RELATIONSHIP OF GROWTH AND PUBERTY IN BEEF HEIFERS FED MONENSIN

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Summary

An experiment was designed to determine the effects of dietary monensin on age and weight at puberty in Bos taurus crossbred beef heifers. One hundred and forty heifers were allotted to two weight classes: heavy (H) and light (L) groups, consisting of heifers above and below the average weaning weight, respectively. Heifers within each weight class were assigned to one of three diets during a 203-d winter feeding period: (1) R, 80% roughage: 20% concentrate; (2) M1, R diet plus monensin (200 mg/head daily) with feed intake restricted to produce average daily gains (ADG) similar to R and (3) M2, R diet plus monensin (200 mg/head daily). ADG was higher (P<.001) for M2 heifers than for R and M1 heifers, which performed similarly. Age and weight at puberty were similar across treatments in L heifers. However, in the H group, HM1 and HM2 heifers were younger (P<.07) at puberty than HR heifers and this difference was not removed by covariate adjustment of either ADG or body weight. Weight at puberty was greater (P<.01) for HM2 heifers than for HM1 or HR heifers; however, this difference was removed by covariate adjustment of either ADG or body weight. Ninety-one percent of LM2 heifers and 100% of all other groups had reached puberty before the breeding season. Pregnancy rates did not differ significantly between treatment groups. Supplementation of a high roughage diet with monensin decreased age at puberty of heifers in the heavy weight class and this decrease was not due to increased body weight or ADG. Perhaps heifers with above average weaning weight possess a greater inherent growth potential than heifers below the average weaning weight and hence are more capable of utilizing monensin to an advantage.

(Key Words: Monensin, Heifer, Puberty, Average Daily Gain.)

Introduction

Recent reports have shown that altering rumen fermentation patterns by varying the quality of dietary energy expedites the onset of puberty. Moseley et al. (1977) reported that 77% of monensin-fed heifers reached puberty compared with only 47% of control heifers with similar weight gains. In another study with Brangus heifers, McCartor et al. (1979) found that heifers fed diets with lower acetic:propionic acid ratios were younger and weighed less at puberty than heifers fed control diets. This concept is supported by Rhodes et al. (1978).
Brahman crossbred heifers were fed a high energy protein-protected lipid, (which increases the amount of energy because it is not degraded in the rumen), or a concentrate diet to achieve similar weight gains. Lipid-fed heifers were fatter with higher plasma triglycerides, lower total VFA concentrations and a lower percentage reached puberty. Conceivably, changes in ruminal fermentation patterns to favor propionic acid production produce an endocrine response and influence the mechanisms regulating puberty. These mechanisms appear to be at least partially independent of body weight gains. Thus, an experiment was conducted to determine if feeding monensin has an effect on age and weight at puberty in heifers which is independent of body weight gains.

**Materials and Methods**

One hundred and forty crossbred Bos taurus beef heifers were assigned to one of two weight groups. The average weaning weight was calculated, and heifers above that weight were assigned to the heavy (H) group (226.9 kg) and those below that weight were assigned to the light (L) group (199.2 kg). These weight groups were further divided into three feed treatments: (R), high roughage diet fed 80% good quality chopped crested wheatgrass hay (IFN 1-05-418) plus 20% concentrate; (M1), R diet plus 200 mg monensin7/head daily fed to produce the same average daily gains (ADG) as R by limiting feed intake by about 10% and (M2), R diet plus 200 mg monensin/head daily fed the same daily dry matter intake as R (table 1).

The concentrate portion of all diets included 70% ground yellow dent corn (IFN 4-02-931) and 30% soybean oil meal (IFN 5-04-600). Monensin premix8 was mixed with soybean oil meal to form a secondary premix which was fed in the concentrate portion of the diet to supply the 200 mg monensin/head daily fed. At six separate times, samples of the secondary premix containing monensin were assayed9. The monensin content of the premix was sufficient to supply the 200 mg desired. Assay values averaged 101% of the theoretical content and ranged from 90 to 117%.

All heifers were group fed in drylots to attain a target weight of 318 kg at the end of a 203-d feeding period. In order to reach the target weight, L heifers were fed to achieve a higher rate of gain than H heifers (.58 vs .45 kg/d, respectively). At 28-d intervals, the heifers were weighed and feed intake was adjusted as necessary. At the end of the experimental period, heifers were removed from the drylots, feed treatments discontinued, and they were placed on range pastures for a 45-d breeding season. Rumen fluid was collected 5 to 7 h after feeding from five heifers per weight x treatment group (30 heifers) at 133 d on test and five different heifers per weight x treatment group at 191 d on test. Rumen samples were assayed9 by standard gas-liquid chromatography techniques for volatile fatty acids (VFA), acetic acid (C2), propionic acid (C3) and butyric acid (C4).

