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Plains Nutrition Council
Spring Conference

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Amarillo
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About the Plains Nutrition Council

The Plains Nutrition Council is an educational and professional organization for persons who work and serve as livestock feeding nutritionists, nutrition consultants, and educators in livestock science. The goal of the Council is to enable its members to more effectively cooperate with each other and to serve the livestock feeding industry more successfully. The Council provides a forum for study, discussion, and promulgation of current research in the field, as well as opportunity for study and evaluation of new product applications from the industry and research sectors. Joint efforts with related organizations in chemistry, engineering, veterinary medicine, and other groups allied to the livestock industry are encouraged.

In 1995, the Plains Nutrition Council celebrated its 25th anniversary. The Council’s goal for the future is to play an increasingly vital role of service to the livestock industry.

1998-99 Officers

Ted McCollum III, President
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FEEDING VALUE OF OPTIMUM® HIGH OIL CORN FOR FINISHING BEEF CATTLE

Steve Soderlund and Fred Owens
Optimum Quality Grains, L.L.C.
West Des Moines, IA 50265

Introduction

Advances in plant breeding and molecular biology over the past decade have resulted in the development of corn grain hybrids with higher oil or starch content, simpler starch extraction, oil richer in oleic acid, protein richer in lysine and methionine, and phosphorus lower in phytate. These traits were selected by plant breeders to increase energy and amino acid content and (or) availability, to reduce waste management problems, and to improve carcass or product quality. To date, the only nutritionally modified trait corn types commercially available are products with higher oil content and more easily extracted starch. This paper will review the current research efforts to determine the feeding value of high oil corn for finishing beef cattle.

Development of high oil corn began at the University of Illinois nearly 100 years ago. However, only in the past 5 years has high oil corn become commercially available through numerous seed companies. High oil corn acres are projected to exceed 1 million acres in the U.S. in 1999. This upsurge in production has been the result of a new production system (TOPCROSS®) that vastly improved yields. The new system involves planting 8-10% high oil pollinator seeds having an oil content from 12-20% with 88-90% male sterile typical seeds. The grain resulting from this cross (Optimum® High Oil Corn) has nearly twice the oil content of typical corn. This is because the germ, which contains nearly all of the kernel’s oil, is enlarged. However, because the enlarged germ displaces some of the endosperm, the starch content of high oil corn is disproportionately lower. Starch content typically declines by approximately 1.3% for each 1% increase in crude fat content. But since oil has approximately 2.25 times the energy value of starch, the gross energy value of high oil corn is 4-6% higher for high oil than typical corn.
The typical nutrient composition of Optimum high oil corn is shown in Table 1. These values represent the mean values of over 13,000 samples analyzed over the past three years by Optimum Quality Grains. High oil corn typically contains slightly more crude protein than typical corn. Because the additional protein is coming from the germ rather than endosperm, the protein of OHOC has a higher biological value and higher concentrations of certain essential amino acids such as lysine.

Table 1. Nutrient composition of OPTIMUM high oil corn, compared to typical corn

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Typical Corn</th>
<th>High Oil Corn</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude fat, %</td>
<td>4.03</td>
<td>7.36</td>
<td>82.6</td>
</tr>
<tr>
<td>Crude protein, %</td>
<td>9.23</td>
<td>9.83</td>
<td>6.5</td>
</tr>
<tr>
<td>Starch, %</td>
<td>71.4</td>
<td>67.9</td>
<td>(4.9)</td>
</tr>
<tr>
<td>Crude fiber, %</td>
<td>2.27</td>
<td>2.4</td>
<td>5.7</td>
</tr>
<tr>
<td>Ash, %</td>
<td>1.32</td>
<td>1.45</td>
<td>9.8</td>
</tr>
<tr>
<td>Calcium, %</td>
<td>.01</td>
<td>.01</td>
<td>-</td>
</tr>
<tr>
<td>Phosphorus, %</td>
<td>.28</td>
<td>.3</td>
<td>7.1</td>
</tr>
<tr>
<td>^2TDN, % beef^f</td>
<td>90.2</td>
<td>94.1</td>
<td>4.3</td>
</tr>
<tr>
<td>^3NE_m, Mcal/lb^f</td>
<td>1.02</td>
<td>1.07</td>
<td>4.9</td>
</tr>
<tr>
<td>^4NE_g, Mcal/lb^f</td>
<td>.71</td>
<td>.75</td>
<td>5.6</td>
</tr>
</tbody>
</table>

1 Values are expressed on a 100% dry matter basis
2 Total Digestible Nutrients
3 Net Energy for maintenance
4 Net Energy for gain
* Based on NRC values for cracked corn

Nutritional Considerations

Substituting high oil for typical corn in the diet will increase the energy density of the ration or maintain a similar energy level while displacing some or all of the fat that would otherwise be added to the diet. Even though the protein content usually is greater for high oil than typical corn, the protein quality of corn remains low. Further, displacement of starch by oil will decrease the supply of starch to be fermented in the rumen and slightly decrease microbial protein output from the rumen. Consequently, the level of bypass protein in ruminant diets probably should not be decreased when high oil corn is used even though high oil corn typically contains more protein than typical corn. Fermentation studies suggest that the rate of ruminal starch digestion is slightly slower for high oil than typical corn grain. When combined with the fact that oil content is greater, this suggests that substituting high oil for typical corn may reduce the incidence of acidosis in cattle fed high concentrate diets. Lower dietary starch also may prove helpful for adapting cattle to high concentrate diets and maintaining feed intake by long-
fed cattle. The oil contained in high oil corn has a fatty acid profile and digestibility similar to that of the oil in typical corn grain. But because the oil is contained in the germ rather than free on the surface of particles, it inherently is less available in the rumen than fat added to the diet. Although one might expect unsaturated fatty acids to be saturated in the rumen, some of the additional unsaturated fatty acids must be escaping ruminal hydrogenation because both depot and milk fat are slightly less saturated when cattle are fed high oil corn. Furthermore, feeding high oil corn does not depress fiber digestion or dry matter intake as is sometimes observed when unsaturated fats are applied to ruminant diets. In addition, high oil corn may be intrinsically superior from a nutritional standpoint because it is identity-preserved and thereby is not blended down with other grains to minimum quality standards. Compared to typical corn, high oil corn generally requires less power to grind and generates less dust when processed. However, processing characteristics will largely depend on the base genetics used to make TC blend® seed and thus will vary among the different seed products.

Recent Feeding Trials with High Oil Corn

Four controlled feeding trials have been conducted to date to determine the value of feeding high oil corn to finishing beef cattle. Grain processing methods have included feeding the grain whole, rolled, and steam flaked. All trials utilized heavy (820-950 lb.) yearling steers fed for relatively short finishing periods (84-112 d). Each individual trial is discussed in more detail below.

Colorado

In the fall of 1997, a study was conducted at the Horton Feedlot Research Center (Brown et al., 1998) to compare high oil with typical corn grain when fed steam flaked to either 26 or 30 pounds per bushel. Three percent tallow was added to the typical corn diets so that all diets should be isocaloric. Compared to typical corn, the high oil corn in this trial averaged 3.2% higher in oil (7.6% vs. 4.4%) and 0.5% higher in crude protein (9.1% vs. 8.7%). To equalize dietary protein levels, the ratio of wheat middlings to cottonseed meal in the supplement was altered so that diets were isonitrogenous. The level of NPN in the supplement was held constant for all diets.

Two hundred English/Exotic mixed breed yearling steers averaging 819 pounds were fed high concentrate diets for 84 days. Steers were allotted to 20 pens (5 pens per treatment) of 10 head each following a 22-day start-up period. All steers were fed typical corn during the start up period. Steers were implanted with Revalor-S® at the start of the trial and Rumensin/Tylan® was supplied in the supplement. Rations were fed twice daily to appetite. Final weights were based on a 4% pencil shrink of final full weights. Steer performance results are shown in Table 2. Steers fed corn flaked at 30 lb./bu. had higher (P< .05) dry matter intakes than steers fed corn flaked at 26 lb./bu. Feeding high oil corn at the 30 pound steam flake weight resulted in higher (P< .10) average daily gains and lower cost of gain compared with other steers. Feed efficiencies were similar among treatment groups. Carcass data is shown in Table 3. There were no significant differences in carcass quality measurements between treatments. Steers fed the high oil corn with a 30 pound test weight tended to produce heavier carcasses with slightly higher marbling scores and a higher percentage of choice carcasses. Results of this study demonstrate
that high oil corn can effectively replace typical corn plus 3% tallow in steam-flaked diets fed to finishing beef steers. Performance was best when high oil corn was steam-flaked to 30 lb./bu. where energy intake and utilization tended to be best. In this study, the finer flake (26 vs. 30 lb./bu.) did not improve performance. In addition, flaking corn at 30 lb./bu. should reduce flaking cost, improve mill efficiency, and increase flake durability.

### TABLE 2. Live Performance Data from Colorado Study

<table>
<thead>
<tr>
<th>Item</th>
<th>Typical Corn</th>
<th>26 lb./bu</th>
<th>30 lb./bu</th>
<th>High Oil Corn</th>
<th>26 lb./bu</th>
<th>30 lb./bu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Wt. Gain, lb</td>
<td>317</td>
<td>317</td>
<td>310</td>
<td>334</td>
<td>310</td>
<td>334</td>
</tr>
<tr>
<td>DM Intake, lb./day</td>
<td>21.9</td>
<td>22.3</td>
<td>21.2</td>
<td>22.8</td>
<td>21.2</td>
<td>22.8</td>
</tr>
<tr>
<td>ADG, lb/day</td>
<td>3.8</td>
<td>3.8</td>
<td>3.7</td>
<td>4.0</td>
<td>3.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Feed/Gain</td>
<td>5.8</td>
<td>5.9</td>
<td>5.7</td>
<td>5.7</td>
<td>5.7</td>
<td>5.7</td>
</tr>
</tbody>
</table>

### TABLE 3. Carcass Quality Data from Colorado Study

<table>
<thead>
<tr>
<th>Item</th>
<th>Typical Corn</th>
<th>26 lb./bu</th>
<th>30 lb./bu</th>
<th>High Oil Corn</th>
<th>26 lb./bu</th>
<th>30 lb./bu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carcass wt., lb</td>
<td>706</td>
<td>706</td>
<td>710</td>
<td>718</td>
<td>710</td>
<td>718</td>
</tr>
<tr>
<td>Fat depth, In.</td>
<td>.36</td>
<td>.37</td>
<td>.36</td>
<td>.37</td>
<td>.36</td>
<td>.37</td>
</tr>
<tr>
<td>KPH, %</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
</tr>
<tr>
<td>Yield Grade</td>
<td>1.9</td>
<td>2.0</td>
<td>1.9</td>
<td>2.0</td>
<td>1.9</td>
<td>2.0</td>
</tr>
<tr>
<td>Marbling Score*</td>
<td>4.1</td>
<td>4.1</td>
<td>3.9</td>
<td>4.2</td>
<td>3.9</td>
<td>4.2</td>
</tr>
<tr>
<td>Yield Grade</td>
<td>1.9</td>
<td>2.0</td>
<td>1.9</td>
<td>2.0</td>
<td>1.9</td>
<td>2.0</td>
</tr>
</tbody>
</table>

*Marbling Scores: 4.0-4.99 = slight; 5.0-5.99 = Small; 6.0-6.99 = Modest

### Idaho

In the fall of 1997, a trial also was conducted at the University of Idaho (Andrae et al., 1998) to evaluate feeding dry rolled high oil corn in an 84-day finishing trial. Sixty yearling Angus-cross steers averaging 906 pounds were allotted to three treatments of 20 head each. Treatments evaluated were: 1) control (typical corn), 2) high oil corn, and 3) high oil corn diluted with roughage so it would be isocaloric with diet 1. High oil corn dry matter averaged 7.04% while the control corn averaged 4.86% oil. In this study, the protein content of the high oil corn used was 8.7% vs. 9.6% for the control corn. In this case, the high oil corn was imported from Nebraska and it was not isogenic to the control corn. Rations were formulated to be isonitrogenous by adding more urea to the high oil corn diets. Steers were fed individually to
appetite twice daily using electronic gates and were implanted with Synovex-S® at the start of the trial. No ionophore or antibiotic was fed. Steers were weighed following an overnight stand without water on two consecutive days at the beginning and end of the 84-day study. Final weights were calculated from hot carcass weight based on an assumed dressing percentage of 62.5%. Carcass data were collected from all carcasses following a 72-hour postmortem chill. Steer performance results are presented in Table 4. Steers fed the typical corn diet had significantly (P<.01) higher dry matter intakes than steers fed either high oil corn or the isocaloric diet. Average daily gain was not significantly (P>.10) different between treatments, but feed efficiencies tended to be better for steers fed the high oil corn diets.

<table>
<thead>
<tr>
<th>TABLE 4. Performance Data from Idaho Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Corn</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>Total Wt. Gain, lb</td>
</tr>
<tr>
<td>DM Intake, lb./day</td>
</tr>
<tr>
<td>ADG, lb/day</td>
</tr>
<tr>
<td>Feed/Gain</td>
</tr>
</tbody>
</table>

Carcass characteristics are shown in Table 5. Carcasses from steers fed high oil corn had higher (P<.05) marbling scores and tended to have higher quality grades than carcasses of steers fed typical corn. Overall, 78% of the high oil corn steers graded choice or above compared to 47% for the control and 67% for the ISO cattle (Figure 1). While feeding high oil corn did not improve live performance in this study, the improvement in carcass quality grade resulted in a substantial economic benefit from feeding high oil corn because the price spread between select and choice carcasses was high.

<table>
<thead>
<tr>
<th>TABLE 5. Carcass Quality Data from Idaho Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Corn</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>Carcass Wt., Lbs</td>
</tr>
<tr>
<td>Fat depth, In.</td>
</tr>
<tr>
<td>KPH,%</td>
</tr>
<tr>
<td>Yield Grade</td>
</tr>
<tr>
<td>‘Marbling Score</td>
</tr>
<tr>
<td>USDA Grade</td>
</tr>
</tbody>
</table>

Marbling Scores: 4.0-4.00 = slight; 5.0-5.99 = Small; 6.0-6.99 = Modest. Means within row differ significantly P<.05.
Iowa State Study

In the winter of 1997, a study was conducted by Iowa State University (Trenkle, 1998) to compare the feeding values of high oil corn with typical corn both with and without added fat. Both corn types were fed in the whole form. In this study, the control corn and the high oil corn were isogenic (same grain parent). The high oil corn contained 7.3% oil and 9.3% protein as compared to the control corn at 4.0% oil and 8.9% protein. Rations were made isonitrogenous by adding extra soybean meal to the control corn supplement. Ninety Continental crossbred yearling steers that averaged 954 pounds were fed high concentrate diets for 107 days. Steers were allotted randomly to three treatments (30 head each). The treatments evaluated were: 1) typical corn with no fat added, 2) typical corn plus 2.7% animal-vegetable blend fat, and 3) high oil corn. All steers were implanted with Component™ TE-S at the time of processing and received Rumensin® in the ration.

Steer performance results are shown in Table 6. Steers fed high oil corn tended to have higher dry matter intakes and average daily gains compared to steers fed typical corn either with or without added fat. Feed efficiencies were not different between treatments. During the first half of the trial, steers fed the rations containing control corn tended to gain faster whereas during the second half of the trial, steers fed high oil corn tended to gain faster.

