INFLUENCE OF FORAGE LEVEL ON PASSAGE RATE, DIGESTIBILITY AND PERFORMANCE OF CATTLE

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ABSTRACT

Two trials (feedlot and metabolism) were conducted to evaluate the influence of level of chopped tall fescue hay (FH) in high concentrate diets on average daily gain (ADG), liquid and particulate passage rates, digestibility and in situ digestibility of corn. In the feedlot trial, 36 Hereford steers were fed diets containing 15, 30 and 50% FH in combination with 74, 59 and 39% whole shelled corn (WSC) and a soybean meal supplement. Steers offered 15, 30 and 50% FH consumed 9.0, 9.0 and 7.6 kg dry matter (DM) per d; gained 1.19, .89 and .67 kg; and had DM to gain ratios of 7.6, 10.1 and 11.5, respectively. A negative correlation was observed between fecal pH and ADG (r = -.52) and between fecal pH and fecal starch (r = -.40). In a 4 X 4 Latin-square trial, four cannulated steers were fed 4, 8, 16 or 24% FH in combination with 86, 82, 74 or 66% WSC and a soybean meal supplement. After 14 d of adaptation, steers were offered ytterbium (Yb)-labelled WSC and were ruminally pulse-dosed with chromium ethylenediaminetetraacetic acid (Cr-EDTA) on the first day of the collection period. Steers fed 4, 8, 16 or 24% FH had the following particulate passage rates: 2.3, 2.7, 2.7 and 2.9%/h from fecal analyses; 2.3, 1.7, 2.4 and 2.8%/h from ruminal analyses; 6.0, 5.3, 6.3 and 8.1%/h for liquid, respectively. With increasing FH level, liquid passage rate exhibited linear and quadratic effects (P<.05), while particulate passage rate (rumen sampling) showed linear and cubic effects (P<.05). The DM and starch digestibilities decreased linearly (P<.05) with increasing FH level, while ADF digestibility increased linearly (P>.05). In situ DM disappearance of corn was not influenced (P>.05) by FH level. (Key Words: Diets, Steers, Festuca Arundinacea, Digestibility.)

Introduction

Previous research has shown that whole shelled corn (WSC) can be utilized satisfactorily when fed with low levels of forage (Vance et al., 1972). The use of more forages and less grain in beef cattle finishing systems may be needed in the future. The main reasons for this are the need for energy conservation, potential world grain shortages and greater world demand to use grain for both human and livestock consumption. Addition of forage to WSC diets may change site (Cole et al., 1976) and extent (Teeter, 1981) of digestion. To date, most research concerning effects of forage level on utilization of WSC has primarily been concerned with these variables. Consequently, limited data are available evaluating effects of low-quality forages in high-concentrate diets as related to animal performance, starch utilization and digesta flow.

Forage source has also been shown to be important when feeding WSC (Rust and Owens, 1981). These investigators found that 50% cottonseed hulls with 42% WSC (fed at 2% of body weight) had the highest starch digestibility in comparison with prairie hay, alfalfa hay and corn silage. In agreement with these data, Teeter (1981) found that increasing cottonseed hulls from 10 to 40% of the diet caused a greater increase in starch digestibility in growing steers than did alfalfa hay increases of the same amount.

The objective of this research was to determine the influence of chopped fescue hay (FH) level in a WSC diet on animal performance, digestibility, liquid and particulate passage rates, as well as rate of in situ dry matter (DM) disappearance.
Materials and Methods

Performance Trial. Thirty-six Hereford steers (292 kg) were assigned by weight to 12 pens and the pens were divided into 3 blocks. Diets randomly assigned to each block consisted of 15, 30 or 50% chopped (2.5 cm) FH (dry basis), with the remaining portion being WSC and a supplement (table 1). Dietary ingredients were mixed prior to feeding and fed ad libitum once daily as a complete diet. At the time of feeding, all orts from the previous day were removed, weighed and recorded. Shrink weights were obtained initially and on d 35, 63, 97 and 141 of the trial. Animals were shrunken by withholding feed and water for 12 h. Before weighing, fecal grab samples were collected to determine fecal pH, starch (FS) and acid detergent fiber (FADF).