Throughout the trial, heifers were observed twice daily for behavioral estrus. To aid in estrus detection, sterile bulls equipped with grease marking harnesses were maintained with the heifers. Puberty was recorded as the first behavioral estrus followed by the development of a palpable corpus luteum. All heifers were bred by artificial insemination during a 45-d breeding season and rectally palpated 60 d after the end of the breeding season to determine pregnancy.

Weight, puberty and conception data were analyzed as a 3 x 2 factorial design, with treatment and weight class as main effects, using Harvey's least-squares procedure for unequal subclass number (Harvey, 1960). A covariate analysis was used to adjust the data for designated characteristics. VFA data were analyzed by unweighted mean analysis of variance (Steel and Torrie, 1960). Single degree of freedom orthogonal comparisons were made within weight class for some traits (Steel and

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7 Monensin sodium: Eli Lilly Co.
8 Supplied by Eli Lilly Co.
9 Assays performed by Eli Lilly Laboratories, Greenfield, IN.
TABLE 2. ANALYSIS OF VARIANCE OF ON-TEST* AND OFF-TESTb BODY MEASUREMENTS

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>ON-TESTc Weight</th>
<th></th>
<th>OFF-TESTc Weight</th>
<th>ADG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
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<td>653</td>
<td>65,099.2***</td>
<td>1.75***</td>
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<td>Weight class</td>
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<td>130,702**</td>
<td>97,369.2***</td>
<td>.06</td>
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<tr>
<td>Interaction</td>
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<td>2,782</td>
<td>12,560.5*</td>
<td>.09</td>
<td></td>
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<td>Error</td>
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<td>1,249</td>
<td>3,137.8</td>
<td>.04</td>
<td></td>
</tr>
</tbody>
</table>

Single degree of freedom comparisons

(1) L: R + M1 vs M2 NS *** ***
(2) L: R vs M1 NS NS NS
(3) H: R + M1 vs M2 NS *** ***
(4) H: R vs M1 NS NS NS

aD 1 of study.
bD 203 of study.
cMean squares.
*P<.05.
**P<.01.
***P<.001.

Torrie, 1960). For body weight and ADG, M2 heifers were compared with R and M1 heifers, and R heifers were compared with M1 heifers. These comparisons were selected because weight gains were projected, by experimental design, to be equal for R and M1 but uncontrolled for M2. For puberty traits, R heifers were compared with M1 and M2, and M1 was compared with M2. These comparisons were selected because the hypothesis under test stated that monensin-fed heifers would reach puberty at a different age and weight than heifers fed a monensin-free diet.

Results and Discussion

At the beginning of the experiment, heifers averaged 236 d of age and weighed 213 kg. The H heifers were 8.9 d older (240.3 vs 231.4 d; P<.01) and 27.7 kg heavier (226.9 vs 199.2 kg; P<.01) than the L heifers (table 2). Means of

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TABLE 3. VOLATILE FATTY ACID CONCENTRATIONS (MOL/100 MOL) AND TOTAL VFA PRODUCTION (MMOL/LITER) IN RUMEN FLUID

<table>
<thead>
<tr>
<th>Volatile fatty acid</th>
<th>Days on test</th>
<th>Light Roughage</th>
<th>Monensin 1</th>
<th>Monensin 2</th>
<th>Heavy Roughage</th>
<th>Monensin 1</th>
<th>Monensin 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td>133</td>
<td>70.6</td>
<td>66.9</td>
<td>67.8</td>
<td>70.0</td>
<td>71.8</td>
<td>66.9</td>
</tr>
<tr>
<td></td>
<td>191</td>
<td>72.7</td>
<td>67.8</td>
<td>72.3</td>
<td>75.1</td>
<td>71.1</td>
<td>69.5</td>
</tr>
<tr>
<td>C3</td>
<td>133</td>
<td>18.6</td>
<td>24.8</td>
<td>24.0</td>
<td>20.2</td>
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<td></td>
<td>191</td>
<td>19.6</td>
<td>25.9</td>
<td>21.5</td>
<td>17.9</td>
<td>22.7</td>
<td>25.2</td>
</tr>
<tr>
<td>C4</td>
<td>133</td>
<td>10.7</td>
<td>8.1</td>
<td>8.2</td>
<td>9.8</td>
<td>7.3</td>
<td>9.6</td>
</tr>
<tr>
<td></td>
<td>191</td>
<td>7.6</td>
<td>6.3</td>
<td>6.3</td>
<td>7.0</td>
<td>6.3</td>
<td>5.3</td>
</tr>
<tr>
<td>Total</td>
<td>133</td>
<td>46.1</td>
<td>43.5</td>
<td>36.1</td>
<td>44.3</td>
<td>37.8</td>
<td>37.1</td>
</tr>
<tr>
<td>VFA</td>
<td>191</td>
<td>58.8</td>
<td>59.8</td>
<td>53.7</td>
<td>50.6</td>
<td>55.7</td>
<td>66.1</td>
</tr>
</tbody>
</table>
on-test traits are not presented, but the analysis of variance is shown in Table 2. Covariate adjustment of body weight for age on test did not remove differences between the H and L groups.