Carcass measurements are shown in Table 7. Although there were no significant differences in any of the carcass measurements, steers fed the control corn with added fat and those fed high oil corn tended to have fatter carcasses. Carcass quality grade distribution is shown in Figure 2. Compared with steers fed typical corn with no added fat, those steers fed corn with added fat or high oil corn tended to have a higher percentage of carcasses that graded choice or above.
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Carcass measurements are shown in Table 7. Although there were no significant differences in any of the carcass measurements, steers fed the control corn with added fat and those fed high oil corn tended to have fatter carcasses. Carcass quality grade distribution is shown in Figure 2. Compared with steers fed typical corn with no added fat, those steers fed corn with added fat or high oil corn tended to have a higher percentage of carcasses that graded choice or above.
### TABLE 6. Performance Data from Iowa State Study

<table>
<thead>
<tr>
<th></th>
<th>Typical Corn (TC)</th>
<th>TC with fat</th>
<th>High Oil Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>0 to 107 days</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM Intake, lb./day</td>
<td>25.2</td>
<td>25.1</td>
<td>25.7</td>
</tr>
<tr>
<td>ADG, lb./day</td>
<td>3.92</td>
<td>3.88</td>
<td>4.03</td>
</tr>
<tr>
<td>Feed/Gain</td>
<td>6.43</td>
<td>6.47</td>
<td>6.38</td>
</tr>
<tr>
<td><strong>0 to 56 days</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM Intake, lb./day</td>
<td>23.2</td>
<td>23.4</td>
<td>23.44</td>
</tr>
<tr>
<td>ADG, lb/day</td>
<td>5.28</td>
<td>5.28</td>
<td>5.01</td>
</tr>
<tr>
<td>Feed/Gain</td>
<td>4.4</td>
<td>4.44</td>
<td>4.67</td>
</tr>
<tr>
<td><strong>57 to 107 days</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM Intake, lb./day</td>
<td>29.4</td>
<td>28.9</td>
<td>30.2</td>
</tr>
<tr>
<td>ADG, lb/day</td>
<td>2.44</td>
<td>2.35</td>
<td>2.99</td>
</tr>
<tr>
<td>Feed/Gain</td>
<td>12.6</td>
<td>12.36</td>
<td>10.40</td>
</tr>
</tbody>
</table>

### TABLE 7. Carcass Quality Data from Iowa State Study

<table>
<thead>
<tr>
<th>Item</th>
<th>Typical Corn</th>
<th>Typical Corn plus Fat</th>
<th>High Oil Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carcass Wt., Lbs.</td>
<td>822.5</td>
<td>828.1</td>
<td>824.5</td>
</tr>
<tr>
<td>Fat depth, In.</td>
<td>.27</td>
<td>.33</td>
<td>.28</td>
</tr>
<tr>
<td>KPH,%</td>
<td>2.4</td>
<td>2.6</td>
<td>2.7</td>
</tr>
<tr>
<td>Yield Grade</td>
<td>2.14</td>
<td>2.55</td>
<td>2.44</td>
</tr>
<tr>
<td>*Marbling Score</td>
<td>3.8</td>
<td>4.1</td>
<td>4.0</td>
</tr>
</tbody>
</table>

*Marbling Scores: 4.0-4.00 = slight; 5.0-5.99 = Small; 6.0-6.99 = Modest
South Dakota Study

In the spring of 1998, a study was conducted by South Dakota State University researchers (Tollefson et al., 1999) to compare feeding value of whole and rolled high oil corn with whole and rolled typical corn without added fat. The same supplement was fed with all diets. One hundred and fifty-four crossbred yearling steers with an initial weight of 925 lb. were blocked by weight and assigned randomly to four treatments. These four treatments included a 1) 10% roughage diet containing unprocessed (whole) corn of typical oil content (regular), 2) 10% roughage diet containing rolled corn of typical oil content, 3) 10% roughage diet with unprocessed high oil corn (HOC), and 4) 10% roughage diet with rolled high oil corn. Groups were fed ad libitum once daily for 112 and 128 days. All steers were implanted with Ralgro® at processing and re-implanted on d 42 with Component™ TE-S. Rumensin®/Tylan® was included in all rations. Interim weights were recorded every 42 days. Steers were taken off feed and water the afternoon before going on test, but only water was removed for the subsequent interim weights. Final weights were calculated from hot carcass weight based on an assumed dressing percentage of 62%. Steer performance results are shown in table 8. Carcass data were collected two days after harvest. Carcass data is shown in table 9.

Steers fed rolled high oil corn tended to consume more dry matter and gain faster but with feed efficiencies similar to steers fed typical rolled corn diets. Steers fed whole high oil corn tended to consume less feed, gain at a similar rate, but have slightly better feed conversion than those fed typical corn. Cumulative ADG was not different (P > .05) between high oil corn and regular corn treatments (3.12 vs. 3.05 lb./d respectively). Likewise, cumulative feed/gain (dry matter basis) values were similar (P > .05) between high oil corn and regular corn treatments (6.83 vs. 6.97, respectively).
TABLE 8: Live Performance Data from South Dakota Study

<table>
<thead>
<tr>
<th>Item</th>
<th>Typical Corn</th>
<th></th>
<th>High Oil Corn</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whole</td>
<td>Rolled</td>
<td>Whole</td>
<td>Rolled</td>
</tr>
<tr>
<td>Total Wt. Gain, lb.</td>
<td>381</td>
<td>386</td>
<td>381</td>
<td>396</td>
</tr>
<tr>
<td>DM Intake, lb./day*</td>
<td>20.93</td>
<td>20.21</td>
<td>20.07</td>
<td>20.95</td>
</tr>
<tr>
<td>ADG, lb./day</td>
<td>3.05</td>
<td>3.04</td>
<td>3.03</td>
<td>3.21</td>
</tr>
<tr>
<td>Feed/Gain</td>
<td>7.09</td>
<td>6.86</td>
<td>6.89</td>
<td>6.76</td>
</tr>
</tbody>
</table>

*Corn type X processing method interaction was significant P<.001.

A significant interaction between corn type (HOC vs. typical) and processing method (whole vs. rolled) was detected for dry matter intake (P < .01). Steers receiving typical/whole and HOC/rolled corn had the highest dry matter intakes (20.93 and 20.95 lb./d, respectively) as compared to steers consuming typical/rolled and HOC/whole (20.21 and 20.07 lb./d, respectively). These data suggest that high oil corn should be processed for optimal utilization in finishing diets.

TABLE 9. Carcass Quality Data from South Dakota Study

<table>
<thead>
<tr>
<th>Item</th>
<th>Typical Corn</th>
<th></th>
<th>High Oil Corn</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whole</td>
<td>Rolled</td>
<td>Whole</td>
<td>Rolled</td>
</tr>
<tr>
<td>Carcass wt., lb.</td>
<td>803</td>
<td>801</td>
<td>798</td>
<td>813</td>
</tr>
<tr>
<td>Fat depth, In.</td>
<td>.53</td>
<td>.48</td>
<td>.51</td>
<td>.47</td>
</tr>
<tr>
<td>KPH, %*</td>
<td>2.60</td>
<td>2.40</td>
<td>2.72</td>
<td>2.57</td>
</tr>
<tr>
<td>Yield Grade</td>
<td>3.25</td>
<td>3.04</td>
<td>3.10</td>
<td>3.08</td>
</tr>
<tr>
<td>Marbling Score*</td>
<td>486</td>
<td>483</td>
<td>473</td>
<td>489</td>
</tr>
</tbody>
</table>

*Processing P=.01, Corn Type P=.06

1Slight = 400, Small = 500

Significant differences were observed (P < .06) in KPH fat between carcasses from steers fed HOC (2.65%) vs. regular corn (2.50%). Furthermore, processing method resulted in significant difference in KPH fat. Carcasses from steers fed whole corn had greater (P < .05) KPH fat as compared to carcasses from steers fed rolled corn (2.66 vs. 2.48). These differences in KPH fat indicate that site or type of nutrients absorbed may have differed between HOC and regular corn as well as between rolled vs. whole corn. No other significant differences in carcass characteristics were observed between HOC and regular corn. Neither carcass quality grade nor
marbling score was altered by diet (P>.05) in this study with 38% of steers fed HOC being graded choice vs. 44% for steers fed regular corn.

**Overview of Feeding Trials**

These feeding studies demonstrate that Optimum high oil corn (OHOC) can effectively replace 100% of typical corn and up to 3% added fat in finishing beef cattle diets. The best performance from OHOC was noted in those trials where the corn was processed. The estimated NE\textsubscript{g} values for OHOC compared to typical corn based on compositional data and from the field trials are shown in figure 3. Based on the Weiss equations for calculating TDN and NE\textsubscript{g} from composition, the high oil corn used in these studies should have 6.7% greater NE\textsubscript{g} than the typical corn grain fed. NE\textsubscript{g} values calculated from feed intake and animal performance data using NRC net energy equations suggested that high oil corn had 6.2% greater NE\textsubscript{g} than control corn when averaged across all trials. However, this value would be substantially higher if only trials comparing processed grains were summarized.

**Figure 3. Estimate of NE\textsubscript{g} of Grain Based on Cattle Performance Compared to Compositional Data**

![Graph showing NE\textsubscript{g} comparison between normal and high oil corn](image)

Carcass quality grade was improved in some but not all studies. In the Idaho study, cattle fed high oil corn had significantly more carcasses that graded choice or above than cattle fed typical corn without added fat. More research is needed to determine whether this improvement in carcass quality grade is in response to high oil corn or simply to the higher energy density of the ration. The apparent lack of performance response in the Idaho study was associated with lower dry matter intake of the high oil corn treatments. The fact that the cattle fed high oil corn tended to have better feed efficiency compared to those fed the control corn suggests that the high oil corn had approximately 4% higher metabolizable energy than the control corn. The control corn fed in this study was not an isogenic variety to the high oil corn. The difference in oil content between the control corn and the high oil corn fed in the Idaho study was only 2.18% units as compared to an average of 3.3% units being expected when compared to the typical grain parent. The high oil corn used in the Idaho study also was lower in crude protein than the control corn.
corn so the researchers increased the urea level in the high oil corn and ISO high oil corn diets to make them isonitrogenous with the control diet. Since high oil corn contains less starch than typical corn, the increase NPN may have increased ruminal ammonia to the point that feed intakes were reduced. Further research is underway to quantify site of starch digestion and microbial protein synthesis that should improve our ability to properly formulate protein supplements for diets based on high oil corn.

In both the Idaho and Iowa State studies, dry matter intake was relatively high resulting in mean fat intakes that exceeded 700 grams per day for the high oil corn treatments. Brandt (1995) concluded from a review of cattle finishing trials evaluating various levels of fat supplementation that for maximum utilization efficiency, fat intake should not exceed 650 grams per day. The fact that the cattle fed supplemental fat to the control corn in the Iowa State trial failed to improve efficiency lends support to Brandt’s conclusion. The South Dakota study revealed a significant corn type by processing interaction on dry matter intake. A similar observation was made in the Colorado study comparing 26 vs. 30 lb./bu steam flaked corn. In this study best performance was noted with the high oil corn flaked at 30 lb./bu. The improved performance was primarily due to the higher dry matter intake of this treatment.

Several studies are currently underway to examine various rates of inclusion of high oil corn and test additional processing methods including high moisture corn. At this time, it is recommended that high oil corn be processed for best utilization. Ration formulation considerations made with high oil corn should be similar to those for formulating rations containing supplemental fat. Even though the protein content usually is greater for high oil than typical corn, the protein quality of corn still is low. With a decreased supply and percentage of starch digested in the rumen, microbial protein output from the rumen may be slightly reduced. Consequently, the level of bypass protein in ruminate diets probably should not be decreased even though high oil corn typically contains more protein than typical corn.

**Economics**

The decision of whether to replace typical corn grain with Optimum high oil corn in cattle finishing rations depends on a number of factors. These include: 1). availability of sufficient quantities of high oil corn, 2). cost or premiums paid for high oil corn, 3). grain yield compared to typical corn (farmer/feeder), 4). fat and protein level of the high oil corn, 5). value of added fat and supplemental protein that may be displaced, 6). predicted difference in animal performance and cost of gain, 7). intrinsic values (lower processing cost, less dust, etc.), 8). carcass value differences, and 9). identity preservation cost.

Currently, farmer feeders are in the most favorable position to capture the value of high oil corn since they can grow and store the crop on their own operation and avoid price premiums and the added cost of identity preservation. They need only assess the added feed value compared to the difference in production cost between high oil and typical corn. Commercial feedlots, however, may need to contract production of high oil corn from local growers or source it from local elevators or grain handlers. In this case, premiums will be assessed to the high oil corn. Premiums for high oil corn will vary depending on the oil content of the grain and the local
supply and demand. Most domestic premiums currently range from $.15-.23/bushel for high oil corn containing 7.0-7.5% oil.

**Future Products and Systems**

Incorporating new traits into grain while maintaining grain yields has been a major challenge for seed companies. With the introduction of the TOPCROSS® production system, yields of high oil corn were increased dramatically. Future product development for ruminants must focus not only on nutritional value of the grain, but also on strategies to improve the value of the beef and milk produced from select grain sources. Ultimately, improved value of consumer products achieved through identity preserved grains and animal products combined with down-stream branding opportunities should help to differentiate consumer products that presumably have greater value. Value chains that will link seed suppliers, through growers, grain handlers, processors, feeders, packers, retailers and ultimately to consumers are beginning to be developed. Such chains will help form customized, identifiable, and responsible food production systems that can enhance not only the nutritional value and consumer appeal of food products, but also the commercial value of food products produced from value enhanced grains.

**REFERENCES**


GRAIN PROCESSING AND HANDLING IN FEED YARDS: CONSERVING AND IMPROVING NUTRITIONAL VALUE

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Introduction

The term “grain processing” can have a different meaning to different users. To one user, grain processing may mean nothing more than cracking the grain prior to inclusion in a ration. To a different user, the term means the total fractionation of the grain with its basic components - protein, starch, fiber, and the like. Regardless of the perception, the intended outcome of any process is to enhance the value of the processed grain.

Review

1. Processing Grain for Ruminants

Historically, there have been a number of processes applied to processing ingredients, particularly grains, for ruminants. Most processing has focused on feedlot cattle because of the relatively high probability of return and because the amount of feed per unit of grain indicates a significant amount of room for improvement. In recent years, however, we have noted a great deal of processing activity targeted toward the dairy industry.

1. Basic Reasons for Grain Processing

There are many reasons for grain processing but they all generally lead to a single primary purpose - to take advantage of and enhance the natural ability of the target animal to convert feed ingredients to food products like meat, milk, or eggs. In the case of feedlot animals, that means attempting to manipulate the rumen micro-flora to efficiently ferment a portion of the diet to bacterial nutrients and other nutrients (Volatile Fatty Acids (VFAs)) that can be directly absorbed and used by the host animal. The processing can range from grinding (to increase surface area available to microbial attack) to starch gelatinization which results in a dramatic increase in the rate of hydrolysis to energy, CO₂, VFAs, and so on. It should be easily recognized that, as the level of processing goes up, there is a corresponding increase in cost. The increased cost of processing will, hopefully, be offset by the improvement in animal performance.

2. Processing Techniques

A partial list of techniques used in grain processing used in feedlots would include:
1. Hammermill grinding
2. Rollermill grinding
3. Roasting
4. Micronizing®
5. Popping
6. Jet-sploding®
7. Reconstituting
8. High moisture ensiling
9. Expanding/extruding
10. Steam pelleting
11. Steam flaking

Each process has useful characteristics and results and has application in certain circumstances. However, steam flaking has become the most prevalent processing method to improve grain utilization for beef cattle. Steam flaking has found particularly high marks in improving the value of grain sorghum.

It is not the purpose of this paper to debate the positive or negative attributes of a particular process but rather to examine changes that take place in the grain that can positively or negatively influence the value of the grain to the feedlot animal.

II. Grinding

Grinding grain results in two distinctive changes in the physical characteristics of the grain that can promote increased utilization by the ruminant. Most grains, and grain sorghum in particular, have a protective seed coat that acts as a barrier to digestion by microbial organisms and enzymes. Grinding by impact (hammermill) or by compression (rollermill) ruptures the seed coat and promotes access to the seed endosperm. Secondly, grinding reduces the particle size of the grain endosperm resulting in a dramatic increase in surface area. Most organisms and digestive enzymes primarily attack the substrate at the surface and logic would lead to the conclusion that the greater the surface area, the greater the rate of fermentation and digestion. Because of the mathematical relationship between the diameter of a particle and its surface area, surface area increases geometrically as particle diameter decreases linearly. In other words, if average particle size of grain is reduced by half (say, 1500 µ to 750 µ), the surface area in a given weight of the grain will increase by 3 to 4 times.

Given the above result, one could argue that we should grind the grain fraction to “flour” to promote the highest rate of fermentation. Needless to say, the obvious conclusion is not always the best conclusion. If fermentation proceeds too quickly, the delicate balance between VFA production and disappearance is upset and metabolic distress can result (acidosis, etc.).

The desirable degree of fineness of grind is often dependent on many factors not the least of which is the grain type being used. Fine grinding is generally desirable with grain sorghum, less so with corn and not at all with wheat. This is due to the relatively low fermentability of grain sorghum endosperm and the high fermentability of wheat with corn and other grains being intermediate.
III. Thermal and Hydrothermal Processing

The majority of the processes listed above (§ IB) involve heat in some form - either wet or dry. In the case of grains processed for ruminants, the purpose of the heat and/or moisture is to induce physical changes in the grain components that would improve the rate and extent of rumen fermentation as well as alter the products of fermentation. The key component affected is, of course, starch.

1. Gelatinization

Nutritionists are concerned with the site, extent, and degree of starch fermentation. As a rule, the higher the level of "gelatinization" the more rapid the starch fermentation takes place. This is often referred to as starch availability.

The definition of gelatinization is often quite varied and means something different to different people. Even cereal and starch chemists struggle with a precise definition. To some, the loss of birefringence is an indication of total gelatinization while others consider increased rates of enzyme hydrolysis as being the best indicator of the level of gelatinization. As a general definition, the following should do - "Gelatinization is the irreversible rupture of native secondary bonds within starch" (Seib, 1971). The rupture of bonds within starch always involves water - that present in the endosperm during thermal processing or that added during hydrothermal processing.

The objective of any of the above processes is to increase the availability of starch to enzymatic hydrolysis. Therefore, this author feels that the only valid tests to determine the level of gelatinization and related starch availability should involve an enzyme system of some type. Microscopic evaluation has too many shortcomings to be of great value not the least of which is training of the microscopist.

There are several ways to determine the relative level of processing. In steam flaked grains, bulk density has been used as a "quick and dirty" test done on site to monitor and control the process. However, results of the procedure may differ due to kernel size, grain moisture, temperature conditioning time, and machine wear (Xiong et al., 1990, Karr, 1984). A procedure that uses a yeast enzyme buffer system fermentation to estimate fermentation potential is useful. This technique can be done by any technician and requires little in the way of equipment expense.