Metabolism Trial. In a 4 x 4 Latin-square trial, passage rate and digestibility of WSC diets with varying levels of FH were evaluated in Hereford steers (averaging 431 kg) fitted with permanent ruminal cannulae. Steers were fed the following diets four times daily at a level equivalent to 1.7% of body weight (DM): 4, 8, 16 or 24% chopped FH in combination with 86, 82, 74 or 66% WSC and a soybean meal supplement (table 1). Animals were confined to metabolism stalls for the entire trial.

Each period of the Latin square consisted of 14 d of adjustment followed by a 12-d collection phase. The marker was offered on d 1 of the collection period followed by 3 d of rumen and fecal sampling to determine passage rates. From d 5 to 9 (5 d of collection), total feces were collected, composited and sampled for the determination of digestibility of starch, neutral detergent fiber (NDF), acid detergent fiber

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### TABLE 1. COMPOSITION OF EXPERIMENTAL DIETS

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Performance study</th>
<th>Digestion study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>30</td>
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<tr>
<td>Fescue hay b (IFN 1-01-908)</td>
<td>15</td>
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<tr>
<td>Whole shelled corn (IFN 4-02-931)</td>
<td>74</td>
<td>59</td>
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<td>Supplement</td>
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<tr>
<td>Ground corn (FN 4-02-861)</td>
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<tr>
<td>Soybean meal (IFN 5-04-604)</td>
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</tr>
<tr>
<td>Molasses (IFN 4-04-696)</td>
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<tr>
<td>Limestone</td>
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</tr>
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<td>Potassium chloride (IFN 6-02-632)</td>
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<td>Trace mineral salt c</td>
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<tr>
<td>Dicalcium phosphate</td>
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<td>.11</td>
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<tr>
<td>Chemical composition</td>
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<tr>
<td>Dry matter</td>
<td>87.7</td>
<td>88.6</td>
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<tr>
<td>Crude protein</td>
<td>11.2</td>
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<tr>
<td>ADF</td>
<td>10.1</td>
<td>16.4</td>
</tr>
<tr>
<td>NDF</td>
<td>24.6</td>
<td>34.8</td>
</tr>
<tr>
<td>Starch</td>
<td>60.9</td>
<td>49.2</td>
</tr>
</tbody>
</table>

a Dry matter basis.
b Fescue hay contained 8% crude protein, 77% neutral detergent fiber and 5.3% lignin on a DM basis.
c NaCl, 95.8%; Zn, 0.035%; Mn, 0.28%; Fe, 0.175%; Cu, 0.035%; I, 0.0075%; Co, 0.007%.
d Vitamin A, 2,250 IU/g; vitamin D, 400 IU/g.
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(ADF) and crude protein (CP). The last 3 d of the collection period were used to perform an in situ Dacron-bag study.

Analytical Procedure. Samples of forages, rumen digesta and feces were dried in a forced-air oven at 55 C for 48 h and ground through a 1 mm screen. The DM was determined on subsamples immediately by oven drying at 100 C.

Feed and fecal samples were analyzed for starch (MacRae and Armstrong, 1968), NDF and ADF (Goering and Van Soest, 1970) and CP (AOAC, 1980). Fecal pH was determined on 20 g of fresh feces prepared by blending 20 g feces with 100 ml freshly distilled water. Rumen buffering capacity was determined by filtering samples through four layers of cheesecloth, centrifuging at 1,500 x g for 5 min, pipetting 10 ml of supernatant and titrating it with .1 N HCl (Emmanuel et al., 1969).

Rate of Passage Procedure. For determination of liquid dilution rates, steers were ruminally pulse-dosed with 500 ml of chromium ethylenediaminetetraacetic acid (Cr-EDTA), before the 0800 h feeding on d 1 of each collection period. Preparation of Cr-EDTA was according to the procedure of Binnerts et al. (1968). Rumen digesta samples were taken specifically from the front, middle and hind portions of the ventral sac in the rumen at 0, 1.5, 3, 6, 12, 24, 36, 48, 60, 72 and 84 h postdosing, composited and strained through two layers of cheesecloth. The rumen liquor was then centrifuged at 3,000 x g for 30 min and Cr was quantitated in the supernatant with a flame spectrophotometer with air-acetylene combustion (Varga and Prigge, 1982).

