RUMINAL VOLATILE FATTY ACID CONCENTRATIONS AND PERFORMANCE OF STEERS FED DIFFERENT LEVELS AND FORMS OF HAY AND GRAIN 1

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Since Armstrong and Blaxter (1957) reported that acetic, propionic and butyric acids have different heat increments for fat synthesis by ruminants, investigators have been studying ways of shifting the ratios of these products of ruminal fermentation to improve animal efficiency. Factors which have been reported to affect ruminal fatty acid ratios include: proportions of roughage to concentrate, pelleting, particle size, heat treatment, various oils, protein level, environment, frequency of feeding and mineral adequacy of the diet (Pfander, 1961).

This experiment was designed to study the effect of flaking corn, grinding hay, feeding all-concentrate rations or administering antibiotics on rumen fermentation as measured by changes in the volatile fatty acid (VFA) ratios in ruminal fluid. Also examined were the reflection of resultant changes in fatty acids on animal performance and carcass characteristics.

Experimental Procedure

Forty-eight Angus steers averaging 340 kg. each were placed on a ration of supplemented ground ear corn for a 14-day preliminary period. Before the experiment began all animals received a subcutaneous implant of 24 mg. of diethylstilbestrol in the left ear. They were self-fed for 111 days in lots of two steers each with four lots of steers assigned to each treatment.

A completely randomized design with a 3 x 2 x 2 factorial arrangement of treatments was used for treatment comparison. The factors were: no hay, long hay and ground hay; flaked corn and ground corn; and a combination antibiotic bolus and no bolus. The rations are given in table 1. All rations were supplemented with protein, calcium and phosphorus to meet recommended requirements (N.R.C., 1963). Vitamin D, trace minerals and vitamin A were also added. The components of the supplements are given in table 2.

Long hay was hand fed in rations 3 and 4 at the rate of 1.8 kg. per head daily. The ground hay portion of rations 5 and 6 was mixed with the other ingredients to make a complete ration. The composition of the ration components is given in table 3. By altering the ratio of ration components the intake of ground hay was maintained at about 1.8 kg. per head per day, and equal protein intake was maintained on all rations during the 111-day feeding period.

At the beginning of the experiment one animal in each lot was given a sustained release bolus containing 6 gm. of antibiotic activity. The antibiotics contained in the bolus were four parts penicillin, seven parts erythromycin, seven parts tylosin and seven parts streptomycin. The steers were weighed without shrinking at 14-day intervals, and an average of two weights taken on the first and last days of the experiment was used as initial and final weights. At 28-day intervals rumen samples were taken between 9 and 10 a.m. by means of a stomach tube; pH was measured immediately by using glass electrodes, and the samples were processed according to the method of Erwin et al. (1961) and analyzed for VFA by means of gas chromatography. At the conclusion of the experiment the animals were slaughtered for carcass measurements. The data were subjected to analysis of variance and differences among treatment means were tested for significance by the multiple range test (Duncan, 1955).

Results and Discussion

A summary of the feedlot data is given in table 4. Steers receiving no hay gained significantly less during the 111-day experiment than did steers receiving long hay or ground hay. This significantly lower gain was due at least in part to the decreased gains during the
first 56 days of the experiment. During this period steers fed no hay gained almost 0.5 kg. per day less than steers receiving hay in their ration. During the last 56 days of the experiment the steers receiving no hay gained about the same as those receiving hay. The steers fed no hay consumed 2.3 kg. less (P<.05) feed per day, but their feed intake per kilogram of gain was still slightly higher than that of steers receiving hay. These feed-lot gains are different from those reported by Wise et al. (1961), in which gain and feed efficiency did not change significantly when an all-concentrate basal ration with or without ground or long hay was fed to 193-kg. calves.