Other techniques involving enzymatic hydrolysis and subsequent determination of reducing sugars (glucose, maltose, etc.) require more sophisticated equipment such as spectrophotometers, scanning calorimeters, and the like. These techniques are great for research but are not very useful in day-to-day operations. There are several good papers that outline these procedures (Xiong, et al. 1990; MacRae and Armstrong, 1968; Atwell et al., 1988; Wootton et al., 1971; Chiang and Johnson, 1977).
2. Processing Factors that Affect Starch Gelatinization

The remainder of this paper will focus on the steam flaking process although much of the discussion would apply to other hydrothermal operations as well.

In steam flaking, the degree of gelatinization is largely dependent on just two factors: steam conditioning and roll pressure. Of the two, it is likely that conditioning is by far the most important. However, neither alone can result in acceptable levels of gelatinization or improved animal performance.

As a general rule, conditioning to at least 200°F, 45 minute retention time, and 20-22% moisture and roll operation resulting in a 26 lbs/bu or lighter flake will result in optimum animal performance. Operating conditions will vary with grain type, moisture content, seed size, grain history, roller condition, steam quality, ambient conditions, and a host of other factors. That is why it is necessary to develop a laboratory assay or other test to be done on-site to monitor and control the flaking operation.

3. Starch Retrogradation

If we assume that it is possible to produce the perfect flake for a specific target animal, the next challenge would be to get the flake blended into the ration, delivered, and consumed with no loss in quality. Historically, items of most concern were flake breakage and non-uniform blending.

Recently, another concern has come to the forefront - that of starch retrogradation. Cereal scientists have been addressing retrogradation for several years because of its affect on the physical quality of various foods - not because of its affect on the nutritional value of that food. Bread staling is a good example of how starch retrogradation can affect the physical properties of a food.

In the case of flaked grains, there is real evidence that retrogradation can negatively affect the nutritional value to the host animal. If true, then an examination of the phenomenon and its causes is in order.

1. Starch Gelatinization and Crystallinity

The starch of most cereal grains is made up of two distinct species - amylose and amylopectin. Amylose is a non-branched polymer of glucose generally organized in a helical structure. Amylopectin, on the other hand, is a highly branched polymer of glucose and typically comprises the majority of the starch in feed grains.

During seed maturation, the amylose and amylopectin produced by the plant are formed into starch granules in the endosperm of the seed. Typically, each granule has both amorphous and crystalline areas within each granule. The degree of crystallinity is characteristic of the starch
source (corn, wheat, potato, etc.) and can be determined with x-ray defraction techniques. Typically, a relatively small portion of the granule is highly crystallized and the majority of the starch granule is amorphic.

If the starch granule is subjected to heat in the presence of water, the water is forced into the granule and it begins to swell. This is the initial step in starch gelatinization. If sufficient water is present and enough heat is applied, the granule will swell to the point it ruptures and the hydrated starch molecules will leach into the water and become solubilized. Anyone who has made gravy has witnessed this phenomenon. It is obvious that all crystallinity has been destroyed in the case of complete gelatinization.

2. Retrogradation

In typical feedlot steam flaking, the rupture of starch granules and complete starch gelatinization simply does not happen. This is because the conditions (water level) and energy (heat and pressure) applied are not severe enough to result in full gelatinization. There is granule swelling and increased availability of the starch to enzymatic or bacterial hydrolysis but the starch granules remain relatively intact.

Because of the presence of heat and moisture, the starch molecules within the granule are somewhat mobile and, if given sufficient time, areas of high amylopectin concentration will begin to recrystallize. Unfortunately, it has been shown that crystalline areas within a starch granule are much less susceptible to hydrolysis than non-crystalline areas. The formation of starch crystalline areas following gelatinization is known as “retrogradation”. The higher the level of retrogradation the slower the rate of starch fermentation in the rumen.

3. Practices that Encourage Retrogradation

Processing flows and material handling systems that do not result in rapid cool down following flaking tend to allow optimum conditions for retrogradation. Though unintentional, the use of negative pneumatic air light systems result in very rapid flake cooling and dehydration and likely prevent significant levels of retrogradation.

Conversely, flaking systems that drop flakes directly into a commodity bunker where they may stay in a pile for 24 hours or more, very likely promote starch retrogradation. In this design, the flakes retain heat and moisture at levels near those at flaking. It is easy to imagine that the starch molecules are highly mobile and may well form indigestible crystals.

Reduced starch availability is relatively easy to determine if a suitable test for gelatinization level is available. Using several large styrofoam coolers, simply hold quantities of flakes near production temperature for 4, 8, 12, 18, and 24 hours. A recent test (Fred Owen, personal comm.) indicated that starch availability (% gelatinization) fell from 65-70% at the time of processing to less than 40% twenty-four hours later. Needless to say, animal performance would likely be affected.
The mechanism by which starch retrogrades is not well understood. Additionally, the effect on fermentation kinetics has not been well documented so the economic loss is unknown. In this case, it is better to be safe than sorry by finding a way to cool and partially dry fresh flakes or take steps to ensure the flakes are used immediately rather than sit in a bunker for several hours.

IV. Future Opportunities

No one can predict the future with any degree of accuracy; however, there are several opportunities that are known to be in the works that can be taken advantage of as they become available. A few of these are listed below in outline form.

1. Improved Steam Conditioning Systems

There is a poor understanding of steam and conditioning operations throughout the feedlot as well as commercial feed industries. This is an active area of research.

2. Precise Moisture Control

New technology will allow improvements in this area. This has been an active area of development but additional technology in surfactants and precise instrumentation is becoming available.

3. Better Conditioning Aids

A better understanding of the objectives of hydrothermal processing and starch chemistry will result in improvements in these chemicals.

4. Genetically Modified Organisms (GMOs)

The genetics (seed) companies are working on “designer” grains specific for each species. The days of commodity grains are numbered.

5. New Process Designs

This may involve rethinking the traditional flaking system or developing replacement processes that result in improved animal performance at a reduced cost. Even today, better roll design, improved steam chest designs, and improved steam systems are becoming available.

6. Improved Mixing and Delivery Systems

New concepts in micro-ingredient delivery and incorporation are being developed. Many additives, available today only in dry form, will be offered in liquid form in the next few years.
7. New Ingredients

Every year, dozens of new ingredients become available to animal agriculture. Most are by-products of some food process or of a fermentation process used to create a new food or medicine. These can be opportunity ingredients and should be examined closely.

Summary

It was the purpose of this paper to review some of the current practices in feedlot grain processing and to point out how processing mistakes can affect animal performance. In many cases, things like an innocent change in the way we handle processed grain can affect its value. Developing a true understanding of basic components like proteins, starches, fats, and fiber can point to where low cost improvements can be made.

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THE PROPOSED USDA-USEPA UNIFIED NATIONAL STRATEGY FOR
ANIMAL FEEDING OPERATIONS - WHAT IS INVOLVED? 1

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Introduction

The number of animals fed at large animal feeding operations has increased in the past few decades. Public awareness about environmental issues such as water quality, waste management, and air quality at animal feeding operations has also increased. As politicians and regulatory personnel attempt to console the public about these environmental issues, the result has been an increase in the number of environmental laws and regulations governing animal feeding operations. Many state, local, and federal environmental laws and regulations are currently being modified. In this paper, we present an overview of the proposed USDA-EPA Unified National Strategy for Animal Feeding Operations (hereinafter called the “draft strategy”) which was released for public review in September, 1998. We also discuss the current and proposed environmental regulations governing animal feeding operations in the state of Texas.

Here a Reg, There a Reg, Everywhere a Reg Reg

In the past twenty years, the U.S. in general has seen a major increase in the number of environmental laws and regulations. Before 1965, there were less than 10 federal environmental laws passed by the legislature. Between 1965 and 1999, that number increased to an overwhelming 69, with a deluge of laws in the late 90’s (Figure 1). Agriculture was exempt from most of these laws and regulations for many years. However, recent public outcry about large feeding operations has led to laws and regulations specifically governing these operations, and it appears likely that more will follow. Not only are the number of federal and state laws increasing, but local city and county commissioners are following suit with their own zoning regulations governing large feeding operations. In many cases, the largest concern has been with odor and air quality, though water quality is also mentioned.

Many states have taken the approach to develop their own regulations that are more strict than the federal regulations. The result has been a wide variety of approaches and techniques for regulating animal waste. As an example of this variability, consider state regulations for governing allowable seepage from ponds and lagoons. In a recent survey of state regulations, it

1 Presented at the Spring Conference of the Plains Nutrition Council, San Antonio, TX, April 8-9, 1999
was found that maximum allowable seepage rates varied between 0.042 and 0.63 cm/day (0.017 to 0.25 inch/day) with some states having no defined regulations for allowable seepage rates (Parker et al., 1999). One might ask why some states are more strict, is it because they value their groundwater more than other states? In discussions with regulatory personnel, it seems the biggest reason for the differences in regulatory values is that the research results on which they are basing their reasoning has been quite varied.

![Diagram of Federal environmental legislation: a plot of the cumulative number of environmental laws and amendments passed in the past 90 years (adapted from Anderson, 1998).](image)

**Definitions and Numbers**

Before we dive into the details of animal feeding regulations, let us first set the stage with some definitions and numbers. Similar to animal nutritionists and other scientists, animal waste management scientists have their own shoptalk, and their vocabulary that can be confusing to the newcomer in animal waste management. In this paper, we discuss “animal feeding operations” or AFOs and “concentrated animal feeding operations” or CAFOs. An AFO is defined as a “lot or facility where animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period and crops, vegetation, forage, growth or post harvest residues are not sustained in the normal growing season over any portion of the lot or facility.” Thus cattle that are pastured on grass are not included in this definition. A CAFO is an AFO where more than 1,000 animal units are confined at the facility (the EPA defines a CAFO as having more than 1,000 feeder cattle, 700 mature dairy cows, or 2,500 swine over 55 pounds).
Also, if an AFO has more than 300 animal units and discharges waste or waste water directly into surface water, then it is classified as a CAFO.

According to USDA, there are approximately 450,000 animal feeding operations in the U.S. Most of these operations are small, with about 85% feeding fewer than 250 animal units. In 1992, there were 6,600 feeding operations with more than 1,000 animal units, while now the estimated number is approximately 10,000. The EPA defines operations that feed more than 1,000 animal units as “concentrated animal feeding operations” or CAFOs, while those less than 1,000 animal units are “animal feeding operations” or AFOs.

**Current Regulations Governing CAFOs in Texas**

The Federal Clean Water Act provides the authority for permitting of CAFOs. These National Pollutant Discharge Elimination System (NPDES) permits include conditions to implement national minimum standards (commonly called effluent guidelines). The NPDES program for CAFOs was first implemented in 1974. It was subsequently modified in 1976 to define what constitutes a CAFO. In 1987, what is now called the Texas Natural Resource Conservation Commission (TNRCC) promulgated its Subchapter B rules specifically for CAFOs.

Many NPDES permits are issued by individual States who have been approved by the EPA to run their own regulatory program. On September 14, 1998, the U.S. EPA authorized Texas to implement its Texas Pollutant Discharge Elimination System (TPDES) program. These new TPDES rules are commonly referred to as the "Effluent Limitations Guidelines" or ELG. As a result of the new ELG, the TNRCC is in the process of amending its Subchapter B rules, which are the current regulations applying to CAFOs in Texas. The final Subchapter B rules are expected in summer, 1999. These rules combine the water and air permitting process for CAFOs.

The NPDES regulations are currently being revised by the EPA, with hopes of completion by December 2002 for beef and dairy feeding operations. When the new NPDES regulations are issues in 2002, the TNRCC has stated they will either adopt EPA’s proposed general permit for CAFOs or will amend their Subchapter B rules to be consistent with the new regulations.

**The Proposed USDA/EPA Unified Strategy**

One of the latest outcomes of the concern for environmental issues at animal feeding operations was the result of the Clean Water Action Plan (CWAP), which was released by President Clinton in February, 1998. One of the items called for in the CWAP was the development of a joint USDA-USEPA Unified National Strategy to minimize the water quality and public health impacts at animal feeding operations (USDA-EPA, 1998). The primary guiding principles of the Strategy are to:

- Minimize water quality and public health impacts from animal feeding operations.
- Establish environmental performance expectations for all animal feeding operations.
- Foster public confidence that animal feeding operations are meeting their performance expectations.
- Focus technical and financial assistance to support animal feeding operations in meeting the national performance expectations.

The key element and probably the most important item in all of the strategy is the establishment of a national performance expectation for development and implementation of "technically sound and economically feasible Comprehensive Nutrient Management Plans (CNMPs) to minimize impacts on water quality and public health." The draft strategy states that CNMPs should contain the following components:

- **Feed management** – “Animal diets and feed should be modified to reduce the amounts of nutrients in manure.” This includes use of enzymes such as phytase to increase phosphorus utilization.

- **Manure handling and storage** – “Manure needs to be handled and stored properly to prevent water pollution from AFOs.” Items to be considered in this component include 1) diverting clean water and runoff around the feedyard, and keeping clean water from roofs and buildings from contacting animal manure; 2) preventing leakage and seepage from ponds and lagoons; 3) storing manure in covered areas to prevent precipitation from coming in contact with manure; 4) treating manure for stabilization and reducing nutrient losses; and 5) management of dead animals to reduce pathogens and odors.

- **Land application of manure** – “Land application should be planned to ensure that the proper amounts of all nutrients are applied in a way that does not cause harm to the environment or to public health.” The strategy also states that land application is usually the most desirable method utilizing manure because of valuable nutrients and organic matter. Considerations for land application include balancing nutrients to prevent application of nutrients at rates that exceed the needs of the crops, and applying manure at times and locations that prevent it from entering surface water bodies or causing nuisances to nearby landowners.

- **Land management** – Cropping and farming techniques such as crop residue management (no-till, ridge-till), grazing management, and other conservation practices should minimize movement of soil, organic materials, nutrients and pathogens to surface water bodies. Items mentioned in the strategy include filter strips, contour buffer strips, and riparian buffers.

- **Record keeping** – “AFO operators should keep records that indicate the quantity of manure produced and ultimate utilization, including where, when, and amount of nutrients applied.” Other record keeping requirements include documentation of soil and manure testing results.
• **Other utilization options** – Other options for the beneficial use of manure include composting and the sale of compost and manure to other farmers. Manure can also be used for power generation by producing biogas (a mixture of methane and carbon dioxide) as a fuel source through anaerobic digestion.

CNMPs are to be site-specific to address the goals and needs of a particular feeding operation. The question arises as to who will be required to have a CNMP, and who should prepare them. The USDA and EPA hope to use voluntary programs as the principal approach to assist feeding operations in developing and implementing CNMPs. These CNMPs are *not required* for feeding operations participating in voluntary programs (as discussed below), though they are strongly encouraged.

**How Will the Strategy Be Implemented?**

The USDA and EPA hope to rely on voluntary programs for the majority of animal feeding operations. They estimate that 95% of all animal feeding operations will be controlled through voluntary programs, while 5% (approximately 10,000 operations with more than 1,000 animal units) will be controlled using regulatory programs such as NPDES permits.

According to the Strategy, it is the Federal government's responsibility to establish national expectations and regulatory requirements for AFOs, and to help provide the tools to achieve these expectations and requirements. The EPA is charged with the regulatory responsibilities, which are then delegated in some cases to the states and local governments who have the responsibility for implementing the Federal programs. Individual producers are responsible for implementing nutrient management plans to minimize the risks of pollution. Integrators are responsible for ensuring that their contract growers are environmentally responsible. Research and educational institutions are responsible for developing new and innovative technologies and analyzing their effectiveness.

**What's Next?**

The public comment period for the Draft Unified Strategy ended January, 1999. The USDA and EPA will then review all public comments and provide responses prior to issuing the final strategy. At the time of writing this paper, the EPA had not provided responses to the public comments.

**Areas of Concern and Room for Improvement**

One of the problems with the proposed “one size fits all” strategy is that it does not take into account the unique aspects of individual animal feeding operations. For example, there is a large difference in manure management and handling practices between swine or dairy operations, which are typically housed under roof, and beef cattle operations which are typically...
located in open, earthen surfaced pens. The draft Strategy mentions of a requirement for storage of manure under cover. While this may be practical for swine, dairy, or poultry operations, it does not make sense for open beef cattle feedyards which are already required to contain all runoff from the pens. Also, covering an entire beef cattle feedyard is not economically achievable.

The Strategy suggests that feed management be an integral part of the nutrient management plans. While this sounds like a great idea, the science of modifying diets to control nutrients is still in the research phase. Although some researchers have shown that diet modification can affect items like phosphorus retention, we still have a lot to learn about the applicability of these results to large scale feeding operations, and more importantly how it might affect the economics of cattle feeding.

The Strategy suggests voluntary efforts as the primary approach for implementing nutrient management plans. However, the new ELG could redefine CAFO to include operations smaller than 1,000 animal units.

The Strategy calls for the animal feeding operator to record where, when, and the amount of nutrients applied through land application. The current situation where waste haulers remove the manure and make arrangements with landowners for land application appears to have worked for more than a decade. Some people are concerned that if animal feeding operators are required to put the burden of record keeping on the waste handlers and landowners, that the ongoing relationships that currently exist might develop some problems, as the waste haulers may not be willing to deal with the extra burden of record keeping. Most landowners currently look at manure as resource and pay for the manure to be applied to their land. If additional record keeping burdens are put on the landowners, they may decide it is not worth the trouble and decide to use inorganic fertilizers exclusively.