Particulate passage rates were determined by feeding steers 25% of their daily corn intake as ytterbium (Yb)-labelled WSC (containing 1,080 mg Yb/kg corn) on d 1 of each collection period. Ruminal and fecal samples were collected at the same time intervals as previously described for the liquid passage rate study. The Yb-labelled WSC was prepared by immersing WSC in distilled water containing 20 mm Yb. The mixture was allowed to equilibrate for 24 h, after which the supernatant was removed and the WSC washed for 6 h to remove unbound and weakly associated Yb (Teeter, 1981). Duplicate fecal samples and strained rumen digesta were dried at 55 C for 48 h, ground through a 1 mm screen, weighed into porcelain crucibles and ashed at 500 C overnight. Upon cooling, the ash was leached by slow oscillation for 12 h with 20 ml of a solution of 3 M HNO₃ and 3 M HCL (10 ml each). After allowing the acid insoluble ash to settle, 5-ml aliquots of the sediment-free liquid was removed for analysis of Yb by atomic absorption spectrophotometry (Teeter, 1981). Turnover rates of WSC and rumen liquid were estimated by regressing the natural logarithms of Cr and Yb concentrations post-peak on time. Fecal excretion rate of the marker was obtained by fitting the single pool model of Pond et al. (1982) to the data.

In Situ Procedure. The influence of FH level on rate of DM disappearance was determined by incubating cracked corn in Dacron bags in the rumen. Duplicate samples (2 g) of cracked corn, which had been screened through a 4,760-μm-pore size screen (to remove the uncracked kernels) and through a 1,680-μm-pore size screen (to remove the smaller particles), were weighed into Dacron bags with a pore size of 17 μm and measuring 8 x 20 cm. The bags were attached to plexiglass spools and placed in the rumen of steers fed diets differing in FH level. Empty bags, serving as blanks, were used to adjust the influx of rumen contents. Bags were removed after 6, 12, 18, 24, 36 and 48 h, washed for 5 min with tap water, dried at 55 C for 48 h and reweighed. Rate of DM disappearance was determined using equations described by Goodrich and Meiske (1978).

Statistical Analysis. Data from the performance trial were analyzed as a split-plot in time. Replication and treatment were tested in the main plot using interaction of replication and treatment as the error term. The subplot contained the effect of time, interaction of time and replication and the interaction of time and treatment. The residual mean square was used as an error term to test the subplot effects. Treatment degrees of freedom for FH level were partitioned to test linear or quadratic response (Steele and Torrie, 1981). Data from the digestion study were analyzed as a 4 x 4 Latin-square design with treatment degrees of freedom for FH level partitioned to test for linear, quadratic or cubic response (Steele and Torrie, 1981).

Results and Discussion

Performance Study. The increase in FH level in the WSC diet (table 2) resulted in a linear decrease (P<.05) in ADG (1.19, .89 and .66 kg/d). Daily DM intakes were similar (P>.05) for steers fed 15 or 30% FH (9.0 kg), but were
TABLE 2. INFLUENCE OF LEVEL OF CHOPPED FESCUE HAY IN A WHOLE SHELLED CORN DIET ON ANIMAL PERFORMANCE

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<th>50</th>
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<td>No. of steers</td>
<td>12</td>
<td>12</td>
<td>12</td>
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</tr>
<tr>
<td>Initial wt, kg</td>
<td>294</td>
<td>294</td>
<td>289</td>
<td>3.07</td>
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<tr>
<td>Final wt, kg</td>
<td>462</td>
<td>419</td>
<td>390</td>
<td>5.01</td>
</tr>
<tr>
<td>ADG, kg</td>
<td>1.19</td>
<td>.89</td>
<td>.66</td>
<td></td>
</tr>
<tr>
<td>DM intake, kg</td>
<td>9.0</td>
<td>9.0</td>
<td>7.6</td>
<td>.51</td>
</tr>
<tr>
<td>DM/gain, kg</td>
<td>7.56</td>
<td>10.11</td>
<td>11.52</td>
<td>.96</td>
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</table>

aADG = average daily gain, DM = dry matter.
bLinear effects (P<.05).

numerically higher than those fed 50% FH (7.6 kg). With increasing grain level, DM:gain ratio linearly decreased (11.5, 10.1 and 7.6; P<.05). The lower performance of steers fed 30 and 50% FH as compared with 15% FH diet may be attributed to lower metabolizable energy value and reduced DM intake. The increase in FH level from 15 to 50% resulted in a quadratic effect (P<.05) observed for FADF (table 3).