Ruminal VFA concentrations after 133 and 191 d on test are shown in Table 3. Total VFA concentrations were similar for all heifers. Ruminal concentrations of C3 were lower (P<.01) in R heifers than in monensin-fed heifers (19.1, 23.6 and 23.5%; R, M1 and M2, respectively). However, concentrations of C2 (72.1, 69.4, 69.1%) and of C4 (8.8, 7.0, 7.4%) were greater (P<.01) in R heifers than in M1 and M2 heifers. This effect of monensin on VFA ratios has been well documented (Dinius et al., 1976; Raun et al., 1976; Richardson et al., 1976).

Mean off-test weights and ADG are shown in Tables 2 and 4. HM2 heifers were 42 kg heavier than HR and HM1 heifers; but in the L group, LM2 heifers were only 17 kg heavier than LR and LM1 heifers resulting in a significant (P<.05) treatment × weight-class interaction. Heifers in group M2 gained faster (P<.001) than R and M1 heifers (.66, .49, .52 kg/d, respectively), but R and M1 heifers performed similarly. ADG did not differ significantly between the H and L groups (.55 vs .56 kg/d). The ADG for the H heifers was much higher than the projected ADG (.45 kg/d), and this was primarily due to the extremely good performance of HM2 heifers (.67 kg/d). Overall daily feed intake was 7.17, 6.41 and 7.17 kg/head for R, M1 and M2 heifers, respectively, and 7.14 and 6.68 kg/head for L and H, respectively. Heifers in M1 made weight gains similar to those of R heifers on 10.6% less feed; whereas, M2 heifers gained 34.7% faster than R heifers on the same daily feed intake. M1 and M2 heifers gained 15.1 and 25.3% more efficiently than R heifers (12.4 and 10.9 vs 14.6 kg feed/kg gain, respectively). Feed efficiency did not differ between weight classes within the R and M1 groups. In contrast, HM2 heifers converted available feed to weight gains more efficiently than LM2 heifers, which suggests there may be a genetic effect of weight class on feed efficiency.

At the end of the 203-d feeding period, 92% (21/23) of LM2 heifers and 100% of all other groups had reached puberty. The two non-cycling LM2 heifers reached puberty during the first 3 wk of the breeding season. One heifer in the HM2 group was eliminated from the summary because of the inability to confirm corpus luteum development.

Mean age and weight at puberty was 373 d and 293 kg (Tables 4, 5) for this set of crossbred beef heifers, which is within the range presented in other studies with Bos taurus crossbred heifers (Wiltbank et al., 1966, 1969; Short and Bellows, 1971; Laster et al., 1972). Age at puberty was not different for L and H heifers (373.2 vs 373.7 d, respectively), and adjustment of age at puberty for ADG did not change the analysis. Weight at puberty was lower for L heifers than for H heifers (281.8 vs 303.8 kg, respectively; P<.001). This difference agrees with data reported by Varner et al. (1977). Furthermore, adjusting weight at puberty for ADG did not remove differences between

