 g of urea to the buffer (Weiss, 1994). Samples of DDGS were analyzed for ether extract con-

Table 2. Supplement composition and feedstuff nutrient content used in Exp. 2 and 3[1]

	Exp. 2		Exp. 3			
Item	Hay	DDGS	Hay	Control	CSM	DDGS
Ingredient, % DM						
Dried distillers grains	—	94.36	—	—	—	97.80
Dry-rolled corn	—	—	—	53.67	65.64	—
Soybean meal	—	—	—	43.31	32.16	—
Molasses	—	2.42	—	—	—	—
Limestone	—	1.78	—	1.67	1.22	1.22
Salt	—	1.20	—	1.13	0.82	0.82
Trace mineral premix[2]	—	0.18	—	0.17	0.12	0.12
Vitamin premix[3]	—	0.06	—	0.05	0.04	0.04
Nutrient content, % DM						
CP	6.6	34.1	6.6	27.8	25.7	32.0
IVDMD	53.4	—	53.4	—	—	—

[1]DDGS = distillers dried grains plus solubles; CSM = corn and soybean meal.

[2]Contained (g/kg premix): 130 Ca; 10 Co; 15 Cu; 2 I; 100 Fe; 80 Mn; and 120 Zn.

[3]Contained 29.9 million IU vitamin A, 6.0 million IU vitamin D, and 7,000 IU vitamin E/kg premix.

tent (AOAC, 1990). Nutrient content of hay and DDGS is listed in Table 1.

Data were analyzed as a replicated 3 × 3 Latin square using MIXED procedures (SAS Inst. Inc., Cary, NC). The model included period, steer, and treatment. Single degree of freedom, orthogonal polynomial contrasts were used to test the effects of increasing supplementation frequency. Differences were considered significant when P-values were <0.05.

Experiment 2: Heifer Performance Trial

Forty-eight crossbred heifers (193 ± 20 kg) were stratified by BW and then assigned randomly to 1 of 8 pens. Pens were then assigned randomly to treatment. Heifers were fed grass hay ad libitum and the equivalent of 1.3 kg·heifer^{-1}·d^{-1} (DM) of a DDGS-based supplement (Table 1) either 3 or 6 d/wk. Supplement was fed Monday through Saturday to heifers on the 6 d/wk treatment and on Monday, Wednesday, and Friday to heifers on the 3 d/wk treatment.

Heifers were weighed on 2 consecutive days at the initiation and termination of the 84-d trial, without limiting intake before weighing. Beginning on d 55 of the experiment, approximately 50 mL of urine was collected from each heifer for 3 consecutive days at approximately 0800 h. Urine samples were composited by animal and analyzed for creatinine and purine derivative concentrations by HPLC (Waters Breeze System, Waters Corp., Milford, MA) according to the procedure of Shingfield and Offer (1999).

Hay used in the experiment was subsampled and analyzed for DM, CP, and IVDMD, and supplements were analyzed for CP as described for Exp. 1 (Table 2). Data were analyzed as a completely randomized design using MIXED procedures (SAS Inst. Inc.). The model included the effect of treatment, and pen was used as the experimental unit.

Experiment 3: Steer Performance Trial

Each year for 2 yr, 48 crossbred steers (213 ± 22 kg) were stratified by BW and assigned randomly to 1 of 8 supplementation groups. Steers in each supplementation group were identified by like-colored ear tags. Supplementation groups (i.e., ear-tag colors) were assigned randomly to 1 of 4 treatments. The control treatment consisted of ad libitum access to grass hay in a dry lot and the equivalent of 2.0 kg·steer^{-1}·d^{-1} (DM) of corn and soybean meal-based supplement (Table 2) fed 6 d/wk. Steers in the other 3 treatments grazed winter range in a common 32-ha pasture and were sorted according to ear-tag color into 1 of 6 pens at 0700 h 6 d/wk. On a pen basis, steers were fed the equivalent of 2.7 kg·steer^{-1}·d^{-1} (DM) corn and soybean meal-based supplement 6 d/wk (**CSM**), or 1.9 kg·steer^{-1}·d^{-1} (DM) DDGS-based supplement either 6 d/wk (**DDGS6**) or 3 d/wk (**DDGS3**) in replicated supplementation groups. Steers in the DDGS3 treatment were offered twice the amount offered to DDGS6 on alternate supplementation days. Treatments were designed to supply similar amounts of energy and meet metabolizable protein and RDP requirements according to NRC (1996). Forage nutrient content was estimated using the equations of Lardy et al. (2004).