Percent FS decreased linearly (P<.05) and fecal pH increased linearly (P>.05) as FH level increased in the diet, which further confirmed reports by Rust et al. (1980) and Turgeon et al. (1983), who found that increasing alfalfa hay levels and alfalfa-brome hay mixture in WSC diets, respectively, decreased percent FS, Turgeon et al. (1983), however, found no relationship between fecal pH and forage level in mixed corn diets. The discrepancy in the relationship between forage level and fecal pH may be attributed to the range of forage levels used in these studies. Turgeon et al. (1983) examined chopped alfalfa-brome hay mixtures from 5 to 15% of the diet, whereas these studies examined FH levels from 15 to 50% of the diet. A positive low correlation (r = .29, P<.01) was observed between percent FS and ADG, while fecal pH was negatively correlated (r = -.52, P<.01) with ADG (table 3). A negative correlation (r = -.39, P<.01) was also observed between fecal pH and percent FS, confirming previous reports by Turgeon et al.

TABLE 3. INFLUENCE OF LEVEL OF CHOPPED FESCUE HAY IN A WHOLE-SHELLED-CORN DIET ON FECAL VARIABLES AND CORRELATION COEFFICIENTS BETWEEN PERCENTAGE FECAL STARCH OR FECAL pH AND AVERAGE DAILY GAIN

<table>
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<th>Item</th>
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<tr>
<td>Fecal ADF, %</td>
<td>14.59</td>
<td>19.71</td>
<td>17.56</td>
<td>1.13</td>
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<tr>
<td>Fecal starch, %</td>
<td>27.39</td>
<td>24.39</td>
<td>18.96</td>
<td>1.92</td>
</tr>
<tr>
<td>Fecal pH</td>
<td>5.99</td>
<td>6.31</td>
<td>6.61</td>
<td>.05</td>
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<table>
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<th>Correlation coefficient</th>
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<td>Fecal starch</td>
</tr>
<tr>
<td>Fecal pH</td>
</tr>
<tr>
<td>Fecal starch</td>
</tr>
</tbody>
</table>

aQuadratic effects (P<.05).
bLinear effects (P<.05).
**P<.01.
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(1983), who found a similar relationship \( r = -0.43 \).

The negative relationship between fecal pH and percent FS may be attributed to increased bacterial fermentation in the distal portions of the small intestine (Russell et al., 1981) for animals fed high-concentrate diets. An inadequate supply of pancreatic amylase has been suggested as a factor limiting small intestinal starch digestion (Karr et al., 1966), thus accounting for greater amounts of fecal starch from steers fed the low FH, high WSC diet. However, Russell et al. (1981) pointed out that as long as intestinal pH remained approximately 6.9, pancreatic amylase activity would be capable of handling the increased corn starch in the 15% FH diet. If intestinal pH were lower than 6.9, the relative activity of pancreatic amylase may not be adequate to hydrolyze the increased starch in the diet. As FH level is decreased in the diet, the linear reduction in fecal pH to 5.99 and linear increase in fecal starch to 27.4% may suggest that pancreatic amylase activity is inadequate for maximal starch hydrolysis.

In contrast to Turgeon et al. (1983), the low but significant correlation between percent FS or fecal pH and ADG may be attributed to the large differences in forage level (15 to 50% FH), accounting for the linear decrease in ADG as forage level increased in the WSC diet. Turgeon et al. (1983) found low correlations \( (P > 0.05) \) between ADG and fecal starch or fecal pH when comparing forage levels of 5 to 15% with WSC.

Metabolism Study. Liquid passage rate averaged 6%/h when FH was fed at 4% of the diet. The increase in FH level to 8% depressed liquid passage rate, while further elevation in FH to 24% of the diet increased liquid passage rate to 8.1%/h \( (P < 0.05 \) linear and quadratic effects). Huntington et al. (1981) also reported an increased liquid passage rate with elevation in forage level.