For Further Information:


References


IS THERE A ROLE FOR NUTRITIONISTS IN ENVIRONMENTAL PLANNING AND MANAGEMENT FOR FEEDYARDS?1, 2

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Texas Agricultural Experiment Station, Amarillo

Introduction

The effects of beef cattle feedyards on ground water, surface water, air quality, wildlife, and the general environment is a growing concern among many groups. The recently released USDA-EPA Draft Unified National Strategy for Animal Feeding Operations (Unified Strategy, USDA-EPA, 1998), new EPA air quality regulations on PM-10 and -2.5 particulates (EPA, 1997), current plans to rewrite the 1974 Effluent Limitations Guidelines and to revise air quality standards for grain elevators and feedmills (Grelinger, 1997; Midwest Research Institute, 1998), discussions to pass legislation to eliminate open lagoons, and state/local regulations that limit or prohibit the construction of "large animal operations" are just a few examples of that concern. Most High Plains feedyards have a good record of compliance with current environmental regulations; however, it is very probable that regulations will change and become even stricter in the future. Unfortunately, it is likely that many of these regulations will be based on politics, rather than on sound science (personnel comment by EPA employee, 1998).

Consulting nutritionists play an important and vital role in the cattle feeding industry. However, with new, ever-stricter environmental regulations, that role may need to change to meet the needs of the client. In the future, the consulting nutritionist may need to be involved in environmental compliance for feedyards. Relevant questions related to this future role are: 1) do consultants want this responsibility; 2) what role can consultants fill; and 3) what benefits can they receive?

Do Consultants Want a Role?

In attempt to answer the first question we did a "nonscientific survey" of 20 nutritional consultants that are members of the Plains Nutrition Council (PNC). We scanned the membership directory of the American Society of Animal Science and recorded the "discipline areas" listed by each consultant. The results are presented in Table 1. Although a wide variety of disciplines were reported by the consultants, none reported in the Waste Management discipline. It should be noted, however, that a number of consultants expressed an interest in

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1 Presented at the Spring Conference of the Plains Nutrition Council, San Antonio, TX, April 8-9, 1999.

2 All programs and services of the U.S. Department of Agriculture are offered on a nondiscriminatory basis without regard to race, color, national origin, religion, sex, age, marital status, or handicap.
the areas of food safety and quality control, that are major concerns to the cattle feeding industry. This indicates that many consultants are willing to make the extra effort to "fill the gaps" and to do their best to solve problems important to the industry and to their clients.

In reality, nutritionists can be considered "manure chemists." In oversimplified terms, the major improvements in beef cattle nutrition over the past 50 years have been accomplished by decreasing the quantity of manure produced (i.e., increasing digestibility). So, in one sense, nutritionists have always been involved with waste management.

The Unified Strategy discusses terms such as "feed management for water quality." As noted by Alex Avery, "The statement 'feed management for water quality' changes the whole goal of the animal feeding operation. Having the most minimal nutrient impact becomes the new goal of feeding" (Avery, 1998). Thus, the nutritionist's role and perspective may need to change in the future to meet environmental regulations.

### Possible Roles of Nutritionists

**Information sources.** Less than 2% of the American public is involved in production agriculture. The vast majority of the public is scientifically and agriculturally illiterate. In a 1990 Gallup poll, 49% of Americans did not know that bread was made from wheat. As regulation increases, nutritionists can serve as knowledgeable information sources that defend and promote agriculture, and correct misinformation that is given to the public. By working with cattle feeders and other groups in a proactive manner, it is possible to limit adverse effects that regulations may have on the beef industry. Because "perception is reality" for many consumers, it is important that accurate information be provided to the public as well as to cattle feeders, feedyard managers, and feedyard owners.

**Paper work.** Under the new proposed water quality regulations, many smaller feedlots, previously not regulated, will be urged to voluntarily develop site-specific "technically sound and economically feasible Comprehensive Nutrient Management Plans (CNMPs)." In addition, many larger feedyards in areas of the country where regulation has been lax, will be required to write or revise CNMPs by the year 2001 (or 2008). The objectives of these CNMPs, as stated in the Unified Strategy, are to "minimize impact on water quality and public health." As noted in the Unified Strategy, "CNMPs should address at a minimum, feed management, manure handling and storage, land application of manure, land management, record keeping, and management of other utilization options." The plans must also address risks from other pollutants such as pathogens and must include a schedule to implement the management practices identified in the CNMP. "CNMPs should encourage and facilitate technical innovation and new approaches to manure and nutrient management. Development and implementation of CNMPs are the ultimate responsibility of the 'feedyard' operator with assistance as needed from certified industry staff, government agency specialists, private consultants, and other qualified vendors."
Table 1. Discipline Areas Reported by 20 Plains Nutrition Council Consulting Nutritionists in the 1998 Membership Directory of the American Society of Animal Science

<table>
<thead>
<tr>
<th>Discipline area</th>
<th>Percent reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruminant nutrition</td>
<td>100</td>
</tr>
<tr>
<td>Production and management</td>
<td>75</td>
</tr>
<tr>
<td>Forages</td>
<td>25</td>
</tr>
<tr>
<td>Animal behavior</td>
<td>20</td>
</tr>
<tr>
<td>Food Safety</td>
<td>20</td>
</tr>
<tr>
<td>Growth and development</td>
<td>20</td>
</tr>
<tr>
<td>Quality control/food safety</td>
<td>20</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
</tr>
<tr>
<td>Meat and muscle biology</td>
<td>5</td>
</tr>
<tr>
<td>Processing and engineering</td>
<td>5</td>
</tr>
<tr>
<td>Regulatory issues/legislation</td>
<td>5</td>
</tr>
<tr>
<td>Waste management</td>
<td>0</td>
</tr>
</tbody>
</table>

The Feed Management component of CNMPs states, “Where possible, animal diets and feed should be modified to reduce the quantities of nutrients in manure.” Records must be maintained of nutrients entering and leaving the operation. Thus, the nutritionist can (or should) play a major role in writing nutrient management plans. Who better knows and understands the quality and quantity of nutrients entering the feedyard, as well as the losses of those nutrients?

Under the proposed regulations, individuals that assist animal feeding operations (AFOs) with Nutrient Management Plans must be trained and certified. The draft strategy estimates that 300,000 AFOs will voluntarily need to develop or revise CNMPs and that 15,000 to 20,000 operations will be considered new Confined Animal Feeding Operations (CAFOs) and be required to develop and implement CNMPs. Therefore, one strategic initiative of the Unified Plan is to increase the number of certified specialists to develop CNMPs. With minimal training, many consulting nutritionists could become listed as certified specialists.

Consulting nutritionists are typically intelligent, motivated individuals capable of doing more than just “nutrition.” Even if they do not become a “certified specialist,” they are capable of including management of manure, compost facilities, wastewater, and wildlife in their areas of expertise.
Adopting/Adapting new technologies. "New" nutritional strategies have the potential to decrease the effects of feedyards on the environment. Obviously, many of these have yet to be "proven" under real world conditions, some are potentially more expensive than common practices, they may require additional management or equipment (feed delivery, feed inventory, feed storage, multiple finishing diets, etc.), and many need additional research. These technologies may have positive effects on the environment by decreasing total nutrient excretion, or by altering the route of excretion. For example, it seems that shifting N excretion away from the urine and to the feces (i.e., decreased apparent digestibility) may decrease ammonia volatilization losses to the atmosphere. The following is a brief list of technologies that are currently available or may be available in the near future.

1. "Use of the NRC, 1996 protein system to decrease feeding of excess N." Formulating diets based on their content of Degraded Intake (DIP) and Undegraded Intake Protein (UIP), rather than on total crude protein, could potentially decrease N excretion and ammonia emissions from the feedlot surface.

2. "Limited feeding / slick bunk management." These technologies have the potential to decrease total nutrient inputs and thereby decrease nutrient excretion. To meet environmental standards, it may be necessary to limit intakes to a greater extent than currently practiced.

3. "Phase-feeding." The swine industry has routinely adjusted the nutrient content of finishing diets (i.e., phase feeding) to more specifically meet the nutrient requirements of animals as they grow - because nutrient requirements change with the physiological state of an animal. Dr. Mike Galyean gave an excellent review of phase-feeding at the 1998 PNC Spring Conference (Galyean, 1998) and noted that there are a number of obstacles to overcome in using phase feeding systems in commercial feedyards. For many years Dr. Rod Preston has proposed decreasing dietary protein concentrations of beef cattle finishing diets as time on feed increased and even total withdrawal of supplemental protein during the final 30 to 60 days on feed (Preston, 1982). Whether this is economically practical under current feeding and management situations is equivocal (Galyean, 1998).

Decreasing the quantity of protein in the diet may have adverse effects on animal performance. Another potential problem with phase feeding of protein in finishing diets is adverse effects on animal health (i.e., increased acidosis problems). However, it may be possible to decrease these adverse effects via the addition of neutralizing agents such as calcium- and magnesium-hydroxides (Boukila et al., 1995).

4. "Precision Feeding." The term "precision ag" is a hot topic today that is normally applied to crop and forage production. Can it apply to finishing beef cattle? In the 1984 Nutrient Requirements of Beef Cattle (NRC, 1984) the protein requirements presented in the tables were to meet the calculated requirements for 50% of a given class of cattle. To meet the requirements of 84% of the cattle, the values needed to be multiplied by 1.14, and to meet the requirements for 100% of the cattle, the values needed to be multiplied by 1.28. Using the values from the 1984 NRC, we calculated animal performance and N excretion (Table 2) when pens of 100 steers
were fed diets formulated to meet the protein requirements of 50%, 84%, or 100% of the animals in the pen. In addition, assuming that animals could be sorted and individually fed based on their genetic potential for performance (obviously a pipe-dream today), overall pen performance and N excretion were calculated (i.e., precision feeding of the bottom-performing 50 steers, middle-34 steers, and best-performing 16 steers). Restricting the dietary protein concentration to meet the requirements of 50% of the cattle in the pen had adverse effects on animal performance and did not appreciably decrease total N excretion. Feeding to meet the requirements of 84% of the cattle rather than 100% had a modest negative effect on animal performance but an appreciable beneficial effect on N excretion. Precision feeding provided the best performance and lowest N excretion.

Table 2. Effects of feeding to meet the crude protein requirements of 50% (9.9% CP), 84% (11.3% CP), 100% (12.8% CP), or of performance groups (precision fed): 100 head of 880 lb., large frame steers

<table>
<thead>
<tr>
<th>Item</th>
<th>50%</th>
<th>84%</th>
<th>100%</th>
<th>Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ration cost, $/ton</td>
<td>108</td>
<td>110</td>
<td>112</td>
<td>109</td>
</tr>
<tr>
<td>N intake, lb/d</td>
<td>34.8</td>
<td>39.8</td>
<td>45.1</td>
<td>37.4</td>
</tr>
<tr>
<td>N excreted, lb/d</td>
<td>27.9</td>
<td>31.9</td>
<td>36.1</td>
<td>29.9</td>
</tr>
<tr>
<td>ADG, lb</td>
<td>2.73</td>
<td>3.39</td>
<td>3.52</td>
<td>3.52</td>
</tr>
<tr>
<td>Feed/gain</td>
<td>8.00</td>
<td>6.49</td>
<td>6.25</td>
<td>6.25</td>
</tr>
<tr>
<td>Cost of gain, $/cwt</td>
<td>43.20</td>
<td>35.70</td>
<td>35.00</td>
<td>34.06</td>
</tr>
<tr>
<td>Days to 1280 lb</td>
<td>146</td>
<td>118</td>
<td>114</td>
<td>114</td>
</tr>
<tr>
<td>N excreted, lb/pen</td>
<td>4,073</td>
<td>3,764</td>
<td>4,115</td>
<td>3,409</td>
</tr>
</tbody>
</table>

5. "Altering animal behavior." Animal behaviors may actually affect the environment. For example, dust events in feedyards usually occur in the late afternoon. A major factor involved with these dust events may be increased animal agonistic activity relating to the lack of feed (Wiggers et al., 1998; Morrow-Tesch et al., 1997 & personnel communication). It has been suggested that modifications of feeding programs could possibly alter animal behavior and decrease any adverse effects on air quality.

6. "Diet formulation." Owens et al. (1994), noted that many commercial trace mineral premixes, when formulated in typical finishing diets, did not meet the animals' requirements for at least one trace mineral. The percentages of the supplements that met requirements were as follows: Cu - 39%, Se - 46%, I & Mn - 54%, Zn - 70%. Galyean (1996) reported that to improve carcass quality and hoof health, a number of consultants provided Zn in finishing diets at concentrations as high as two to 10 times the NRC (1984) requirement. Copper supplementation was often two to four times NRC recommendations. The dietary mineral of
major concern, from an environmental stand point, is phosphorus. Erickson et al. (1998) noted that performance by yearling steers was not adversely affected by feeding diets with P concentrations as low as 0.14%. Thus, it may be possible to decrease the quantities of some minerals in finishing diets without adversely affecting animal performance.

7. “Increase Nutrient Recycling.” We recently reported that oscillating dietary protein concentrations between low and high concentrations at 48-hour intervals could potentially increase N retention, possibly by increasing N recycling within the gut (Cole, 1999). More data are needed, and there are a number of management obstacles that need to be overcome before this procedure could be used by the industry. Such procedures may also work for several minerals, especially those that can enter the rumen via the saliva. However, the use of these procedures may be restricted to “limit-feeding” situations. Other procedures may become available that increase nutrient recycling and thereby decrease nutrient inputs and outputs.

Balancing cost of gain and performance with environmental/waste management concerns. In order to meet some future environmental regulations, it is possible that animal performance and cost of gain will have to be sacrificed. For example, concentrations of some dietary nutrients such as N, P and some trace minerals may need to be decreased to reduce their concentration in manure and feedlot runoff. More expensive sources of nutrients (i.e., organic trace minerals, etc.) that may be more bioavailable might have to replace cheaper nutrient sources. “Safety margins” in diet formulation may have to be decreased. The nutritionist will have to balance these factors to determine the optimum point from an economical, liability (i.e., risk), and ecological stand point.

In the classic publication “Feeds and Feeding” (Morrison, 1961) an entire chapter was devoted to the manurial value of feeding stuffs. Morrison wrote “In purchasing feeds, one should consider not only their feeding value but also their worth as fertilizers. ... To determine which feeds are the cheapest ..., one should deduct the manurial value per ton from the gross price.” Today the objectives may be different but the results are similar. In formulating diets it may be necessary to evaluate the effects of those feeds on costs of waste management and manure disposal and include those costs as a portion of the diet costs. For example, if manure must be applied to land based on its P content, rather than its N content (a highly probable event in the near future), feedyard manure with a high P content will become less valuable and more difficult to sell (or give away) than manure with a low P content.

Benefits to the Consultant

New regulations are a potential opportunity to consulting nutritionists. Under the proposed Unified Strategy regulations, an estimated 100,000 + small cattle feedlots and several hundred larger operations that did not previously come under regulation, will either be required to or asked to voluntarily submit CNMPs to EPA by December 2002 (or 2008 for small operations). These cattle feeding operations will need expert help and guidance in formulating these plans. The Unified Strategy notes that operators use “qualified specialists from the public and private sectors to assist in development and implementation of CNMPs.” With budget and personnel cuts within agencies such as USDA-NRCS, it is very likely that there will not be
sufficient numbers of "public" sector employees to do the job. Therefore, private sector specialists, that are trained and certified, will be needed to do the job.

Conclusion

In a recent Feedstuffs article, Karl Hess and Frank Bryant of Sustainable Environmental Solutions, Inc., an agricultural environmental consulting firm in Lenexa, KS, wrote "The public is demanding that everyone - and that includes agriculture - be held accountable for their impact on the environment. This means big changes for American agriculture - changes in how it produces its commodities and changes in forces that influence its markets. ... Agricultural producers who resist change face a big and growing problem. ... It may not seem fair or right to make agriculture pay such a high price for America's new environmental conscience - especially after 100 years of being the world's breadbasket - but there is a lot in life that's not fair or right, and the trick is how to accept what is now inevitable" (Hess and Bryant, 1998). Dr. John Sweeten states the situation in a similar manner: "The public will never be satisfied with CAFOs. As yesterday's and today's questions are answered, the public will demand answers to new questions. Prepare for it, and become a part of the debate."

References and Related Literature


FEEDING BEHAVIOR OF FEEDLOT CATTLE: DOES BEHAVIOR CHANGE WITH
HEALTH STATUS, ENVIRONMENTAL CONDITIONS AND PERFORMANCE
LEVEL?

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Introduction

Achieving an optimal level of health and performance by cattle throughout the feeding
period will play an important role in overall economic return. The role of feeding behavior in
this process remains unclear; however, health and performance of cattle are directly related to
that animal achieving an optimal level of nutrient intake. Overall feeding behavior patterns in
cattle appear to be highly repeatable whether cattle are on pasture or fed in confinement (Dulphy
et al., 1980; Stricklin, 1987; Hicks et al., 1989). In general, this pattern is diurnal in nature with
periods of peak feeding activity occurring in early morning (dawn) and early evening (dusk).
For cattle fed in confinement, feeding activity is also related to the temporal and spatial
distribution and availability of feed, with the presentation of new feed acting as a stimulus to
initiate feeding activity (Dulphy et al., 1980). The potential relationship between the behavioral
aspects of feeding and/or watering activity of feedlot cattle, and growth, feed intake and health
remains undefined. Hicks et al. (1989), based on visual observations, suggested that frequencies
of feeding, ruminating and lying behavior were positively related to growth of feedlot cattle.
Hutcheson and Cole (1986), indicated that stressors associated with marketing and transport can
greatly depress feed intake during the initial 7-14 days after arrival in the feedlot. Likewise,
morbidity resulting from the above stressors will reduce the percentage of calves which will
consume feed as compared to cattle which do not become sick (Hutcheson and Cole, 1986).

