BOVINE HAIR AS AN INDICATOR OF CALORIE-PROTEIN STATUS

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SUMMARY

Hair samples from beef cattle were examined to determine their response to feeding varying levels of protein and energy. Blood urea nitrogen (BUN) and nitrogen balance tests were also performed to provide a reference for comparison.

Twenty-four weanling calves each weighing approximately 200 kg were equally divided into four groups and were fed the following percentages of the N.R.C. recommendations for crude protein with energy to give the indicated predicted gain: high protein-high energy (HP-HE) group -- 111%, 1.0 kg/day; high protein-low energy (HP-LE) group -- 102%, .2 kg/day; low protein-high energy (LP-HE) group -- 65%, .8 kg/day; low protein-low energy (LP-LE) group -- 45%, .2 kg/day, respectively. After 60 days all groups received the HP-HE ration for a 30-day repletion period.

Hair samples were taken from the back and stomach regions on day 1 and every 15 days thereafter until the conclusion of the experiment on day 90. Several parts of the root and shaft were measured and evaluated, including percent of the hairs in the anagen (active) phase, percent of the bulbs in atrophy, shaft diameter, bulb diameter and bulb length.

Of all the hair parameters evaluated in this study, percent of the bulbs in atrophy was the only one effective in diagnosing a protein or energy deficiency. Differences among groups (P<.01) found on day 15 remained through day 60. As energy and/or nitrogen intake decreased, percent of the bulbs in atrophy increased (P<.001). Average daily gain, nitrogen balance and BUN results reflected the level of protein and energy intake.

(Key Words: Bovine Hair, Protein, Energy, Deficiency, Atrophy, Condition.)

INTRODUCTION

The evaluation of an animal's condition is usually subjective and often inaccurate unless aided by a knowledge of its nutritional background. Objective tests, such as the nitrogen balance test and blood urea nitrogen (BUN) analysis, can be helpful in determining a protein or energy inadequacy. These tests can also be misleading if the background of the animal is not known. Also, tests such as these are designed mainly for research purposes and not for evaluating an animal's condition in field situations.

Bradfield (1968) observed changes in the hair as a result of protein and calorie deficiencies in humans. Bradfield (1972) reported that during a protein deficiency, blood protein levels were maintained at the expense of other tissues including hair. Hair changes occurred on the shaft of the hair and on parts of the hair bulb (Anonymous, 1968; Bradfield, 1968, 1971, 1972; Bradfield et al., 1969a,b; Bradfield and Jelliffe, 1970).

A simple, practical method for diagnosing a protein or calorie deficiency prior to development of conditions resulting in economic loss would be very useful to the livestock industry. The purpose of this study was to see if hair from cattle could be used to diagnose a protein and/or energy deficiency as had been done with hair from humans. Attempts were made to determine the effectiveness and the practicality of the test.

MATERIALS AND METHODS

Twenty-four steer calves of either Hereford x Angus or Hereford breeding, weighing approximately 200 kg were purchased. They were acclimated to the experimental facilities and were fed a balanced pre-experimental ration for 3 weeks. The steers were divided into four weight-equalized and breed-equalized groups. The treatments consisted of four different rations (table 1) of varying levels of protein and energy which were fed to the appropriate
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groups on days 1 through 60. On days 61 through 90, all groups received the high protein-high energy (HP-HE) or control ration which was fed to provide 1.0 kg per day gains and was balanced for all other nutrients (N.R.C., 1970). Rations 2, 3 and 4 were fed to provide the following percentages of the crude protein requirement and energy for the following expected gains: 102%, .22 kg/head/day (high-protein-low energy); 65%, .79 kg/head/day (low protein-high energy); 45%, .21 kg/head/day (low protein-low energy), respectively. The rations were balanced for all other nutrients by amount per day (N.R.C., 1970).

Two animals from each group were selected for nitrogen balance tests. Two 5-day trials were conducted on days 26 through 30 and 56 through 60 while the groups were fed their respective rations. A third trial was conducted on days 86 through 90 while they were all fed the same ration.