Increasing FH level in the diet resulted in linear \( (P < 0.05) \) and cubic \( (P < 0.05) \) effects on particulate passage rates of corn calculated from rumen analyses (table 4). Steers fed 8% FH had slower particulate passage rates of corn than those fed 4, 16 or 24% FH \( (1.7 \) vs 2.3, 2.4 and 2.8%/h). Level of FH had no influence \( (P > 0.05) \) on particulate passage rates of corn calculated from fecal analyses. Other reports have also been inconclusive regarding the relationship between passage rates measured from ruminal and fecal samples. Mudgal et al. (1982) found a close association between ruminal- and fecal-retention times in sheep. Contrary to these findings, with FH as a forage source, a low correlation \( (r = 0.33) \) was observed between fecal- and ruminal-retention times in steers. These results are consistent with reports by Mira and MacRae (1982), who fed steers high-concentrate diets and found differences between fecal- and ruminal-retention times.

The depression in particular passage rate as FH level is decreased in high-concentrate diets for steers agrees with other reports (Cole et al., 1976; Owens et al., 1979). When feed intake was held relatively constant, Bines and Davey (1970) found that increasing forage level in a high-concentrate diet promoted faster particulate rumen turnover rates. Evans (1981b) suggested that increased dietary forage level may be associated with increased rumination and salivation or may be due to an alteration in the rumen microbial population. Faichney and Griffiths (1978) also found that particular turnover-rates were slower for sheep with no rumen protozoa relative to those with rumen protozoa fed concentrate diets. Perhaps, the alteration in rumen microbial population may contribute to reduced particulate turnover-rates in cattle fed high-concentrate diets.

Unless accompanied by an increase in rate of digestion leading to a reduction in extent of digestion of certain feed constituents, faster passage rate may cause a postruminal shift in digestion. However, rate of in situ ruminal DM disappearance was not influenced by FH level (table 4), although a tendency existed for a greater rate at the 24 vs 4% FH levels.

The decrease in DM digestibility as FH level increased from 4 to 24% of the diet had a linear \( (P < 0.05) \) component (table 5). However, steers fed 8% FH had a higher DM digestibility than those fed 4 and 24% FH \( (81.2 \) vs 78.8 and 71.9%). These data agree with reports by Bines and Davey (1970), but are in contrast to those of Cole et al. (1976). The latter found that DM digestibility decreased as forage level increased from 0 to 14% of the diet, then it subsequently increased as forage level increased from 14 to 21% of the diet. Differences in DM digestibility trends between the two studies may be attributed to particulate passage rate. While particulate passage rate of corn increased linearly with FH level, Cole et al. (1976) found that particulate passage rate only increased with forage level to 14% of the diet, and then
TABLE 4. INFLUENCE OF FORAGE LEVEL ON LIQUID AND PARTICULATE PASSAGE RATES OF WHOLE SHELLED CORN AND RATE OF IN SITU DRY MATTER DISAPPEARANCE OF CORN

<table>
<thead>
<tr>
<th>Item</th>
<th>Fescue hay level, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
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<tr>
<td>Liquid passage rate, %/h ab</td>
<td>6.0</td>
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<tr>
<td>Passage rates of labelled corn, %/h c</td>
<td>2.3</td>
</tr>
<tr>
<td>Rumen</td>
<td>63.1</td>
</tr>
<tr>
<td>Feces c</td>
<td>63.1</td>
</tr>
<tr>
<td>Retention time, h c</td>
<td>5.2</td>
</tr>
</tbody>
</table>

aLinear effect (P<.05).
bQuadratic effects (P<.05).
cPassage rate and retention time of labelled corn estimated from rumen and fecal sampling.
dCubic effect (P<.05).
eK is the rate constant for 1 pool model (Pond et al., 1982).

it decreased for the 21% forage level treatment. The increase in FH level in the diet also resulted in a linear (P<.05) decrease in starch digestibility. Starch digestion coefficients are lower than those reported by Cole et al. (1976), who fed cottonseed hulls (CSH) with WSC. The lower starch digestibility with FH in combination with WSC may be attributed to forage source. Previous reports (Rust and Owens, 1981) indicated that addition of CSH to WSC diets was better than alfalfa hay, prairie hay, sorghum or corn silage for improving starch digestibility. The increase in FH level also exerted a linear (P<.05) increase in ADF digestibility.

Rumen and fecal pH were not influenced (P>.05) by FH level (table 5). Contrary to the performance trial, fecal pH did not increase as FH level increased from 4 to 24% of the diet. Since intake was held constant at 1.7% of body weight in the metabolism trial, these data may suggest that corn starch intake was not high enough to depress fecal pH. Russell et al. (1981) have reported a high correlation between fecal pH and corn starch consumption in steers fed a high concentrate diet.