Feeding behavior remains as one of the most important and little understood component
of the cattle feeding industry. Commonly, most of what is believed to be true about confined
cattle’s feeding behavior has been obtained by systems that either do not represent commercial
production or management situations; depend on physical observation of a sub-set of cattle
presumed to be representative of all individuals within a pen; or interfere with natural expression
of feeding behavior. While these systems have resulted in important but limited findings, it is
presumed, individual cattle respond differently to the management systems, environmental
changes and health challenges, which are imposed upon them.

While a limited body of research as well as a posteriori knowledge would suggest a direct
relationship may exist between an animal’s behavior, health, and performance-related
characteristics, establishing these relationships through conventional research techniques has
been difficult and limited in the scope of data which can be collected. Conventional techniques
used for evaluating behavioral patterns have typically employed direct visual observation for a
specified period of time. While this technique does allow for a variety of behaviors to be
observed and recorded, it is very labor and time intensive. This generally has limited the total
amount of time which can be devoted to direct observation, such that the behavioral data
collected typically represents only a window in time and may not be representative of longer
term behavioral patterns which an individual or group of animals may express. Other techniques
employed to evaluate behavior in cattle include the use of Calan gates and Pinpointer systems (Cole, 1995). An advantage for both of these systems includes the ability to measure individual animal feed intake. Disadvantages include the requirement for animal training and adaptation to the equipment and a disruption of social interaction as it relates to feeding behavior.

In the summer of 1996 Roche Animal Nutrition and Health initiated a project utilizing a novel technology (GrowSafe Systems®, Limited, Airdre, Alberta, Canada) to study many aspects of feeding behavior of cattle which previously had not been possible within a commercial feedlot setting. The system is unique because it is largely invisible to both cattle and feedlot management, in that it does not interfere with expression of animal’s natural feeding behavior or the interaction which occurs among a group of animals. Likewise, this system allows for the normal, routine feed delivery and management which occurs on a daily basis. The initial objectives of this research initiative were to determine if differences in health status existed and if these differences could be used to improve management of newly received cattle. Our objectives have continued to expand as our knowledge of the system’s strengths and weaknesses has increased. At present, we operate three systems in commercial feed yards with two systems located in the panhandle of Texas and one system located in Alberta, Canada. The objectives of the program include identifying and predicting health status of newly received cattle, characterization of cattle responses to environmental change, determination of feeding behavior differences between cattle of differing performance levels, and activity of social groupings while at the feed bunk.

**Equipment Description**

Feeding and watering behavior data were collected using an electronic monitoring system developed by GrowSafe Systems Limited® (Airdre, Alberta, Canada). The system records individual animal feeding and watering visits and location every 5.25 to 6 seconds. Four components make up the system (Figure 1): 1) RF ear tag containing a passive transponder and a capacitor molded in plastic (Allflex). The eartag, which is located in the bottom third of the ear, is also used for individual animal identification. 2) an antenna incorporated into a neoprene mat located in the feedbunk, 3) a reader panel located between two antenna in the feedbunk, and 4) a desktop computer located in a remote location at the feedyard.

Figure 1. Diagram of GrowSafe feeding behavior monitoring system.
The antenna in the neoprene mat, which is attached to the side of the feedbunk away from the cattle, can read the passive transponder at a distance of 18 to 21 inches. The antenna housed in the neoprene mat radiates a 134.2 kHz pulsating electromagnetic field. The energy generated by the magnetic field is collected by the transponder and stored in the capacitor located in the eartag. When a sufficient charge in the capacitor is obtained the transponder transmits its information back to the antenna. The reader panel differentiates several transponders at the same time and stores the approximately 1 minute of data. Individual cells within the antenna that are read in time sequence every 5.25 to 6 seconds accomplish separation of multiple transponder signals. Every 15 seconds the computer requests the reader panel data to be transferred to the computer and the data is written to the hard drive of the computer. Each individual animal has a data file consisting of location and yes or no data points representing each 5.25 to 6 second cycle of the antenna (Buhman, 1998; Sowell et al., 1998). The mean feeding and watering duration is then calculated from the raw data. Individual feed and water consumption cannot be determined with the system.

A feeding or watering event can be defined in multiple ways. Frequency of feeding events is defined by the absence of the individual from the feedbunk. The time span of the absence used to define a feeding event is not fixed and can range from 10 seconds to infinity. Each site also includes a weather station that is located in close proximity to the pen. The weather stations gather temperature, barometric pressure, wind speed, wind direction, relative humidity, and precipitation data at approximately 30 minute intervals. Environmental data is included in a separate file within the GrowSafe System.

**Definition of Feeding Behavior Variables**

The system allows one to specify the amount of time that cattle are absent from the bunk to determine feeding events, duration, and frequency. Schwatzkolf-Genswein et al. (1998) evaluated the impact of varying the length of time used to define a feeding event from 6 to 600 seconds when cattle were fed ad libitum or a restricted intake. The duration of feeding increased with the length of absence used to define a feeding event for ad libitum and restricted intake. However, the difference between the two feeding regimens was not impacted by the time interval used to define an event. Sowell (1997) also reached a similar conclusion concerning the amount of time used to define a feeding event when reviewing data from a commercial feedlot. Data from all sites is currently evaluated using an absence time of 5 minutes to define a feeding event.

Feeding duration is defined in two methods. The first method, “In to Out”, is the sum of time spent at the feedbunk between 5 minute absences. In to Out duration accounts for the time that an animal spends chewing feed or engaging in other social activities while standing at the bunk. The second method, “Head Down”, is the sum of all 5.25-second data points when the animal’s eartag is within the read range of the antenna. Head Down duration does not account for the time that cattle spend chewing feed while standing at the feedbunk. Actual visual observations of cattle, while attending the feedbunk in a pen equipped with the GrowSafe System, however, suggests that cattle are typically consuming feed when their eartag is in contact with the antenna.

Feeding frequency is defined as the number of independent visits made each day to the feedbunk that are separated by at least a 5 minute absence. Feeding intensity can be defined by
three methods. The first method, “In to Out intensity”, is defined as In to Out duration/feeding frequency. The measure of intensity provides an indication of the amount of time spent per visit including time when the animal is standing near the bunk but not actually consuming feed. The second method, “Head Down intensity”, is defined as Head Down duration/feeding frequency. This measure of feeding intensity provides an indication of the amount of time spent per visit actually consuming feed. The third, “Swingle intensity”, is defined as (Head Down duration/In to Out duration) * 100. Dr. Spencer Swingle, the originator of this conceptual approach to feeding intensity, provides an indication of the proportion of time spent at the bunk that is dedicated to feed consumption. The original premise for expressing feeding intensity in this manner, was that the more aggressive animals that one might assume would have superior average daily gain and feed intake would spend a greater proportion of time spent at the bunk consuming feed.

**Effects of Health Status on Feeding Behavior**

Sowell et al. (1997, 1998), Buhman (1998) and Daniels et al. (1999) have described effects of health status on feeding and watering behavior of calves during the receiving period. Sowell et al. (1997, 1998) reported that light weight calves that were pulled during a 32 d receiving period spent 51% less time at the feed bunk during the initial four days after arrival and 23% less time during the entire 32 d period than untreated calves (Figure 2).

Figure 2. Mean daily feeding duration (minutes/day) for treated and untreated lightweight calves

Daniels et al. (1999) evaluated the effects of health status, metaphalactic administration of two different injectable antibiotics, and route of antibiotic administration on feeding and watering behavior of lightweight calves received at McElhaney Cattle Co., Welton AZ. Daniels et al (1999) data agree with those of Sowell et al. (1997, 1998) indicating that morbid calves spent 40 to 41% fewer minutes per day at the feedbunk than untreated, and presumably healthy calves throughout two 21-d receiving studies. Interestingly, calves that received metaphalactic treatment tended to spend more time at the feedbunk than non-medicated control calves.
Untreated steers did spend a greater percentage of total time at the bunk in response to the third feed delivery than treated calves. However, the percentage of total time spent at the feed bunk was not influenced by health status for other feed deliveries or for the remainder of the day (Sowell et al., 1997, 1998). While the GrowSafe System does not measure individual feed consumption it seems unlikely that morbid calves that spend 23 to 41% less time at the feed bunk during the receiving period could consume as much feed as untreated calves. This observation is supported by individual average daily gain observations during the receiving period. Performance information suggests that untreated calves will gain weight 22 to 29% more rapidly than calves that are pulled and treated for respiratory disease (Hutcheson and Cole, 1986, Sowell et al., 1998, Buhman, 1998).

Buhman (1998) investigated the effects of health status on two groups of heifers (initial weights, 517 or 550 lb) originating from auction barns in the Southeast. Differences in feeding duration, based on health status, were less dramatic than those observed by Sowell et al. (1997, 1998); however, differences in feeding duration were noted for days 11 to 27 between cattle pulled and deemed sick based on additional medical evaluation and those not pulled or considered not sick after further evaluation. The existence of lung lesions and the extent of the lesion detected at the time of slaughter did not appear to be strongly related to an individual animal’s feeding or watering behavior during the first 57 to 62 days on feed.

Initially, most researchers involved in the project were optimistic that the GrowSafe System could be used to identify cattle in need of medical attention, based solely on feeding or watering duration or frequency. This expectation has been replaced with the knowledge that feeding and/or watering duration and frequency may differ based on health status with a tremendous overlap existing between pulled and un-pulled populations. Attempts are still ongoing to use behavior data to identify and predict differences in health status of feedlot cattle. Preliminary information suggest that the system may be able to identify potentially morbid animals 3 to 4 days before a pen rider would pull an animal based solely on visual determination of health status. The behavior model currently developed from medical pull records, however, tends to identify the same individuals as the pen rider. Accurate identification of all cattle in need of medical attention whether by visual or behavioral means remains a separate and elusive goal.

**Potential Impact of Environmental Changes of Feeding Behavior**

Changes in environmental conditions are frequently sited as the cause of corresponding alterations in feed consumption, occurrence of ruminal acidosis, and metabolic disorders. Presumably, these changes in environmental conditions are related to changes in individual animal’s overall behavior, including feeding behavior. The environmental components frequently indicated by feedyard personnel as being involved in behavioral changes include high wind, changes in barometric pressure, extremes in temperature or heat load (combination of temperature and humidity) and day length. Evaluation of environmental effects on feeding behavior requires analysis of several large data sets collected across all seasons of the year in order to separate the effects of days on feed and day length from other components. We continue to obtain behavioral and environmental data in the hope that analysis of the combined data sets collected in various geographic locations across seasons will yield useful information that could serve as a factual basis for implementing management changes. The following data presented in
this manuscript represents the observations of one such study conducted at Cactus Research, Cactus, TX from February, 1998 until June, 1998. Because of the limited duration of this study, the effects of time on feed, season and environmental changes cannot be separated. Consequently, interpretation of the following data should be regarded as a preliminary attempt to evaluate this type of data.

**Temperature Effects**

Feeding duration measured by the Head Down method, decreases with time on feed with a high of 92 minutes on day 13 and a low of 26 minutes on days 104 and 132 of the feeding period (Figure 3). The magnitude of day to day variation in feeding duration also appears to decrease as time on feed increases. This relationship appears to be independent of season based on observations at other behavior sites.

Figure 3. Average daily temperature and feeding duration (minutes/day) across time on feed (Whitley and McCollum, 1999).

Spikes in temperature appear to result in a corresponding inverse spikes in feeding duration early in the feeding period; however, this response appears to become less apparent after day 40 (Whitley and McCollum, 1999). The relationship between ambient temperature and feeding duration is described by the linear equation $Y = -0.8497X + 98.949$ ($R^2 = 0.7697$) where $X$ is ambient temperature and $Y$ is predicted feeding duration (Figure 4).
Figure 4. Relationship between ambient temperature and head down feeding duration.

The linear relationship, while strong, is more likely of a casual rather than causal nature. Ambient temperature effects in this data however, cannot be separated from either time on feed or season. Feeding duration decreases with time on feed regardless of season and likewise ambient temperature should increase with time on feed as the feeding period progresses from February into the spring and summer months. The effects of heat load (combination of ambient temperature and relative humidity), which would be associated with the summer season have not yet been determined.

Wind Speed and Barometric Pressure

High wind speed has been suggested by some in the cattle feeding industry to contribute to the metabolic disorder complex. Wind velocity above a certain level, may reduce feed consumption and feeding duration or simply reduce feeding duration so that feed consumption occurs over a shorter period of time. Data shown in the following figures represents one set of cattle fed from February 1998 until June 1998. Effects of days on feed, season, and ambient temperature have not been separated from the potential effects on feeding behavior attributable solely to the wind and as such this preliminary data should be interpreted with caution. Average daily wind speeds above 14 mph appear to result in a reduction in Head down feeding duration during the first 50 to 60 days on feed. After this point in time effects of average wind speed are less apparent. The relationship between average daily wind speed and feeding duration was described by the linear equation $Y = -0.8497x + 98.949$ ($R^2 = 0.7697$) where $X$ is average daily wind speed and $Y$ is predicted Head down feeding duration. The low correlation coefficient for this relationship suggests that wind speed accounts for only 1.4% of the variation in Head down feeding duration. If feeding duration is related to average daily wind speed it maybe a threshold response. Currently, feed intake information for the pen has not been compared with feeding duration on days of high wind. Consequently, it is not known if cattle consumed the same
amount of feed as on a less windy day in a shorter period of time or if feed consumption decreased to the same extent as feeding duration.

Figure 5. Average daily wind speed and feeding duration across time on feed (Whitley and McCollum, 1999)

Average daily barometric pressure, based on day to day change in barometric pressure and daily range in barometric pressure did not appear to be related to Head down feeding duration or day to day change in Head down feeding duration. Additional data is needed to more clearly separate environmental factors that contribute to changes in daily feeding duration.

Barometric pressure and wind speed are examples of factors that may be important in altering feeding duration and(or) feed consumption. However, the existing data is not adequate to fully evaluate the effects of these and other potentially important factors that may alter feeding duration because of the confounding effects of time on feed and season of the year.

**Feeding Behavior and Average Daily Gain**

If feeding behavior could be used as a measure to predict average daily gain, cattle could be sorted, where possible, into more effective outcome groups. Hicks et al. (1989) reported that the frequency of eating, ruminating, and lying are correlated with animal performance while percentage of total time spent eating tended to be related to average daily gain of the feeding period. In studies conducted by Sowell et al. (1998) and Schwatzkolf-Genswein (1998) attempts to describe the relationship between feeding duration and individual average daily gain resulted in highly significant relationships with very poor correlation coefficients. Most attempts to relate feeding behavior with average daily gain or feed efficiency have viewed rate of gain as a continuous variable rather than grouping cattle into outcome groups based on the mean rate of
gain for the pen. Whitley and McCollum (1999) used our data to separate steers into three possible rate of gain groupings. The first group consisted of 13.6% of 384 steers from four pens that had average daily gains that were > 1 standard deviation above the mean of the group (Good ADG). The second group consisted of 74% of the steers that had average daily gains that fell between ± 1 standard deviation from the mean (Moderate ADG). The third group consisted of 12.4% of the steers that had average daily gains that were < 1 standard deviation below the mean. They then plotted the head down feeding duration, feeding frequency and Swingle intensity for each group.

Head down duration of the three rate of gain outcome groups appears to be different after cattle were re-implanted on day 72. Feeding duration of cattle with the poorest average daily gains appears to separate from those with moderate or good rates of gain as early as d-41 on feed. Surprisingly, cattle with the best average daily gains tended to spend the least amount of time at the feedbunk, followed by those with moderate rates of gain while those with the poorest rates of gain spent the most time at the bunk. Frequency of feedbunk visits was not different among the three average daily gain outcome groups. This observation was unexpected based on the findings of Hicks et al. (1989) who suggested that the frequency of eating was more related to animal performance than total time spent eating. However, their study was conducted with 8 steers per pen that were physically observed every 30 minutes during a 24 hr period on day 40 of a 138-d feeding period. Our data suggests that time on feed is an important consideration that was not accounted for by Hicks et al. (1989).

Figure 6. Head down feeding duration (minutes/day) of good, moderate and poor rate of gain outcome groups across time on feed (Whitley and McCollum, 1999)
Swingle intensity (Head down duration/In to out duration *100) was also determined for the three average daily gain outcome groups (Figure 7). Separation of good, moderate and poor rate of gain groups based on Swingle intensity appears to occur earlier than when based on Head down feeding duration. Cattle with a good rate of gain may separate as early as day 12 or 13 from those with moderate or poor rates of gain. Cattle with a poor rate of gain may separate from those with a moderate rate of gain by day 40 of the feeding period. When Dr. Swingle first proposed this method of identifying intensity, the expectation was that cattle with a good rate of gain would spend a greater proportion of their total time at the feed bunk with their head down consuming feed. Data from Figure 7 indicates the exact opposite. Cattle with the best average daily gains spend less total time at the feed bunk and of that time they spend a smaller percentage actually consuming feed. Cattle with a moderate average daily gain are in the middle and those with the poorest average daily gains spend the most time at the feedbunk and a greater percentage of that time is spent with their head down presumably consuming feed.