Steers were weighed on 2 consecutive days at the initiation and termination of the 62-d experiment, without limiting intake before weighing. Hay was subsampled and analyzed for DM, CP, and IVDMD, and supplements were analyzed for CP as described for Exp. 1 (Table 2).

Data were analyzed as a completely randomized design using MIXED procedures (SAS Inst. Inc.). The model included the effects of treatment, year, and their interaction. Supplementation group was used as the experimental unit.

A partial budget was used to compare costs and calculate the cost of BW gain associated with each treatment. Amounts of grazed forage and hay consumed were calculated from intake predictions using level 1 of the NRC (1996) model. Hay ($0.067/kg, as fed), corn ($0.087/kg, as fed), and soybean meal ($0.213/kg, as fed) were valued using 10-yr average prices reported by Mark et al. (2005) and a value of $0.083/kg (as fed) was used for DDGS. Winter range was valued at half the average rate for normal usage-season grazing, according to published data ($13.83/animal unit month; Johnson et al., 2005) for the agricultural statistics district in which the study was conducted. Budgets included $0.013/kg for labor and equipment associated with feeding hay and $0.039/kg for delivery of corn, soybean meal, and DDGS. It was assumed that cattle in the DDGS3 treatment were checked only on the day they were supplemented and that the cost of delivering twice as much supplement 3 d/wk was exactly half the cost of delivering supplement 6 d/wk.

RESULTS AND DISCUSSION

Experiment 1: Digestion Trial

Hay and total DMI decreased linearly ($P = 0.06$ and $P = 0.08$, respectively) as supplementation frequency decreased (Table 3). Similarly, as DDGS supplementation frequency decreased, hay ($P = 0.07$) and total ($P = 0.08$) OM intake decreased. Daily NDF intake decreased linearly ($P = 0.07$) as supplementation frequency decreased. Apparent total-tract DM ($P = 0.002$), OM ($P = 0.002$), and NDF ($P = 0.07$) digestibility of the diet decreased linearly as supplementation frequency decreased. When the disappearance of NDF from hay was analyzed, a linear decrease in digestibility was observed ($P = 0.03$).

The depression in fiber digestion observed in this study was likely a result of the lipid content of the DDGS. The ether extract content of the DDGS used in this experiment was 10.2% (DM). On the day of supplementation, DDGS constituted 33 and 50% of the diet of steers supplemented every other day and every third day, re-

Table 3. Effect of distillers dried grain supplementation frequency on steer DM, OM, and NDF intake and OM and NDF digestibility (Exp. 1)

	Treatment[1]				*P*-value[3]	
Item	D	2D	3D	SEM[2]	L	Q
Daily DMI, g/kg BW						
Hay	23.6	22.2	22.2	0.4	0.06	0.20
Total diet	26.7	25.0	25.1	0.5	0.08	0.21
Daily OM intake, g/kg BW						
Hay	19.3	18.0	18.1	0.3	0.07	0.19
Total diet	23.7	22.2	22.3	0.4	0.08	0.21
Daily NDF intake, g/kg BW	16.9	15.8	15.9	0.3	0.07	0.20
Diet apparent total-tract disappearance, g/kg						
DM	581	560	550	4	0.002	0.31
OM	623	603	591	5	0.002	0.49
NDF	588	578	574	6	0.07	0.66

[1]D = daily supplementation; 2D = supplementation every other day; 3D = supplementation every third day.

[2]n = 18.