Blood samples were taken from the jugular vein of each animal on days 1, 15, 30, 45 and 60 while they were fed their respective test rations and days 75 and 90 while they were all fed the same ration. The blood samples were analyzed for urea nitrogen using the method developed by Foster and Hochholzer (1971).

Hair samples were taken from three different locations on the days that blood was taken. One sample was taken from the lumbar region to the left of the midline, a second sample was taken from the stomach region on the right side and a third sample was taken from the lumbar region on the right side to measure hair growth. The third region had been shaved on day 1 of the experiment. Hair samples were plucked from each of the locations using a curved hemostat with the tongs covered with thin rubber tubing to prevent slipping and excessive breaking of hair samples. Hair taken from the left lumbar and stomach regions were weighed and measured for length. Under the microscope, hair samples were measured for bulb diameter, bulb tip diameter, shaft diameter and bulb length and evaluated as to whether they were in the anagen (active) or telogen (inactive) phase (figure 1). Anagen hairs were also examined to determine if they were atrophied.

The results of the nitrogen balance trials, BUN tests and the hair study were analyzed statistically using the one-way analysis of variance and the two-way analysis of variance. Statistical differences between treatments and between days were determined with the LSD

<table>
<thead>
<tr>
<th>Item</th>
<th>HP-HE</th>
<th>LP-HE</th>
<th>LP-LE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn (Kg DM/head/day)</td>
<td>1.85</td>
<td>.62</td>
<td>.62</td>
</tr>
<tr>
<td>Corn silage (Kg DM/head/day)</td>
<td>2.46</td>
<td>.81</td>
<td>.81</td>
</tr>
<tr>
<td>Beet pulp (Kg DM/head/day)</td>
<td>4.47</td>
<td>1.14</td>
<td>1.14</td>
</tr>
<tr>
<td>Cottonseed meal (Kg DM/head/day)</td>
<td>.87</td>
<td>.31</td>
<td>.31</td>
</tr>
<tr>
<td>Mineral supplement (Kg DM/head/day)</td>
<td>.30</td>
<td>.12</td>
<td>.12</td>
</tr>
<tr>
<td>Total crude protein by analysis (Kg DM/head/day)</td>
<td>.82</td>
<td>.62</td>
<td>.62</td>
</tr>
<tr>
<td>Mean ME/head/day (actually fed)</td>
<td>16.60</td>
<td>8.04</td>
<td>7.82</td>
</tr>
</tbody>
</table>

a Experimental rations were fed from days 1 through 60. On days 61 through 90 all groups received the HP-HE ration.

b High protein-high energy (HP-HE), high protein-low energy (HP-LE), low protein-high energy (LP-HE), low protein-low energy (LP-LE).

c The mineral supplement contained: 93.3% Aurofloc 10, chlorella, 22 mg/kg; 4% Vitamin A (325,000 IU/g), 2.5% dicalcium phosphate, 2.5% defol molasses and 71.5% ground corn.
RESULTS AND DISCUSSION

Actual average daily gains during the 60-day period when the animals were on the test rations were 1.08, .25, .69 and .18 kg/head/day for the high protein-high energy (HP-HE), high protein-low energy (HP-LE), low protein-high energy (LP-HE) and low protein-low energy (LP-LE) groups, respectively. During the 30-day repletion period, predicted daily gains and actual daily gains in kg/head/day were 1.05, 1.14 (HP-HE); 1.05, 1.50 (HP-LE); 1.15, 1.37 (LP-HE); and 1.05, 1.52 (LP-LE), respectively.

The results of the nitrogen balance study are shown in table 2. The animals on the HP-HE ration had high levels of nitrogen retention, as expected, throughout the 90-day trial. Relatively low levels of retained nitrogen were found for the animals on the HP-LE ration, with much of the protein apparently being utilized for energy purposes. The steers fed the LP-HE ration had slightly higher levels of nitrogen retention than the steers on the HP-LE ration. The most deficient ration, the LP-LE ration, produced the lowest levels of nitrogen retention. Lofgreen et al. (1951), Broster et al. (1969) and Eskeland et al. (1974) have studied the effects of energy intake on nitrogen balance of ruminants and have shown an increase in nitrogen retention with increased energy intake.