Explanations for these observations remain unclear; however, several possibilities may seem plausible. Cattle that spend a greater portion of time at the feed bunk with their head down may have a reduced rate of feed consumption or a smaller bite size than cattle with moderate or good rates of gain. These same cattle may be those more prone to acidosis either inherently or because of their eating pattern. The steers with the poorest rates of gain may be the more aggressive animals and consequently expend a greater amount of energy defending or maintaining their social position while at the feedbunk and elsewhere in the pen. Hicks et al. (1989) noted that average daily gain was most highly correlated with time spent resting followed by time spent rumination. Steers with a good rate of gain would have more time to for lying and ruminating; although, the activities of steers away from the bunk has not been monitored in any of the studies conducted using the GrowSafe system. Steers that have a lower Swingle intensity may chew their feed more completely while at the feed bunk resulting in a greater salivary production and ruminal buffering capacity resulting in a group of steers that are less susceptible to acidosis. Greater salivary flow could also shift the digestion of a portion of the starch from the rumen to the small intestine (Froetschel et al., 1989; Streeter et al., 1995) thereby improving the overall utilization of energy.

Implications

Monitoring and evaluation of feeding behavior is a valid research tool that may lead to an improved ability to identify cattle in need of medical treatment, segmentation of cattle into expected performance outcome groups and modify the way cattle are managed during environmental adversity. However, additional data is needed to allow the separation of days on feed and seasonal effects. Differences in cattle type and stress level will likely impact the behavioral response to stressors. Consequently, data collected with a wide range of cattle types would appear to be needed to confirm existing health status findings. Future research will focus on the effects social groups, metabolic disorder syndrome, and environmental factors on the feeding and watering behavior of cattle.
Figure 7. Swingle intensity (head down duration /in to out duration*100) of good, moderate and poor rate of gain outcome groups across time on feed (Whitley and McCollum, 1999)

Literature Cited


DEVELOPMENTS IN THE MANAGEMENT AND SUPPLEMENTATION OF STOCKER CATTLE ON WHEAT PASTURE

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INTRODUCTION

Winter wheat pasture is a very unique and economically important renewable resource in Oklahoma and the southern Great Plains. Income is derived from both grain and the increased value that is added, as weight gain, to growing cattle that are grazed on wheat pasture. The potential for profit from grazing stocker cattle on wheat pasture is exceptionally good because of the high quality of the forage and the very favorable seasonality of prices for stocker and feeder cattle that favor price appreciation of the cattle.

Supplementation of cattle grazing wheat pasture is of interest in order to (a) provide a more balanced nutrient supply and feed additives such as ionophores and bloat preventive compounds, (b) substitute supplement for forage where it is desirable to increase stocking rate in relation to grazing management and (or) marketing decisions, and (c) substitute supplement for forage under conditions of low forage standing crop. It is said that "risk" decreases the value of cattle.
Predicting performance of wheat pasture stocker cattle is particularly challenging because of the potentially large variation in weather and forage standing crop. If weight gains of growing cattle cannot be predicted with some degree of accuracy, realistic breakevens, which are prerequisite to sound marketing decisions, cannot be calculated. The ability to predict cattle performance will become more important as the feedlot and stocker segments of the industry compete for supplies of stocker/feeder cattle, and as coordinated beef productions systems come to fruition. Results of some of the supplementation studies that we have conducted over several years at OSU are reported herein.

MINERAL CONTENT OF WHEAT FORAGE

Wheat pasture poisoning is a non-infectious metabolic disorder of cows grazed on wheat pasture. It occurs most frequently in mature cows that are in the latter stages of pregnancy or are nursing calves, and that have been grazing wheat pasture for 60 days or more. Cows with wheat pasture poisoning have low blood concentrations of both calcium and magnesium. While a similar, tetany-like condition may occur in stocker cattle, its incidence is extremely low. Considerable variation occurs in the mineral composition of wheat forage. Until more complete
data are available the data in Table 1 have been selected to indicate the calcium, phosphorus, magnesium, and potassium content of wheat forage in relation to the requirements for the same minerals of a 400 lb steer calf gaining 2 lb per day.

Table 1. Mineral composition of wheat forage.

<table>
<thead>
<tr>
<th>Item</th>
<th>Calcium</th>
<th>Phosphorus</th>
<th>Magnesium</th>
<th>Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition, % of DM</td>
<td>.35</td>
<td>.25 - .40</td>
<td>.15</td>
<td>3-5</td>
</tr>
<tr>
<td>Requirement</td>
<td>.56</td>
<td>.26</td>
<td>.10</td>
<td>0.7</td>
</tr>
</tbody>
</table>

*400 lb growing steer gaining 2 lb/day and consuming 11 pounds DM/day.

The values indicate that wheat forage contains marginal to sufficient phosphorus and magnesium, excess potassium (which is characteristic of small grains forages in general) and inadequate amounts of calcium for growing cattle. Therefore, calcium is the macromineral of primary concern in many wheat pasture grazing situations. In these situations, wheat pasture stockers should be supplemented with an additional 10 grams of calcium per day. While this may seem to be a very small amount of calcium (and therefore perhaps not of practical importance), for perspective the total calcium requirement of a 400 lb steer calf gaining 2 lb/day is 28 grams. The additional calcium could be included as calcium carbonate in other supplements or a mineral mixture. No mineral mixture will be efficacious if desired amounts are not consumed. Intake of mineral mixtures must be monitored.

The lower values for phosphorus content of wheat forage (Table 1) are from Bushland, Texas (Stewart et al., 1981). In this area, and perhaps the Panhandle of Oklahoma and Southwestern Kansas, wheat pasture stocker cattle should also receive supplemental phosphorus depending on soil type and actual mineral analysis of wheat forage. More recently we encountered a case of phosphorus deficiency in a group of growing steers grazing wheat pasture near Loyal, Oklahoma (i.e., North-Central Oklahoma). The farm had been in alfalfa for about 6 years prior to putting it into wheat. The application of phosphorus fertilizer for the wheat crop was less than recommended from soil test results. Phosphorus, calcium, magnesium and potassium contents of wheat forage samples collected on January 14 were, respectively, 0.16, 0.26, 0.16 and 1.72 % of DM. The Angus steers appeared healthy and were fairly fleshy, but seemed to crave bones, which were present in a native grass area adjacent to the wheat pasture, from carcasses of cows that had died in previous years. Depraved appetite or pica is a classical sign of phosphorus deficiency in beef cattle. We changed the mineral mixture that was being fed from a low-phosphorus mineral (4.0 %) to a mineral mixture that contained 12% calcium, 12% phosphorus and 12% salt. According to the owner, this resolved the bone chewing problem.

The question relative to the effect of feeding mineral mixtures (often high-magnesium mineral mixtures) to wheat pasture stockers on the incidence of bloat is commonly raised. There is no evidence to support the suggestion that supplemental magnesium will decrease the incidence and(or) severity of bloat of stocker cattle on wheat pasture. There may be a relationship between ruminal motility (and the ability of stocker cattle to eructate ruminal gases) and the CALCIUM status of the cattle. Ruminal and gut motility is greatly compromised by subclinical deficiencies of calcium. Therefore, the concern of providing additional calcium to growing cattle on wheat pasture is two-fold: (1) to meet requirements for growth and (2) to
perhaps decrease the bloat problem by an effect on ruminal motility. An interesting question is: Are the so-called "dry bloat" problems that are sometimes observed in wheat pasture stocker cattle related to a subclinical deficiency of calcium?

**PROTEIN SUPPLEMENTATION**

This section is included to briefly summarize some of the rationale and results of research conducted at Oklahoma State University (OSU) relative to the idea of providing undegradable intake protein to growing cattle on wheat pasture, and not as as thorough review of this subject. The National Wheat Pasture Symposium was held at OSU in the fall of 1983 to summarize the database relative to production and utilization of wheat pasture by cattle. Beever (1984) presented data that was interpreted to suggest that performance of rapidly growing cattle on wheat pasture may be limited by flow of inadequate amounts of non-ammonia N (NAN) to the small intestine. Johnson et al. (1974) reported CP values of wheat forage of 25 to 31% of DM during January to April with 17 to 33% of the nitrogen (N) being in the form of non-protein nitrogen (NPN). Horn et al. (1977) observed total soluble N and soluble NPN concentrations of wheat forage of 45 to 62 and 25 to 37% of total N, respectively. Beever et al. (1976), in studying different conservation methods for perennial ryegrass, observed a significant negative relationship \( r = -0.98, P<0.001 \) between the amount of N flowing to the small intestine (grams per 100 g N consumed) and solubility of forage N in .01% pepsin in .1N HCl. Egan (1974), Ulyatt and Egan (1980) reported large losses (i.e., 40 to 45%) of ingested N from the rumen of sheep fed high-protein ryegrass. Studies by Vogel et al. (1989a) showed that N of immature and mature wheat forage exist kinetically as two distinct pools with different rates of in situ ruminal disappearance. Approximately 50 to 75% of total forage N disappeared from a "very rapid disappearance" pool at rates of 16 to 19% per hour. Broderick (1984) also suggested the presence of two "degradation fractions" of N of alfalfa hay. MacRae and Ulyatt (1974) reported that 63% of the variation in live weight gain of sheep grazing ryegrass or white clover pasture was associated with the amount of NAN absorbed from the small intestine, and that there was no relationship between live weight gain and energy absorbed as volatile fatty acids (i.e., a measure of the "energy status" of the animals). These data indicated that the traditional concept that performance of growing cattle on wheat pasture is not limited by protein status should be reevaluated.

Studies were conducted at OSU over four wheat pasture years to determine the effect of feeding additional escape protein on weight gains of stocker cattle grazing wheat pasture. Details of the studies have been reported by Vogel et al. (1989b) and Smith et al. (1989). Cattle received no supplement (other than free-choice access to a commercial mineral mixture) or were fed daily 2 lb of a corn-based energy supplement or supplements that provided about .25 kg of protein from high-escape protein as cottonseed meal produced by mechanical extraction, meat meal, meat and bone meal or corn gluten meal. The .25 kg of protein from high-escape protein is very similar to the levels used by Anderson et al. (1988) in which supplemental escape protein increased gains of steers grazing smooth brome pastures. The supplements were isocaloric and contained similar amounts of calcium, phosphorus and magnesium. Monensin was included in the supplements to supply 130 to 150 mg/head/day.
Daily gains of the cattle were increased (P<.03) about .22 lb by the overall effect of supplementation. Provision of additional ruminal escape protein as cottonseed meal, meat meal, meat and bone meal, or corn gluten meal did not increase gains (P>.30) as compared with the corn-based energy supplement. Our conclusion has been that even though wheat forage contains large amounts of N that is rapidly degraded in the rumen, intakes of fermentable OM appear to provide energy for sufficient microbial protein synthesis in the rumen for growth of stocker cattle. In a later study reported by Phillips et al. (1995), nitrogen retention of lambs fed freshly harvested wheat forage in metabolism stalls was not improved by supplemental undegradable intake protein from cottonseed meal, feather meal plus corn gluten meal, or blood meal as compared with a corn-based energy supplement.

Interestingly the Level I Model of the 1996 Beef Cattle NRC, with the default microbial efficiency of 13%, predicts a negative metabolizable protein balance of 47 grams/day for a 450-lb growing steer on wheat pasture with an "ME allowed ADG" of 2.11 lb. Clearly, additional data relative to the partitioning of forage protein into degradable and undegradable intake fractions, microbial efficiency, etc. are needed to resolve the fundamental relationships underlying this question.

**ENERGY SUPPLEMENTATION**

Feeding moderate amounts of an energy supplement to growing cattle on wheat pasture is a way of increasing the stability of the enterprise, improving the predictability of cattle performance (i.e., decreasing production risk), and increasing stocking rate and flexibility by having more cattle on hand for grazing during the graze-out period. Because of the seasonality of stocker/feeder cattle prices and the dynamics of breakeven selling prices in stocker cattle budgets, the latter of these can be particularly important to the economics of growing cattle on wheat pasture.

**Silage**

There are areas of the southern Great Plains where silage is used very successfully to "stretch" available wheat forage and/or allow initial stocking densities on wheat pasture to be increased. In studies reported by Vogel et al. (1987 and 1989c), use of supplemental silage allowed initial stocking density on wheat pasture to be doubled without decreasing weight gains of stocker cattle. Supplemental silage decreased wheat forage intake linearly (P<.10). Each pound of added silage DM decreased DM intake of wheat forage by .66 lb. Extent of ruminal digestion of DM and NDF of wheat forage was increased by feeding silage indicating that silage had a positive associative effect on utilization of wheat forage (Vogel et al., 1989c).

**High-Starch versus High-Fiber By-Product Feed Based Supplements**

The response of growing cattle on wheat and/or other small grain pastures to supplemental grain has been variable. In studies reported by Elder (1967), Lowrey et al. (1976a, b), Utley and McCormick (1975, 1976), and Gulbransen (1976), steer grazing days/ hectare or stocking densities were increased 1.25- to 2-fold and daily gains were increased by .05 to .30 kg by feeding grain at levels of 1 to 1.5% of BW. Supplement conversions (kilograms of supplement/kilogram
of increased gain/hectare) ranged from 6.7 to 10.3. To prevent adverse effects of starch on ruminal fermentation, high-fiber byproduct feeds, such as wheat middlings, soybean hulls, and corn gluten feed, offer alternatives in formulating energy supplements with fairly high energy densities. The potential for using these byproduct feeds in supplementing growing cattle on wheat pasture is particularly good because of the rapid rate of ruminal degradation of wheat forage (Zorrilla-Rios et al., 1985) and the relatively low ruminal pH (Andersen and Horn, 1987).

During the three wheat pasture years of 1989/90, 1990/91 and 1991/92, we conducted studies to evaluate type of energy supplement (i.e., a corn-based, high-starch versus a high-fiber by-product feed based energy supplement) for growing cattle on wheat pasture. The high-fiber energy supplement contained about 47% soybean hulls and 42% wheat middlings (as-fed basis) and potentially may have less negative effects on forage intake and utilization than the high-starch supplement. The supplements were hand-fed 6 days/week at a level of about .75% of body weight (i.e., 4 lb/day for a 533 lb steer) and stocking rate was increased 22 to 44%. Non-supplemented, control cattle had free-choice access to a high-calcium commercial mineral mixture throughout the study. The objective of this supplementation program with respect to increasing stocking density was much different from that of Grigsby et al. (1991), Rouquette et al. (1990), and Branine and Galyean (1990), who fed energy supplements at levels of .15 to .20% of BW to cattle grazing rye-ryegrass or wheat pastures without increasing stocking density. Conversions of a corn-based energy supplement of 1.3 to 3 lb/lb of increased gain/animal were reported by Grigsby et al. (1991). Details of our studies have been reported by Horn et al. (1991), Cravey et al. (1993), and Horn et al. (1995). In general, results were as follows:

**Supplementation Response.** Over the 3-year period, weight gains during the fall/winter and early spring grazing period (i.e., up to time of jointing of wheat) were increased by energy supplementation (regardless of type of energy supplement) by an average of .33 lb/day, and were 2.02, 2.33, and 2.38 lb/day for the control, high-starch, and high-fiber supplemented steers, respectively. The gain response was similar at all stocking densities which increases the scope of application of the results. Mean consumption of the supplements was .65% of body weight which was a little less than the target of .75%.

**Type of Energy Supplement.** Type of energy supplement (i.e., high-starch vs high-fiber) did not affect weight gains of the cattle. In general, one would expect the difference in response by cattle to high-fiber versus high-starch energy supplements to decrease as the amount of supplement fed decreases and as crude protein content of the forage increases. The level of supplement fed in these studies was relatively small and wheat forage contains excess crude protein. Substitution of the supplements (i.e., units change in forage OM intake per unit increase in supplement OM intake) was calculated by regression of forage intake on amounts of supplement consumed. Substitution did not differ (P > .60) for the two types of supplements and was -.91 (Cravey, 1993). The mechanism for substitution of the supplements for forage has not been identified, but would not be expected to be the result of a ruminal nitrogen deficiency as has often been the case in grazing studies as discussed by Horn and McCollum (1987).

**Supplement Conversion.** Mean conversion of the supplements (expressed as lb of as-fed supplement per lb of increased gain per acre) was about 5.0 for both types of supplement, and did
not differ \((P > .95)\). This is substantially less than conversions of 9 to 10 that have traditionally been used in evaluating the economics of energy supplementation programs for wheat pasture stocker cattle.

**Cattle Preference for Supplements.** Cattle seemed to like the high-fiber supplement and consume it much more readily than the corn-based high-starch supplement. Generally, the cattle consumed the high-fiber supplement in a matter of 10-30 minutes in the morning; whereas, the corn-based supplement was eaten over at least 2 feeding periods during the day (morning and mid-afternoon). From a feed and bunk management standpoint, this difference in the supplements is extremely important on days of inclimate weather (i.e., rain, snow etc.) and in situations of bird predation where contamination of feed bunks by bird excreta was substantial for the corn-based supplement. In addition, the potential for acidosis is much less for the high-fiber supplement provided that the wheat middlings used in the high-fiber supplement don't contain a lot of fine starch.