[3]L = linear effect of supplementation frequency; Q = quadratic effect of supplementation frequency.

spectively, adding 3 and 5% fat to the diet. Feeding fat at these levels may be enough to depress fiber digestibility. The fat in corn is predominantly unsaturated triglycerides (Coppock and Wilks, 1991). Unsaturated lipids tend to be more detrimental to ruminal fermentation than are saturated lipids (Jenkins, 1993). Jenkins and Fotouhi (1990) observed decreased DM and ADF digestibility in wethers when only 2.4% corn oil was added to the diet.

An additional possible explanation for the decreased digestibility in the infrequently supplemented treatments was altered gastrointestinal motility. Some plant protein sources contain biologically active peptides that have hormone-like activity and are capable of influencing gut motility (Froetschel, 1996). Changes in gut motility resulting from the effects of greater levels of fat or RUP on the digestive endocrine system may have occurred (Allen, 2000), which may partially explain the decreased digestibility.

Experiment 2: Heifer Performance Trial

Heifers fed DDGS 6 d/wk gained 0.07 kg/d more ($P = 0.01$) BW than heifers fed DDGS 3 d/wk (Table 4). As in Exp. 1, the reduced BW gain in less frequently supplemented heifers may be related to effects of ruminal fat concentration on forage digestibility. Feeding 3 d/wk at the levels used in this experiment would result in an addition of 5.4% fat to the diet on the day of supplementation.

One proposed mechanism whereby high levels of fat in the diet depress fiber digestion is via negative effects on ruminal microorganisms (Jenkins 1993). Theoretically, purine derivative:creatinine ratios are indicative of microbial growth in the rumen (Shingfield, 2000), and if fat content of the diet was the reason for decreased BW gain in the infrequently supplemented treatment, a decreased purine derivative:creatinine ratio would be expected. Purine derivative:creatinine ratio may not be an accurate determinant of absolute quantities of microbial purine production, but has been shown to be useful in determining relative differences in purine production among treatments (Shingfield, 2000). The ratio of purine derivatives:creatinine was not different ($P = 0.12$) between treatments in this experiment. This may be a result of the short (3-d) urine collection period in relation to the supplementation schedule. Supplement was fed on Monday and Wednesday and urine was collected on Tuesday through

Table 4. Performance and purine derivative:creatinine ratio in urine of heifers fed the daily equivalent of 1.3 kg (DM) distillers dried grains either 3 or 6 d/wk (Exp. 2)

	Treatment			
Item	3 d/wk	6 d/wk	SEM[1]	*P*-value
Initial BW, kg	193	193	0.6	0.42
Final BW, kg	253	259	0.9	0.01
ADG, kg/d	0.72	0.79	0.01	0.01
Purine derivative:creatinine	1.29	1.22	0.03	0.12

[1]n = 8.

Table 5. Body weight and ADG of steers fed a corn and soybean meal-based supplement in a dry lot (control) or while grazing native winter range (CSM) or fed distillers dried grains while grazing winter range either 6 (DDGS6) or 3 (DDGS3) d/wk (Exp. 3)

	Treatment					*P*-value[2]		
Item	Control	CSM	DDGS6	DDGS3	SEM[1]	Trt	Year	T × Y
Initial BW, kg	212	212	213	213	2	0.98	<0.001	0.77
Final BW, kg	266[a]	270[a]	264[a]	254[b]	2	0.004	<0.001	0.09
ADG, kg/d	0.89[a]	0.92[a]	0.82[a]	0.65[b]	0.04	0.004	0.24	0.11
Supplement, kg/d	2.00	2.70	1.90	1.75				

[a,b]Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]n = 16.

[2]Trt = treatment effect; Year = year effect; T × Y = treatment × year interaction.

Thursday. Increased concentrations in the infrequently supplemented treatments would be expected if purine derivative and creatinine concentrations in the urine were reflective of the previous day's diet.

Other explanations for decreased BW gains in the infrequently supplemented treatment include decreased forage intake. Decreased forage intake has been observed when high levels of DDGS are fed infrequently in high-forage diets and is consistent with the results of Exp. 1. Loy et al. (2007) fed DDGS at 0.08% of BW on alternate days and observed decreased forage intake.