After 30 days on the repletion or HP-HE ration, all animals exhibited high levels of nitrogen retention, especially the animals that had been on the LP-LE ration. One of the animals from the LP-HE group had a low level of feed intake during the final digestion trial causing the nitrogen retention to be lower than expected. The LP-LE group had a high level of feed intake during the final trial with approximately the same nitrogen digestibility as the rest of the groups but a much higher utilization of absorbed nitrogen, thus accounting for the high nitrogen retention value. The response of the LP-LE group to the repletion ration is typical of a compensatory response (Paquay et al., 1972).

Blood urea nitrogen values reflected the energy-protein ratio of the rations fed in the sample taken on day 15 (table 3). These values remained fairly constant during the 60-day period while the groups were on their respective rations. The HP-HE group maintained normal values (The Merck Veterinary Manual, 1973) which were different (P<.01) than all other groups. The LP-HE group had very low levels of BUN indicating that NH₃ was being incorporated efficiently into microbial protein allowing little free NH₃ to be absorbed. The opposite of this situation was occurring with the HP-LE group where BUN values were very high. With this treatment, NH₃ would be expected to be in

TABLE 2. GRAMS OF NITROGEN RETAINED PER ANIMAL a EACH DAY

<table>
<thead>
<tr>
<th>Days of study</th>
<th>Experimental groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HP-HE</td>
</tr>
<tr>
<td>26–30</td>
<td>39c</td>
</tr>
<tr>
<td>56–60</td>
<td>27c</td>
</tr>
<tr>
<td>86–90</td>
<td>26c</td>
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</table>

a Values given are means, n = 2.

b Standard error.

c,d Means within same line bearing different superscript letters differ significantly (P<.01).

e,f Means within same line bearing different superscript letters differ significantly (P<.05).
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TABLE 3. EFFECT OF PROTEIN AND ENERGY LEVELS ON BLOOD UREA NITROGENa

\[(\text{mg/100 ml})\]

<table>
<thead>
<tr>
<th>Day of study</th>
<th>Experimental groupsb</th>
<th>HP-HE</th>
<th>HP-LE</th>
<th>LP-HE</th>
<th>LP-LE</th>
<th>SEc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.1d</td>
<td>11.7d</td>
<td>12.3d</td>
<td>11.9d</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>10.3d</td>
<td>16.4e</td>
<td>3.3f</td>
<td>5.9fh</td>
<td>.7</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>10.9d</td>
<td>20.4e</td>
<td>2.7f</td>
<td>6.4gh</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>11.4d</td>
<td>21.1e</td>
<td>2.2f</td>
<td>7.1fh</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>11.1d</td>
<td>17.1e</td>
<td>2.6f</td>
<td>4.8fh</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>12.5dg</td>
<td>6.4ei</td>
<td>9.8dfh</td>
<td>8.8fh</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>9.0d</td>
<td>6.1d</td>
<td>7.3d</td>
<td>7.1d</td>
<td>.8</td>
<td></td>
</tr>
</tbody>
</table>

aValues are given as means, \(n = 6\).
bGroups received respective rations from day 1 through day 60. On days 61 through 90 all received the HP-HE ration.
cStandard error.
d,e,f Means within same line bearing different superscript letters differ significantly (\(P<.01\)).
g,h,i Means within same line bearing different superscript letters differ significantly (\(P<.05\)).

plentiful supply in the rumen with a relatively short supply of carbon skeletons on which to attach to form microbial protein or an inadequate supply of energy (ATP) needed for microbial synthesis. The excess \(\text{NH}_3\) would be absorbed to form urea in the liver. Lewis (1957) and Preston et al. (1965) examined the response of BUN to different levels of nitrogen and energy intake and found that nitrogen intake was positively correlated with BUN while increasing levels of energy tended to decrease the BUN level. The HP-HE and LP-LE groups had BUN values intermediate to the HP-LE and LP-HE groups. When animals were returned to the repletion diet, BUN values returned to slightly lower than normal values, presumable due to increased utilization of absorbed nitrogen in an attempt by the body to compensate for the 60 days on the depletion rations. The reason for the low levels of BUN on day 90 for all groups was not apparent.