**Risk Aversion.** We addressed the issue of risk aversion and input decisions relative to energy supplementation of stocker cattle under various cattle and supplement price scenarios (Coulibaly et al., 1996), and concluded that, in general, supplementation decreases production risk.

**Feedlot Performance.** Because wheat pasture cattle are some of the more fleshy cattle that are placed on feed, we were interested in the potential effect of energy supplementation on subsequent feedlot performance and were able to "follow the cattle through the feedlot" in two of the three years. Supplementation did not affect feed intake or feed gain \((P > .30)\) in one year whereas daily gain was decreased by about 0.20 lb \((P < .05)\). In another year, supplementation did not \((P > .80)\) affect feedlot daily gain.

**Economic Analysis (a.k.a.: Will it Pay?)**

There are several levels of economic analyses that can be used in evaluating the economics of supplementation programs and other management decisions in stocker cattle programs. Three of them are briefly discussed below.

**Comparison to Value of Weight Gain**

One approach is to simply compare cost of the additional weight gain to the gross value of weight gain in the stocker program. From the data reported by Trapp (1998) for Oklahoma City National Stockyards, we have fit price \(($/\text{cwt})\) to sale weight for stocker/feeder steers and heifers over two periods of time (1988-97, 10 years; and 1992-97, 5 years). Prices were related to weight as follows:

<table>
<thead>
<tr>
<th></th>
<th>Price (($/\text{cwt})) = (150.11 - .1579x + .00008x^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price (($/\text{cwt})) = (132.03 - .1286x + .00007x^2)</td>
<td></td>
</tr>
<tr>
<td>Price (($/\text{cwt})) = (120.78 - .1166x + .00007x^2)</td>
<td></td>
</tr>
<tr>
<td>Price (($/\text{cwt})) = (104.65 - .0902x + .00006x^2)</td>
<td></td>
</tr>
</tbody>
</table>

If one then adjusts the prices for seasonality, value of weight gain for purchasing calves in October and selling feeders in March are shown in Table 2. The value of weight gain for
growing steers on wheat pasture from 450 to 650 lb or from 450 to 750 lb ranged from about $54 to $61/cwt. Values for adding 200 lb to 350- or 450-weight heifers are substantially higher.

Table 2. Value of weight gain, $/cwt.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Steers</td>
<td>Heifers</td>
</tr>
<tr>
<td>350 - 550</td>
<td>- - - -</td>
<td>$73.01</td>
</tr>
<tr>
<td>450 - 650</td>
<td>$60.61</td>
<td>$66.27</td>
</tr>
<tr>
<td>450 - 750</td>
<td>$54.77</td>
<td>- - - -</td>
</tr>
</tbody>
</table>

If the cost of the additional weight gain from supplementation is less than the value of weight gain, supplementation would be profitable. At a supplement conversion of 5 lb supplement per lb of increased gain per acre and a feed cost of $140/ton, supplement cost per lb of increased gain would be $0.35. REMEMBER this is valid only if stocking density is increased since supplement conversion is expressed on an increased gain per acre basis. Also, any additional costs incurred in feeding the supplement (e.g., fuel, labor, etc.) should be included in the evaluation.

Budgeting the Stocker Operation

Microcomputer spreadsheet programs such as the "OSU STOCKER PLANNER" developed by Don Gill are excellent tools for evaluating a myriad of questions, management decisions, etc. in a stocker cattle program. Many of you are familiar with the program. Copies can be downloaded from our web site (http://www.ansl.okstate.edu/). Pasture can be priced on (1) a cost of gain basis or (2) as $/CWT of cattle/month. In addition the pasture cost input can be "finessed" to achieve any pasture cost ($/head) that you want.

Whole-Farm Economic Analysis

As stated earlier, this energy supplementation program has the potential advantage of allowing stocking density to be increased by about one-third. This allows more cattle to be purchased in the fall on seasonally low markets and to be available to graze-out a greater proportion of wheat in the spring. In a previous report (Horn et al., 1992), whole-farm net returns were estimated for three government farm program alternatives for the 1990/91 wheat pasture year (non-participation, the 5-month option and 0/92) and three cattle price scenarios that reflected stocker/feeder price spreads in real dollars of -$22.00 (low profitability), -$16.00 (moderate profitability) and -$7.00 (high profitability). The energy supplementation program (and increased stocking density) increased exposure to down-side price risk and resulted in lower whole-farm net returns under the low cattle price scenario. On the other hand, the energy supplementation program captured the benefits of favorable cattle price movements, and increased whole-farm net returns under the moderate and high price scenarios.
THRESHOLD HERBAGE ALLOWANCE FOR INITIATION OF ENERGY SUPPLEMENTATION PROGRAMS

Two studies were conducted (Redmon et al., 1995) to determine the relationship between in vitro organic matter (OM) disappearance in diets of cattle grazing wheat pasture and herbage allowance, the relationship between wheat forage intake (kg OM/100 kg BW) and herbage allowance, and the relationship between estimated daily gain of growing beef cattle grazing wheat pasture and herbage allowance. Paddocks were differentially grazed with growing beef cattle to produce an array of different herbage mass levels, expressed as kg dry matter (DM)/hectare. Each experimental paddock was then continuously stocked with three steers during each 7-day forage intake trial. Estimated daily gain was calculated from forage intake and net energy values calculated from diet organic matter disappearance data. Forage intake, organic matter disappearance, and estimated daily gain were related to daily herbage allowance, expressed as kg DM/100 kg BW/day, and herbage mass utilizing a quadratic equation with a plateau function. Plateaus for diet OM disappearance, forage intake, and daily gain were achieved at herbage allowances between 20 to 24 kg DM/100 kg BW/day, and decreased markedly at herbage allowances below this range. These data were interpreted as suggesting that a herbage allowance of 20 to 24 kg DM/100 kg BW/day may provide a threshold allowance for initiation of energy supplementation programs for growing cattle on wheat pasture. Similarly, Ellis et al. (1984) reported that DM digestibility by steers grazing annual ryegrass was progressively decreased (P<.01) as herbage allowance was reduced to less than 30 kg/100 kg BW.

IONOPHORES FOR WHEAT PASTURE STOCKER CATTLE AND DEVELOPMENT OF A SMALL-PACKAGE MONENSIN-CONTAINING ENERGY SUPPLEMENT

Two ionophores, monensin and lasalocid, are available for wheat pasture stocker cattle. Both of them, if delivered in the proper dosage, increase weight gains of growing cattle on wheat pasture by .18 to .24 lb/day over that of the carrier supplement (Horn et al., 1981 and Andersen and Horn, 1987), and improve the economics of supplementation programs. In addition, producer experience and research (Branine and Galyean, 1990) indicate that monensin decreases the incidence and severity of bloat from wheat pasture. Other characteristics of the two ionophores are listed below. The "+" sign indicates a more favorable or greater response of one over the other.

<table>
<thead>
<tr>
<th>Weight Gain Response</th>
<th>Monensin</th>
<th>Lasalocid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bloat protection</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Palatability</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Potential for toxicity</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>FDA clearance for everyday feeding</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

If the ionophore is included in a mineral mixture with a relatively low target intake (i.e., .25 to 1 lb/head/day) it has to be present at a greater concentration in order to supply the daily dosage.
of 150 to 200 mg/head than if it is included in a larger amount of some other feed or supplement. Therefore, the palatability advantage of lasalocid favors its use over monensin in mineral mixtures. In a preliminary study that we conducted many years ago (Horn and Phillips, 1985) consumption of a cottonseed meal- and wheat middling-based mineral mix, which contained either monensin or lasalocid, by stocker cattle on wheat pasture was .28 and .53 lb/head/day for the monensin and lasalocid-containing supplements, respectively. The supplements contained 400 mg ionophore/lb and the target daily intake was .50 lb/head.

During the 1991/92 wheat pasture year we measured voluntary intake of three different commercial mineral mixtures by cattle at the Marshall Wheat Pasture Research Unit. Pastures ranged from 18 to 42 acres and small numbers of cattle, as compared with the industry, grazed each pasture. The mineral mixtures were fed in a single weather vane-type mineral feeder in each pasture. No salt or other supplement was fed during the trial. Water from a rural water system was supplied in each pasture by a single water fountain. Intake of the different mineral mixtures is shown in Table 3.

Table 3. Intake of different mineral mixtures (1991/92 wheat pasture year).

<table>
<thead>
<tr>
<th>Manufacturer: Ionophore Concentration: Target intake, lb/head/day</th>
<th>Wheat Gainer Mineral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral</td>
<td>Wheat Pasture</td>
</tr>
<tr>
<td>Farmland</td>
<td>Pro Mineral B1440b</td>
</tr>
<tr>
<td>None</td>
<td>720 mg lasalocid/lb</td>
</tr>
<tr>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Mean (± SD) intake, Lb/hd/day</td>
<td>.30 ± .09</td>
</tr>
<tr>
<td>Number of pastures Head/pasture</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>5 to 7</td>
</tr>
</tbody>
</table>

*Presently named "Wheat Pasture Pro Mineral". Contained 20% salt, 16% calcium, 4% phosphorus, 5.5% magnesium and 150,000 I.U. Vitamin A per pound. Eleven observations at 6-day intervals per pasture mean.

bContained same mineral and vitamin concentrations as footnote "a" above. Eleven observations at 6-day intervals per pasture mean.

cContained 20% salt, 7% calcium, 6.75 magnesium and 30,000 I.U. Vitamin A per pound. Ten and eight observations at 6- and 5-day intervals for mix 1 and 2, respectively.

Intake of the Wheat Gainer Mineral was excellent and averaged .30 lb/head/day. This level of intake would provide 21 grams of calcium, and is consistent with the type of mineral needed to supply additional amounts of calcium to growing cattle on wheat pasture. Intake of the lasalocid-containing mineral was also good and would have supplied 166 mg of lasalocid. In previous research (Andersen and Horn, 1987), we observed a weight gain response by wheat pasture stockers to 200 mg/day of lasalocid but NOT to 100 mg/day of lasalocid. In general, intake of the monensin-containing mineral mix was low and was consistent with previous experience (Horn and Phillips, 1985) where we compared intake of a monensin- versus lasalocid-containing mineral mixture. Intake of the monensin-containing mineral mixture was too low to provide sufficient monensin to increase cattle performance.
During the last few years, several feed manufacturers have marketed a "new" monensin-containing mineral mixture for stocker cattle. This mineral mixture is typically an "R1620" formulation and contains 810 mg monensin/lb, about 10% calcium, and either no magnesium or a much lower concentration of magnesium than the mineral mixture (6.75% Mg) that we used in the 1991/92 study (Table 3). The lower concentration of magnesium may improve intake of the mineral. Recently, Brazle and Laudert (1998) reported that weight gains of yearling steers given free-choice access to a "R1620" mineral mixture while grazing either intensive early stocked or season-long native summer grass tended to be increased by .22 lb/day (P>.05) or were increased .16 lb/day (P<.08), respectively, as compared with the mineral mixture without monensin. Daily intake of the "R1620" mineral mixture was about 3.4 oz/steer versus 5.0 oz/steer for the mineral mixture without monensin. Thus, monensin intake was about 170 mg/steer, and may have been too low for maximum gain improvement of the steers that averaged about 670 to 700 lb during the study. Similar studies need to be conducted to evaluate the efficacy of these mineral mixtures for wheat pasture stocker cattle.

Variation in daily intake of supplements as well as mean overall supplement intake affect the response of grazing cattle to supplementation programs, and should be considered when selecting among the different strategies for getting appropriate additives into grazing cattle. In the study reported by Andrae et al. (1994), improvements in weight gain of cattle grazing wheat pasture and fed a monensin-containing energy supplement decreased as variation in daily supplement intake increased. Also, improvement in weight gains of cattle that consumed greater than 150 mg monensin/head/day was greater than that of cattle that consumed less than 150 mg/head/day of monensin.

Self-Limited Monensin-Containing Energy Supplement

Because of problems associated with delivering a sufficient amount of monensin by mineral mixtures and other considerations as discussed above, one of our initial research objectives within the Expanded Wheat Pasture Research Program was to develop a small-package, self-limited monensin-containing energy supplement for wheat pasture stocker cattle. The target level of consumption of this supplement is 2 to 3 lb/head/day and the supplement should:

1. Help balance the energy:crude protein ratio of wheat forage as discussed, from a conceptual standpoint, by Hogan (1982).
2. Provide monensin to:
   A. Improve the economics of the supplementation program.
   B. Decrease the incidence of bloat.
3. Provide additional calcium for growth of stocker cattle.
4. Provide a means from a management standpoint of getting other feed additives into the cattle when needed [i.e., Bloat Guard (poloxalene) in cases of severe or protracted bloat outbreaks].

Details of the individual year studies have been reported by Horn et al. (1990), Horn et al. (1992), and Beck et al. (1993). Note: Because of the low targeted level of intake of the
supplement, stocking densities were not changed when this supplement was fed. The supplement is designed to "supplement" wheat forage rather than to "substitute" for wheat forage.

Composition of this supplement is shown in Table 4, and the mean (± standard deviation) of supplement and monensin intakes are shown in Table 5. The supplement was fed as a 3/16-inch pellet during the first two years and in the meal form during the third and fourth years. While we experienced some over consumption (i.e., mean overall daily consumption of monensin greater than 200 mg) of the supplement by one group of cattle during each of the first two years, mean intakes were "close" to the target. In general, the target supplement intake of 2 to 3 lb/head/day was more closely achieved by feeding the supplement in meal form. Feeding the supplement in meal form probably slowed rate of consumption of the supplement and may have increased the taste of salt. Control of intake of the self-limiting supplement was particularly challenging during the 1992/93 wheat pasture year because it was so wet. There were times in which the cattle just didn't seem to want to fight the mud and, therefore, stayed closer to the feeder and source of water.

Table 4. Composition (as-fed basis) of self-limiting monensin-containing energy supplement*.  

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground milo</td>
<td>62.81</td>
</tr>
<tr>
<td>Wheat middlings</td>
<td>20.97</td>
</tr>
<tr>
<td>Sugarcane molasses</td>
<td>4.79</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>4.00</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>2.54</td>
</tr>
<tr>
<td>Magnesium oxide</td>
<td>.75</td>
</tr>
<tr>
<td>Fine mixing salt</td>
<td>4.00</td>
</tr>
<tr>
<td>Rumensin 60 Premix</td>
<td>.125</td>
</tr>
</tbody>
</table>

*Fed as 3/16-inch pellet during the first two years and in the meal form during the third year.

†Increased to 6%, at the expense of milo, depending on supplement intake.

‡To provide 75 mg monensin/lb of supplement.
Table 5. Daily consumption of self-limited monensin-containing energy supplement*.
(Mean ± std. dev.).

<table>
<thead>
<tr>
<th>Pasture</th>
<th>1</th>
<th>2</th>
<th>n^b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trial 1 (1989 - 90)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Supplement, lb/head</td>
<td>2.63 ± 1.00</td>
<td>4.24 ± 1.02</td>
</tr>
<tr>
<td></td>
<td>Monensin, mg/head</td>
<td>197 ± 75</td>
<td>318 ± 77</td>
</tr>
<tr>
<td></td>
<td>Trial 2 (1990 - 91)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Supplement, lb/head</td>
<td>4.08 ± 1.29</td>
<td>2.41 ± 1.19</td>
</tr>
<tr>
<td></td>
<td>Monensin, mg/head</td>
<td>306 ± 96</td>
<td>181 ± 89</td>
</tr>
<tr>
<td></td>
<td>Trial 3 (1991 - 92)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Supplement, lb/head</td>
<td>2.00 ± .71</td>
<td>2.00 ± .77</td>
</tr>
<tr>
<td></td>
<td>Monensin, mg/head</td>
<td>150 ± 53</td>
<td>150 ± 58</td>
</tr>
<tr>
<td></td>
<td>Trial 4 (1992 - 93)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Supplement, lb/head</td>
<td>2.67 ± 1.28</td>
<td>3.13 ± 1.52</td>
</tr>
<tr>
<td></td>
<td>Monensin, mg/head</td>
<td>200 ± 95</td>
<td>235 ± 114</td>
</tr>
</tbody>
</table>

*Supplement was fed as a 3/16-inch pellet during the first two trials and in the meal form during trials 3 and 4.
^bNumber of observations. Consumption of supplement was measured twice weekly.

Cattle performance data is shown in Table 6. Weight gains were consistently increased by about .5 lb/day by the supplement. At feed costs of $80, 110 and 140/ton, per-head profits were increased by $15 to $31 (1990 dollars) depending on profit potential that existed during the 10-year period, 1980-89. These increased per-head returns do not include additional profits as a result of decreased death loss due to bloat as a result of feeding the monensin-containing energy supplement. Each one percent decrease in death loss would be worth another $5 to $7/head depending on cost of the cattle and when they died.

Table 6. Effect of self-limited monensin-containing energy supplement on daily gains (lb) of steers.