### Table 4. Least-Squares Means of Off-Test Measurements and Reproductive Traits

<table>
<thead>
<tr>
<th>Growth trait</th>
<th>Light</th>
<th></th>
<th></th>
<th>Heavy</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Roughage</td>
<td>Monensin 1</td>
<td>Monensin 2</td>
<td>Roughage</td>
<td>Monensin 1</td>
<td>Monensin 2</td>
</tr>
<tr>
<td>ADG, kg/day</td>
<td>1.12</td>
<td>1.19</td>
<td>1.41</td>
<td>1.06</td>
<td>1.08</td>
<td>1.48</td>
</tr>
<tr>
<td>Body weight, kg</td>
<td>307.0</td>
<td>309.9</td>
<td>324.9</td>
<td>322.7</td>
<td>324.9</td>
<td>366.0</td>
</tr>
<tr>
<td>Age at puberty, d</td>
<td>377.6</td>
<td>369.3</td>
<td>372.7</td>
<td>383.1</td>
<td>369.3</td>
<td>368.8</td>
</tr>
<tr>
<td>Weight at puberty, kg</td>
<td>278.1</td>
<td>279.6</td>
<td>287.7</td>
<td>296.6</td>
<td>292.8</td>
<td>322.1</td>
</tr>
<tr>
<td>% pregnant</td>
<td>86.4</td>
<td>83.3</td>
<td>78.3</td>
<td>82.6</td>
<td>95.8</td>
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<td></td>
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<td>(20/24)</td>
<td>(18/23)</td>
<td>(19/23)</td>
<td>(23/24)</td>
<td>(23/24)</td>
</tr>
</tbody>
</table>

*a See Table 1 for analysis of variance.

*b See Table 5 for analysis of variance.
TABLE 5. ANALYSIS OF VARIANCE OF AGE AND WEIGHT AT PUBERTY

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Age at puberty</th>
<th>Weight at puberty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>3</td>
<td>1,661.8</td>
<td>24,765***</td>
</tr>
<tr>
<td>Weight class</td>
<td>1</td>
<td>8.6</td>
<td>81,728***</td>
</tr>
<tr>
<td>Interaction</td>
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<td>251.5</td>
<td>6,878</td>
</tr>
<tr>
<td>Error</td>
<td>133</td>
<td>879.4</td>
<td>3,154</td>
</tr>
</tbody>
</table>

Single degree of freedom comparisons

(1) L: R vs M1 + M2
(2) L: M1 vs M2
(3) H: R vs M1 + M2
(4) H: M1 vs M2

*Meansquares.
†P<.06.
*P<.05.
***P<.001.

weight classes. These data suggest that the occurrence of puberty was limited by age in heavy heifers and by weight in light heifers. Dietary monensin affected age and weight at puberty, but the response was observed only in the H heifers (table 4, 5). Within the L group, puberty was not affected by monensin supplementation as demonstrated by similar pubertal ages and weights for LR, LM1 and LM2 heifers. Covariate analysis with the previously mentioned adjustments did not alter these findings. However, in the H group, HR heifers were 14 d older (P<.06) at puberty than HM1 and HM2 heifers and the latter two were similar (383.1, 369.3, 368.8 d, respectively). Weight at puberty was less (P<.05) for HR heifers than for HM1 + HM2 heifers (see individual df, table 5), but this difference was due to the body weight of HM2 heifers (296.6, 292.8, 322.1 kg; HR, HM1, HM2, respectively). HM1 weighed less (P<.001) than HM2. Adjustment for ADG did not alter treatment effects on age at puberty but removed treatment effects on weight at puberty.

At the end of the feeding trial, all heifers were removed from the feedlots and placed on range pastures for a 45-d artificial insemination breeding season. Pregnancy rates for R, M1 and M2 heifers were 84.5, 89.6 and 87.0% (table 4), which were not significantly different. Pregnancy rates were nonsignificantly higher (P>.25) in H heifers (91.4%) than in L heifers (82.7%). Also, there was no significant interaction of treatment with weight group for pregnancy rates. Moseley et al. (1977) and McCartor et al. (1979) have shown no deleterious effects of monensin on pregnancy rates.

This study indicated that age at puberty was significantly decreased in heifers fed monensin, and this difference was not due to increased ADG or increased body weight. This was limited, however, to heifers in the H group. The mechanism whereby monensin affects the onset of puberty remains to be identified. Yet, if age at puberty is lowered, perhaps the maturation of the endocrine system responsible for puberty occurs sooner. In support of this line of reasoning, a greater ovarian responsiveness to exogenous gonadotropin stimulation (Busmich et al., 1980) and a greater pituitary responsiveness to both estradiol and gonadotropin releasing hormone (Randel et al., 1980; Randel and Rhodes, 1980a,b) has been demonstrated in prepubertal beef heifers fed monensin. It is tempting to hypothesize a relationship between the onset of puberty and the processes of rumen fermentation, energy metabolism and responsiveness of the endocrine system.

Literature Cited


Randel, R. D. and R. C. Rhodes, III. 1980a. Effect of