TABLE 3. PROXIMATE ANALYSIS OF FEEDSTUFFS INCLUDED IN THE EXPERIMENTAL RATIONS

<table>
<thead>
<tr>
<th>Feed</th>
<th>Dry matter</th>
<th>Crude protein</th>
<th>Ether extract</th>
<th>Crude fiber</th>
<th>Ash</th>
<th>Gross energy kcal./gm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flaked corn</td>
<td>90.0</td>
<td>8.6</td>
<td>3.9</td>
<td>3.2</td>
<td>1.1</td>
<td>4.10</td>
</tr>
<tr>
<td>Ground corn</td>
<td>89.3</td>
<td>8.2</td>
<td>3.6</td>
<td>3.5</td>
<td>1.2</td>
<td>4.07</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>92.7</td>
<td>16.6</td>
<td>1.7</td>
<td>27.0</td>
<td>6.8</td>
<td>4.25</td>
</tr>
<tr>
<td>Suppl. I</td>
<td>91.3</td>
<td>39.7</td>
<td>0.7</td>
<td>7.2</td>
<td>10.9</td>
<td>4.07</td>
</tr>
<tr>
<td>Suppl. II</td>
<td>93.6</td>
<td>37.5</td>
<td>1.3</td>
<td>5.2</td>
<td>15.2</td>
<td>3.92</td>
</tr>
</tbody>
</table>

* Supplement I was fed to steers receiving no hay.
* Supplement II was fed to steers receiving hay in their ration.

There were no significant differences in gain due to physical form of corn or antibiotic treatment; however, during the first 56 days steers receiving antibiotics gained 0.15 kg. per day less than those receiving no antibiotics. Dressing percent for steers receiving no hay was significantly lower than for those fed hay; steers fed no hay graded two-thirds of a grade

TABLE 4. PERFORMANCE OF STEERS FED DIFFERENT LEVELS AND FORMS OF HAY AND GRAIN AND ANTIBIOTIC TREATMENTS

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hay</th>
<th>Corn</th>
<th>Antibiotic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
<td>Long</td>
<td>Ground</td>
</tr>
<tr>
<td>No. steers</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Final wt., kg.</td>
<td>443</td>
<td>464</td>
<td>478</td>
</tr>
<tr>
<td>Av. daily gain, kg.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–56 days</td>
<td>0.73*</td>
<td>1.20*</td>
<td>1.22*</td>
</tr>
<tr>
<td>56–111 days</td>
<td>1.09</td>
<td>1.09</td>
<td>1.25</td>
</tr>
<tr>
<td>Av. daily feed, kg.</td>
<td>7.5*</td>
<td>9.8*</td>
<td>9.9*</td>
</tr>
<tr>
<td>Feed/kg. gain, kg.</td>
<td>8.40</td>
<td>7.83</td>
<td>8.07</td>
</tr>
<tr>
<td>Av. daily feed intake, kg.</td>
<td>6.4</td>
<td>7.2</td>
<td>7.4</td>
</tr>
<tr>
<td>Corn</td>
<td>1.1</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Supplement</td>
<td>1.1</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Hay</td>
<td>0.0</td>
<td>1.8</td>
<td>1.8</td>
</tr>
</tbody>
</table>

* Means on the same line within a subgroup bearing different superscript letters differ significantly (P<.05).
less (P<.05) than steers fed long hay; and cooler shrink was significantly (P<.05) lower for steers fed no hay (table 5). Marbling was greater in carcasses of steers fed long hay; however, the differences were not significant. The additional marbling was the major reason responsible for the higher carcass grade of steers fed long hay. Most of these differences can be explained by the degree of fatness of the animals or by their final weights. There were no significant differences in any carcass measurements due to either the form of corn fed or to the antibiotic treatment.

A summary of the analyses on ruminal fluid samples is given in table 6. Steers fed long hay had a higher pH than those fed ground hay, and both were higher than that of steers fed no hay. Total VFA concentration followed an inverse pattern in that steers fed long hay had a lower concentration than steers fed either ground hay or no hay. Balch and Rowland (1957) also found that pH of ruminal fluid varied inversely with the concentration of VFA and the lowest pH was observed with low-hay diets. Similar results have been reported by Raun et al. (1962) and Luther and Trenkle (1963).