Van Soest and Jones (1980) suggested that the exchange buffering-capacity of fiber is substantial, and has been overlooked as a source of buffering in the gastrointestinal tract. Consequently, addition of forages to high-concentrate diets may improve rumen buffering-capacity and enhance feed utilization. However, FH level had no effect (P>.05) on rumen buffering-capacity. Perhaps, differences in FH level, may not have been sufficiently high to demonstrate an effect, because the extreme levels (4 vs 24% FH) showed a difference of only 6.3 meq/liter.

Liquid and particulate passage rates observed in our study were lower than those (avg 7.4 and 3.8%/h, respectively) for studies cited by Evans (1981a,b) in which forage level varied from 0 to 100%. However, Teeter (1981) found rumen particulate passage rates of 2.9%/h and 3.9%/h, respectively, when Yb was bound to a portion of the corn in a 78%-WSC diet and in a 90%-prairie hay diet for cattle fed at 1.7% of body weight. The passage rates of corn for steers fed a 78% concentrate diet observed by Teeter (1981) were similar to those found in our study for steers fed a 74% concentrate diet (24% FH level). The faster particulate passage rates (3.9%/h) for a forage diet observed by Teeter (1981) were agreeable with that of Evans (1981b) who compared levels of forage from 0 to 100%. Bines and Davey (1970) also demonstrated that forage level in high concentrate diets increase particulate passage rate.

An increase in feed intake has also been shown to enhance rumen particulate (Owens et al., 1979; Mudgal et al., 1982) and liquid
TABLE 5. INFLUENCE OF FESCUE HAY LEVEL ON DIGESTIBILITY, RUMINAL AND FECAL VARIABLES

<table>
<thead>
<tr>
<th>Item</th>
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<td>78.8</td>
<td>81.2</td>
<td>74.1</td>
<td>71.9</td>
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<td>94.1</td>
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<td>64.0</td>
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<td>56.2</td>
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<td>5.7</td>
<td>5.7</td>
<td>5.8</td>
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<tr>
<td>Rumen buffering capacity, meq/liter</td>
<td>92.2</td>
<td>89.7</td>
<td>92.5</td>
<td>98.5</td>
<td>3.5</td>
<td></td>
</tr>
</tbody>
</table>

*Linear effects (P<.05).

In the performance trial, the feed intakes (2.4, 2.5 and 2.2%, respectively, expressed as a percentage of body weight with increasing dietary forage level) for steers were higher than those (1.7% for all dietary forage treatments) for steers in the metabolism trial. The failure of cattle to consume the low forage (4% FH) diet at levels above 1.7% of body weight resulted in adjusting all diets in order to assure constant feed intake among treatments.

Although feed intake in the performance and metabolism trials were dissimilar, the increase in FH level resulted in a linear decrease in ADG and linear increase in passage rate of corn and concomitant reduction in DM and starch digestibility, respectively. The reduction in ADG with increasing dietary FH level from 15 to 30% at the higher DM intake may partially be attributed to an increase in ruminal particulate passage rate. Other workers (Colucci et al., 1982) also found that at higher intakes, faster passage rates of feed through the digestive tract was the major cause of lower digestibility. Owens et al. (1979) also observed a linear increase in liquid passage rate from the rumen with incremental increases in feed intake from maintenance to twice maintenance for steers fed an 84% rolled corn diet. As indicated by Van Soest (1975), increase in feed intake will pressure the flow of particulate matter resulting in an escalation of passage rate. The higher DM intake may have resulted in greater effects of forage level on liquid and particulate passage rates for steers in the performance study than that observed in the digestion study. Likewise, at higher intakes, increase in forage level in finishing diets may promote more rumination and maximize the associative effects between forages and grains which, in turn, may account for increased rumen particulate passage rate.

In conclusion, increasing FH level in a WSC-based diet resulted in a linear (P<.05) decrease in ADG and feed efficiency. At constant feed intake, increasing level of FH from 4 to 24% also resulted in a curvilinear increase (P<.05) in liquid and particulate passage rates (using rumen sampling technique) in steers. Although feed intakes were different for steers in the performance and metabolism studies, for the 15 and 30% FH diets in the performance trial, the effects of FH level on ADG may be attributed to an increase in passage rate and concomitant linear reduction in DM and starch digestibilities.

**Literature Cited**