Hair Study. With the exception of measuring for atrophied bulbs, objective hair measurements were too variable to produce significant results or trends. The reason for this variation was due primarily to the differences in hair sizes within an animal. Percent of the hairs in atrophy proved to be the strongest and most useful parameter for diagnosing a protein or calorie deficiency. If bulb diameters of anagen hairs were less than or equal to shaft diameters and appeared shrunken, they were considered to be atrophied. The hair of animals responded to both a protein deficiency and an energy deficiency as shown in figure 2. The high values of percent atrophied hairs from the first sample could be attributed to the relatively poor condition of the animals when purchased even though they were subjected to a three-week pre-experimental ration. The first sample taken after the animals were given their respective rations, day 15, produced significant differences in percent atrophy. The HP-HE group had percent atrophy values that were less (\(P<.01\)) than any of the other groups while the LP-LE group had atrophy values higher (\(P<.01\)) than any of the other groups. There was no difference (\(P>.05\)) between the HP-LE and LP-HE groups. These same differences persisted until the animals were fed the repletion ration. The sample

![Figure 2. Effect of protein and energy levels on hair bulb atrophy. Each point represents the mean of six animals expressed as percent of the bulbs that were in atrophy.](image-url)
TABLE 4. TREATMENT EFFECT ON HAIR GROWTH (cm)

| Time interval (days) | HP-HE | HP-LE | LP-HE | LP-LE | SE
|----------------------|-------|-------|-------|-------|-----
| 15–30                | .9c   | .5d   | .5d   | .6d   | .6d |
| 30–45                | .7c   | .6c   | .6c   | .4d   | .09 |
| 45–60                | .7c   | .6c   | .8c   | .7c   | .08 |
| 60–75                | .3c   | .8d   | .8d   | .8d   | .10 |
| 75–90                | .3c   | .3c   | .3c   | .2c   | .14 |

aValues given are means, n = 6.
bStandard error.
c,dMeans within same line bearing different superscript letters differ significantly (P<.01).

taken 15 days after the animals were placed on the repletion ration resulted in no significant differences among the groups; however, the LP-LE group had a noticeably higher percentage of atrophied hairs possibly indicating its subjection to a more severe degree of depletion. Least squares analysis indicated that as protein and caloric restriction increased, the percent atrophy markedly increased (P<.001).

The determination of the phase of activity of the hair produced no significant differences among groups; however, a trend in the phase of activity occurred in all groups during the course of the trial which was thought to be seasonally influenced (Yeates, 1955). On day 1 of the trial in the first part of November, approximately 50% of the hair was in the anagen phase. This value increased to approximately 70% on December 1, then decreased quite rapidly to about 10% activity on January 31. Hayman (1965) reported similar results.

The hair growth study showed that the hair growth rate was dependent on nutrient intake (table 4). The HP-HE group had a significantly higher growth rate than the other groups for the first 45 days of the study. On day 60 hair growth rate was not significantly different among groups. On day 75, the growth rate of the HP-HE group was less (P<.01) than the other groups indicating that the growth rate had reached a plateau. On day 90, all groups had essentially the same low growth rate. Martin et al. (1969) found that calves fed low protein or low energy rations had hair growth which was significantly slower than control calves.

Nitrogen balance tests, blood tests and hair tests all demonstrated the influence of the treatments. In this study BUN was highly correlated with an energy to protein ratio value (r = -.94). Percent of the hairs in atrophy responded to either a protein or energy deficiency with an additive response when both nutrients were deficient (r = -.92).

The use of hair as an indicator for protein and/or energy deficiency appears to have potential. It must be realized that the treatments of this experiment were more severe than would be encountered in most practical situations. Further studies would be required to determine whether hair response was sufficiently sensitive, for instance, to respond to an energy or protein deficiency before a reduced weight gain or lowered feed efficiency occurred.

LITERATURE CITED