The molar percent concentration of the fatty acids shows differences in acetate, propionate and n-valerate due to hay treatments. Steers fed no hay and ground hay had significantly (P < .05) less acetate and more propionate than did those fed long hay. Several investigators have reported that increasing the percent of concentrate in the diet resulted in a narrower acetate-propionate ratio (Brown et al., 1958; Putnam and Davis, 1958; Raun et al., 1962; Donefer et al., 1963). Balch and Rowland (1957) and Wright et al. (1963)

### TABLE 5. CARCASS DATA OF STEERS FED DIFFERENT LEVELS AND FORMS OF HAY AND GRAIN AND ANTIBIOTIC TREATMENTS

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hay</th>
<th>Corn</th>
<th>Antibiotic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
<td>Long</td>
<td>Ground</td>
</tr>
<tr>
<td>Cold carcass wt., kg.</td>
<td>258a</td>
<td>274ab</td>
<td>281b</td>
</tr>
<tr>
<td>Dressing %</td>
<td>60.7a</td>
<td>62.8b</td>
<td>62.1b</td>
</tr>
<tr>
<td>Carcass grade</td>
<td>11.4a</td>
<td>13.1b</td>
<td>12.3ab</td>
</tr>
<tr>
<td>Marbling</td>
<td>5.1</td>
<td>6.3</td>
<td>5.6</td>
</tr>
<tr>
<td>Cooler shrink, %</td>
<td>1.76a</td>
<td>1.88b</td>
<td>1.91b</td>
</tr>
<tr>
<td>Rib eye, sq. cm.</td>
<td>71.0</td>
<td>73.5</td>
<td>73.5</td>
</tr>
<tr>
<td>Fat over eye, cm.</td>
<td>1.37</td>
<td>1.77</td>
<td>1.60</td>
</tr>
</tbody>
</table>

a, b Means on the same line within a subgroup bearing different superscript letters differ significantly (P<.05).

e High Good=11, Low Choice=12 and Average Choice=13.
d Slight~4, small~5, and modesty~6.

### TABLE 6. RUMEN SAMPLE DATA OF STEERS FED DIFFERENT LEVELS AND FORMS OF HAY AND GRAIN AND ANTIBIOTIC TREATMENTS

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hay</th>
<th>Corn</th>
<th>Antibiotic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
<td>Long</td>
<td>Ground</td>
</tr>
<tr>
<td>Rumen pH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-56 days</td>
<td>5.8a</td>
<td>6.3b</td>
<td>6.0ab</td>
</tr>
<tr>
<td>56-111 days</td>
<td>5.6a</td>
<td>6.5b</td>
<td>6.1c</td>
</tr>
<tr>
<td>0-111 days</td>
<td>5.7a</td>
<td>6.3b</td>
<td>5.9e</td>
</tr>
<tr>
<td>Molar percent of VFA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>38.9a</td>
<td>45.5b</td>
<td>41.3a</td>
</tr>
<tr>
<td>C3</td>
<td>40.3a</td>
<td>35.4b</td>
<td>40.2a</td>
</tr>
<tr>
<td>C4</td>
<td>12.4</td>
<td>12.1</td>
<td>11.5</td>
</tr>
<tr>
<td>i-C5</td>
<td>2.7</td>
<td>3.1</td>
<td>2.9</td>
</tr>
<tr>
<td>n-C5</td>
<td>5.6a</td>
<td>3.9b</td>
<td>5.9b</td>
</tr>
<tr>
<td>C10/C2</td>
<td>1.02a</td>
<td>1.34b</td>
<td>1.05a</td>
</tr>
<tr>
<td>Total VFA concentration, µ moles/ml.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-56 days</td>
<td>174</td>
<td>145</td>
<td>170</td>
</tr>
<tr>
<td>56-111 days</td>
<td>129a</td>
<td>98b</td>
<td>116bh</td>
</tr>
<tr>
<td>0-111 days</td>
<td>156a</td>
<td>126b</td>
<td>184n</td>
</tr>
</tbody>
</table>

a, b Means on the same line within a subgroup bearing different superscript letters differ significantly (P<.05).
TABLE 7. MEAN PERCENT OF ACETATE IN RUMINAL FLUID AS AFFECTED BY ANTI-
BIOTIC AND HAY TREATMENTS*  