Experiment 3: Steer Performance Trial

Steers receiving the control, CSM, and DDGS6 treatments had similar ADG and BW, but both were reduced in the DDGS3 treatment (Table 5). Incomplete consumption of the offered supplement likely contributed to reduced performance. Steers in the DDGS3 treatment were offered the daily equivalent of 1.9 kg/steer (4.4 kg/steer on the day of supplementation), but only an average of 1.75 $kg \cdot steer^{-1} \cdot day^{-1}$ (DM) of supplement was consumed over the course of the experiment. At the beginning of the experiment, steers in the DDGS3 treatment weighed 213 kg. Offering 4.4 kg of supplement was 2.06% of their BW. Therefore, incomplete consumption of the supplement was likely due to physical fill. Incomplete consumption of the supplement accounted for only a portion of the reduction in BW gain. A reduction of 0.15 kg/d of this supplement would be expected to result in only a 0.06 kg/d decrease in ADG (NRC, 1996).

The slower rate of BW gain in DDGS3 steers is consistent with results from Exp. 1 and 2 and suggests that reduced forage digestibility resulting from less frequent supplementation of DDGS may have occurred. Body weight gain was similar between the CSM and DDGS6 treatments even though the CSM supplement contained starch. Decreased fiber digestibility resulting from addition of starch to the diet has been demonstrated (Sanson et al., 1990). This experiment was not designed as a direct measure of the negative associative effects of starch supplementation on forage digestibility but if fiber digestibility was not decreased by feeding DDGS 6 d/wk, which contained no starch, then it was not decreased by feeding the CSM supplement. These results agree with Bodine and Purvis (2003) and Bowman et al. (2004) and indicate that the balancing diets for RDP requirements when feeding supplements containing nonstructural carbohydrates may reduce the negative effects of starch on fiber digestibility.

The cost of BW gain was greatest for steers in the control treatment, primarily because of the costs associated with feeding hay (Table 6). Even though ADG was greatest, the cost of BW gain was also greatest for CSM among those steers that grazed range because corn and soybean meal are more expensive than DDGS. Feeding DDGS 6 d/wk resulted in

Table 6. Costs associated with feeding a corn and soybean meal-based supplement to steers in a dry lot (control) or grazing native winter range (CSM) or feeding distillers dried grains either 6 (DDGS6) or 3 (DDGS3) d/wk to steers grazing range (Exp. 3)

Item	Control	CSM	DDGS6	DDGS3
Supplement cost, $	17.23	21.03	9.78	9.01
Supplement delivery, $	4.84	6.53	4.59	2.11
Hay cost, $	20.27	—	—	—
Range cost, $	—	8.60	11.11	11.38
Total cost, $	42.34	36.16	25.48	22.50
Cost of gain, $/45 kg	76.72	63.38	50.12	55.83

the lowest cost of BW gain. Total costs were least but ADG was also least for steers in the DDGS3 treatment, resulting in a greater cost of BW gain among steers fed DDGS. A cost reduction of $2.48/animal during the feeding period was realized by infrequent feeding of DDGS. This cost reduction represents the maximum amount of savings that could be achieved by feeding 3 d/wk instead of 6 d/wk. If it were necessary to incur costs on days when supplement was not fed, for reasons such as breaking ice or monitoring health status, or if it cost more to haul more supplement for delivery, then the savings achieved by infrequent supplementation would be diminished. In this study, the cost savings associated with infrequent supplementation were not sufficient to offset the decreased animal performance and would not be recommended.

IMPLICATIONS

Typically, infrequent feeding of protein supplements reduces costs without decreasing animal performance. However, improved animal ADG resulted from daily feeding of DDGS. More frequent supplementation may be required to optimize animal performance when DDGS constitutes more than 15% of the diet. Further research is necessary to determine whether feeding frequency can be reduced when DDGS is fed at lower levels.

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