<table>
<thead>
<tr>
<th>Hay</th>
<th>Antibiotic</th>
<th>No bolus</th>
<th>Bolus</th>
</tr>
</thead>
<tbody>
<tr>
<td>No hay</td>
<td>44.8</td>
<td>37.0</td>
<td></td>
</tr>
<tr>
<td>Long hay</td>
<td>44.0</td>
<td>47.1</td>
<td></td>
</tr>
<tr>
<td>Ground hay</td>
<td>40.6</td>
<td>42.1</td>
<td></td>
</tr>
</tbody>
</table>

* Significant (P<.05) interaction due to antibiotic and hay treatments.

have also reported decreases in acetate-
propionate ratio when ground hay was added
to the diet instead of long hay.

Steers fed no hay had 40% greater con-
centration of n-valerate than did those steers
receiving hay in their ration. Other investiga-
tors have reported similar increases in the
higher VFA. Balch et al. (1955) reported that
percent of the higher fatty acids was greater
on high concentrate rations, and Belasco
(1956) found that valerate increased mark-
edly when starch was the sole carbohydrate in
an in vitro experiment.

The form of corn fed tended to affect ruminal pH and total VFA. Steers fed flaked
corn had a pH of 6.1 compared to a pH of
5.9 for ground corn. This difference
approached significance (P<.10). Animals fed
ground corn had a larger total concentration of VFA in their ruminal fluid than animals fed
flaked corn. There were no differences in molar
percent of the individual acids or the acid
ratios due to the form of corn that was fed. Newland et al. (1962) have also reported a
lowered acetate-propionate ratio when flaked
corn was fed compared with ground corn;
however, Raun et al (1962) reported that dry
steam-autoclaved corn widened the acetate-
propionate ratio.

There were no differences in pH, total VFA
concentration, molar percent of the individual
acids or VFA ratios due to the administration
of antibiotic boluses. There was a significant
interaction between the antibiotic and the hay
treatments on molar percent of acetate in the
ruminal fluid (table 7). There was a higher
percent of acetate without hay, a lower per-
cent with long hay, and little difference with
ground hay, in the ruminal fluid of animals
receiving antibiotics compared to those re-
ceiving no antibiotics.

Summary

Forty-eight Angus steers averaging 340 kg.
were self-fed for 111 days on rations consist-
ing of no hay, long hay, or ground hay with
flaked or ground corn. Half of the steers on
each ration were given a sustained release anti-
biotic bolus. Feed-lot gains, feed efficiency,
carcass data, ruminal pH, and VFA concen-
tration were measured.

Steers receiving no hay gained less and had
lower feed consumption per day than steers
receiving hay in their ration. There were no
significant differences in feed efficiency. Steers
receiving no hay had lower dressing percent,
less cooler shrink and lower carcass grades
than steers receiving long hay. Those receiving
no hay had a lower ruminal pH than those
receiving ground hay, and both were lower
than steers fed long hay. Steers fed long hay
had more acetate and less propionate with a
wider acetate-propionate ratio. Steers fed no
hay had more n-valerate than steers fed hay;
however, those fed long hay had less total
VFA. Steers receiving flaked corn had molar
percents of VFA similar to those receiving
ground corn but less total VFA than did the
steers fed ground corn. There were no dif-
fferences in VFA concentration due to the ad-
ministration of antibiotics.

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