<table>
<thead>
<tr>
<th>Trial No.</th>
<th>Dates (Days)</th>
<th>Treatment</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>October 26, 1989 to February 24, 1990 (120 days)</td>
<td>Control</td>
<td>1.76</td>
<td>Monensin/energy Supplement</td>
<td>2.29^a</td>
</tr>
<tr>
<td>2</td>
<td>November 13, 1990 to March 14, 1991 (120 days)</td>
<td>2.42</td>
<td>2.91^b</td>
<td>+.49</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>November 17, 1991 to March 6, 1992 (120 days)</td>
<td>2.31</td>
<td>2.76^c</td>
<td>+.45</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>November 13, 1992 to March 14, 1993 (122 days)</td>
<td>1.65</td>
<td>2.12^a</td>
<td>+.47</td>
<td></td>
</tr>
</tbody>
</table>

^aGreater than control (P < .03).
^bGreater than control (P < .003).
^cGreater than control (P < .15).
While this supplement was designed to be self-limited, it has not been approved by the Food and Drug Administration (FDA) for free-choice feeding and it does require close management. Monensin in large amounts will kill cattle. However, if one considers the LD$_1$ for monensin to be 5.5 mg/kg body weight (Potter et al., 1984) or 1250 mg/head/day for a 500-lb steer, then there is a theoretical safety ratio of 4.17 for 500-lb cattle consuming 300 mg monensin/day. Each year of these studies, cattle had free-choice access to large round bales of grass hay during periods of low wheat forage availability and (or) snow/ice cover of wheat in an attempt to curb appetite and prevent over consumption of the self-limited supplement. Other management practices that may help achieve the desired level of intake of self-limited supplements by cattle on pasture include placement (location) of feeder(s) with respect to water and other cattle loafing areas, adjustments of the feed hopper door (i.e., How readily does the supplement flows out of the feeder or how difficult is it for the cattle to get at the supplement?), and availability of other sources of salt such as block salt. Proportional adjustments in drug concentration of the supplement can also be made to achieve the desired level of intake.

Modifications of the Formula

We had an additional opportunity to study this supplementation program during the 1995/96 wheat pasture year at the Marshall Wheat Pasture Research Unit. The “original” formula for this supplement contained about 67% ground milo and 21% wheat middlings. The wheat middlings were included primarily to improve pellet quality during the first two years of the study. The objective of the 1995/96 study was to determine if substitution of equal proportions of wheat middlings and soybean hulls (midds/hulls) for the ground milo and wheat middlings of the original formula affected intake of the self-limited supplement and cattle growth performance. The monensin concentration of the supplement was also decreased from 75 mg/lb (“original” formula) to 60 mg/lb in order to provide a greater margin in relation to the FDA approved level of monensin intake.

Mean intake of the milo-based (“original” formula) and the midds/hulls-based supplements from December 7, 1995 through March 13, 1996 (98 days) was 2.06 and 2.33 lb/steer/day, respectively. There was no difference between intake of the two supplements. This will give greater flexibility in formulating this supplement depending on the availability and cost of energy feedstuffs. Monensin consumption averaged 124 and 140 mg/steer/day for the milo- and midds/hulls-based supplements, and was lower than the desired level of 180 to 200 mg.

Daily weight gain of steers during the 98-day study averaged 2.12 lb (non-supplemented, control), 2.41 lb (milo-based supplement), and 2.36 lb (midds/hulls-based supplement), and was increased by supplementation but not by type of supplement (i.e., milo- versus midds/hulls-based supplement). The gain response to supplementation was substantially less than that of our previous studies, and probably due to the lower mean intake of supplement and monensin particularly during the early part of the study.
What are the Limiters of Intake?

**Salt.** During the first year of these studies we sometimes increased the level of salt in the supplement from 4 to 6% when consumption was greater than desired and/or provided plain block salt for the cattle. These levels of salt were based on initial conversations with some of you, and in subsequent years we have stuck with the 4% level, and have not conducted studies to evaluate the sensitivity of supplement consumption to salt level.

**Monensin.** Using four wheat pastures equipped with Pinpointer feeders near Stillwater, we (Paisley and Horn 1996a and 1996b) examined the effect of monensin on voluntary consumption of the self-limited supplement. Each 22-acre pasture was grazed by 11 fall-weaned steer calves from one of the OSU beef cow herds. The pastures were about 681 meters long and 125 meters wide and had automatic waterers at the south end of each pasture. The Pinpointer feeders were located within 17 meters of the waterers in each pasture. The steers had free-choice access to the milo-based supplement with 4% salt and either no monensin or 75 mg monensin/lb as-fed. Supplements were fed in meal form, and were sampled each time feed was added to the hopper bin to verify monensin concentrations. Supplement intakes of each group of steers from January 17 to April 12 (84 days) were calculated from feed and weekly weigh-backs because of large discrepancies between the calculated data and Pinpointer data. Thus, no data was obtained relative to frequency of supplement intake and meal size by the individual steers.

Supplement intakes were analyzed as a repeated measures design with week and treatment in the model. Because there were no week by treatment interactions (P>.15), the data were pooled across weeks. Mean intakes (± std. Dev.) of the supplements were: 4.72 ±1.52 and 5.35 ± 0.93 lb DM (0 mg monensin); and 1.34 ± 0.35 and 1.54 ± 0.52 lb DM (75 mg monensin/lb), and were decreased by monensin (P<.001). Overall weight gains of steers of the two treatments were not different (P=.24) even though they consumed much lower amounts of the monensin-containing supplement.

**Magnesium Oxide.** Similar studies as described above for monensin were conducted by Paisley (1998) with the milo-based supplement containing 4% salt, 75 mg monensin/lb, and four levels of magnesium oxide (BayMag) using the Pinpointer feeders. Levels of magnesium oxide were .25, .75, 1.25, and 1.75 % of the as-fed supplement. Actual magnesium concentrations were .49, .85, 1.17, and 1.56 % as-fed, and the supplements analyzed 80 to 85 mg monensin as-fed. Forty eight spring-born Angus X Hereford crossbred steers were obtained from one of the OSU beef cow herds. Steers were initially weighted November 8 and assigned to one of four pastures. Cattle were fitted with pinpointer collars on November 13 and allowed to adapt to feeders for 8 days prior to the intake measurements. Final weights were taken December 20, with both initial and final weights recorded after a 14-h shrink.

Because supplement intakes of individual animals were measured, steer weights and daily gains were analyzed as a completely randomized design with animal as the experimental unit. Supplement intakes were analyzed using two models. Model I included treatment, steer(treatment), day, and treatment x day as sources of variation, and was used to analyze all 1344 intake observations (28 days x 48 steer). For Model II, individual supplement intakes were
averaged across the 28-day intake period, and the 48 observations were analyzed with treatment as the only independent variable. For both models, pre-planned linear, quadratic, and cubic orthogonal contrasts were used to interpret the effect of increasing levels of magnesium oxide on supplement intake and animal performance.

Table 7. Effect of energy supplementation with increasing levels of magnesium oxide on performance of steers grazing winter wheat.

<table>
<thead>
<tr>
<th>Item</th>
<th>Level of magnesium oxide, %</th>
<th>Contrast&lt;sup&gt;a&lt;/sup&gt;</th>
<th>SE&lt;sup&gt;b&lt;/sup&gt;</th>
<th>L</th>
<th>Q</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.25</td>
<td>.75</td>
<td>1.25</td>
<td>1.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW Nov. 8, lb</td>
<td>562</td>
<td>556</td>
<td>548</td>
<td>533</td>
<td>15.5</td>
<td>.18</td>
</tr>
<tr>
<td>BW Dec. 20, lb</td>
<td>632</td>
<td>637</td>
<td>616</td>
<td>605</td>
<td>16.2</td>
<td>.16</td>
</tr>
<tr>
<td>ADG, lb/d</td>
<td>1.71</td>
<td>1.98</td>
<td>1.67</td>
<td>1.74</td>
<td>.132</td>
<td>.74</td>
</tr>
</tbody>
</table>

<sup>a</sup>Observed significance level for linear (L), quadratic (Q), and cubic (C) contrasts.
<sup>b</sup>Standard error of the means

Final weights and daily gains of steers were not affected (P>.11; Table 7) by increasing levels of MgO. Both Models I and II indicated that supplement intake increased linearly (P<.05) with increasing levels of magnesium oxide (Table 8). Differences in intake among the supplements were small, and mean consumption of all supplements was less than the target of 2 to 3 lb/steer/day. Time (minutes/day) that the steers spent in the feeders was influenced in a quadratic manner (P<.01) by level of MgO. Although not significant (P>.05), visits/day appeared to follow the same quadratic trend as eating time. These results indicate that inclusion of MgO at levels up to 1.75% of supplement does not limit intake. Coffey and Brazle (1994) reported that magnesium-mica at levels up to 50% did not limit intake of a ground milo supplement by steers grazing smooth bromegrass supplements.

Table 8. Intake of a self-limited monensin-containing energy supplement with increasing levels of magnesium oxide.

<table>
<thead>
<tr>
<th>Item</th>
<th>Level of magnesium oxide, %</th>
<th>Contrast&lt;sup&gt;*&lt;/sup&gt;</th>
<th>SE&lt;sup&gt;b&lt;/sup&gt;</th>
<th>L</th>
<th>Q</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.25</td>
<td>.75</td>
<td>1.25</td>
<td>1.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intake, lb-hd&lt;sup&gt;-1&lt;/sup&gt;-d&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>1.31</td>
<td>1.45</td>
<td>1.27</td>
<td>1.93</td>
<td>.055</td>
<td>.01</td>
</tr>
<tr>
<td>Min. eating suppl.</td>
<td>15.5</td>
<td>13.5</td>
<td>13.7</td>
<td>20.2</td>
<td>.54</td>
<td>.03</td>
</tr>
<tr>
<td>Visits to feeder</td>
<td>2.66</td>
<td>2.53</td>
<td>2.52</td>
<td>3.13</td>
<td>.075</td>
<td>.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Model II</td>
<td></td>
</tr>
<tr>
<td>Intake, lb-hd&lt;sup&gt;-1&lt;/sup&gt;-d&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>1.31</td>
<td>1.45</td>
<td>1.27</td>
<td>1.93</td>
<td>.162</td>
<td>.03</td>
</tr>
<tr>
<td>Min. eating suppl.</td>
<td>15.5</td>
<td>13.5</td>
<td>13.7</td>
<td>20.2</td>
<td>1.37</td>
<td>.02</td>
</tr>
<tr>
<td>Visits to feeder</td>
<td>2.66</td>
<td>2.53</td>
<td>2.52</td>
<td>3.13</td>
<td>.190</td>
<td>.11</td>
</tr>
</tbody>
</table>

<sup>*</sup>Observed significance level for linear (L), quadratic (Q), and cubic (C) contrasts.
<sup>b</sup>Standard error of the means

Hand-Fed Monensin Supplement

While some producers prefer self-limiting supplements that can be fed free-choice, others prefer to hand-feed supplements. Hand-feeding obviously allows much better control of
supplement intake, and monensin has FDA approval for every other day feeding to stocker cattle. During the 1992/93 wheat pasture year we (Andrae et al., 1994) made slight modifications to the self-limited supplement and hand-fed it every other day at the level of 4 lb/head (or 360 mg monensin) to steers (552 lb mean initial weight) in individual feeding stalls adjacent to wheat pasture. Feedstuff composition of the hand-fed supplement is shown in Table 11. Daily weight gains were increased by .56 lb/steer, which is similar to that observed in the free-choice studies. We also looked at variation in supplement intake by individual steers and partitioned them into low, moderate, and high variation groups based on the standard deviations of supplement intake. Variation of supplement intakes decreased as mean supplement intakes increased (i.e., the two were inversely related) as shown in Table 9, and mean supplement intakes were significantly different among all three levels of variation. This suggest that cattle with the least variable intakes tended to consume the entire amount of supplement that was offered more often than those in more variable groups. Daily gains also increased as variation in supplement intake decreased. Supplemented steers with monensin intakes greater than 150 mg/day tended to have greater weight gains than those with monensin intakes less than 150 mg/day (Table 10). These data accentuate the importance of not only formulating supplements and managing supplementation programs in order to achieve desired mean intakes by the herd, but to also minimize variability of supplement intake.

An additional study regarding this supplementation strategy was conducted during the 1997/98 wheat pasture year by Paisley et al. (1998). The hand-fed supplement (also shown in Table 11) was similar to that used before except that Smectite was used as a pellet binder and Rumensin 80 Premix was used at a concentration of 0.125% of the as-fed supplement to provide 100 mg monensin/lb of supplement. One-hundred and ten (110) steers and eight wheat pastures
were used, and the steers had (1) free-choice access to a high-calcium mineral supplement without an ionophore or (2) were hand-fed 4 lb of the monensin-containing energy supplement every other day. Results are shown in Table 12. Daily consumption of the supplements averaged 0.30 and 1.83 lb/steer for the mineral and monensin-containing energy supplements, respectively. Daily gains of cattle fed the energy supplement were increased by 0.39 lb as compared with cattle fed the mineral supplement. Supplement conversion, expressed as lb of supplement per lb of increased gain, was 4.69.

Table 11. Feedstuff composition (% as-fed) of hand-fed monensin-containing energy supplements.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground milo</td>
<td>66.65</td>
<td>62.15</td>
</tr>
<tr>
<td>Wheat middlings</td>
<td>21.00</td>
<td>21.00</td>
</tr>
<tr>
<td>Sugarcane molasses</td>
<td>4.80</td>
<td>5.00</td>
</tr>
<tr>
<td>Limestone</td>
<td>4.00</td>
<td>4.30</td>
</tr>
<tr>
<td>Dicalcium phosphate, 21% P</td>
<td>2.55</td>
<td>2.55</td>
</tr>
<tr>
<td>Magnesium Mica (Smectite)</td>
<td></td>
<td>4.00</td>
</tr>
<tr>
<td>Fine Mixing Salt</td>
<td>.50</td>
<td>.50</td>
</tr>
<tr>
<td>Magnesium oxide</td>
<td>.35</td>
<td>.22</td>
</tr>
<tr>
<td>Rumensin 60 Premix</td>
<td>.15c</td>
<td></td>
</tr>
<tr>
<td>Rumensin 80 Premix</td>
<td></td>
<td>.125f</td>
</tr>
<tr>
<td>Vitamin and Trace-Mineral Premix</td>
<td></td>
<td>.10</td>
</tr>
<tr>
<td>Vitamin A-30</td>
<td></td>
<td>.05</td>
</tr>
</tbody>
</table>

*Andraé et al., 1994.
ªPaisley et al., 1998.
Appreciation is expressed to Farmland Industries, Inc. for providing this supplement as an 11/64-inch pellet.
ªFine mixing salt (99.5% NaCl).
ªTo provide 90 mg monensin/lb of supplement.
ªTo provide 100 mg monensin/lb of supplement.

Averaged over the two years, this supplementation program has increased weight gain of wheat pasture stocker steers by 0.48 lb/day.

Further Studies On Bloat

In a study reported by Paisley and Horn (1998), twelve rumen cannulated steers that grazed the same wheat pasture near Stillwater were randomly allotted to three experimental groups. Gelatin capsules containing nothing, monensin, or lasalocid were placed directly into the rumen of each steer each day. Dosage of the ionophores was 300 mg/day because the steers weighed 1164 ± 67 lb. After a preliminary period of 16 days, the steers were assigned a bloat score each morning from March 15 through March 28 (14 days). While the wheat was in a rapid growth stage during this time, it was fairly immature. Hard freezes on the mornings of March 14, 15 and 16 increased the incidence of bloat and slowed the rate of wheat growth. Bloat scores were as follows:
0 = Normal, no visible signs of bloat.
1 = Slight distention of left side of animal.
2 = Marked distention of left side of animal. Rumen distended upward toward top of back. Animal has asymmetrical (egg-shape) look when walking away from observer.
3 = Severe distention. Distension is above top of back and visible from right side of animal.

Steer days of bloat (i.e., the number of days that steers had a bloat score of 1, 2 or 3) and the mean bloat score for each group of steers is shown in Table 13. Monensin decreased (P<.05) both the incidence and severity of bloat and was more efficacious for prevention of bloat than lasalocid. This study supports the earlier suggestions, as referenced in the first paragraph of this paper, relative to the use of monensin for prevention of bloat of wheat pasture stocker cattle.

Table 12. Forage availability, supplement intake, and performance of steers grazing winter wheat and receiving either the alternate day energy supplement or mineral.

<table>
<thead>
<tr>
<th>Item</th>
<th>Mineral-supplemented</th>
<th>Monensin/energy supplement</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pastures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Forage Mass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec. 5, lb DM/acre</td>
<td>2681</td>
<td>2565</td>
<td>334.5</td>
</tr>
<tr>
<td>Jan. 20, lb DM/acre</td>
<td>2378</td>
<td>2351</td>
<td>196.6</td>
</tr>
<tr>
<td>Feb. 20, lb DM/acre</td>
<td>2059</td>
<td>1989</td>
<td>201.1</td>
</tr>
<tr>
<td>Supplement intake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supp. Intake, lb/day</td>
<td>.30</td>
<td>1.83</td>
<td>--</td>
</tr>
<tr>
<td>Monensin, mg/day</td>
<td>0</td>
<td>183</td>
<td>--</td>
</tr>
<tr>
<td>Calcium, g/day</td>
<td>21.9</td>
<td>18.7</td>
<td>2.73</td>
</tr>
<tr>
<td>Phosphorous, g/day</td>
<td>5.5</td>
<td>7.5</td>
<td>.67</td>
</tr>
<tr>
<td>Magnesium, g/day</td>
<td>7.5</td>
<td>5.61</td>
<td>.95</td>
</tr>
<tr>
<td>Cattle performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of steers</td>
<td>52</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Initial wt, lb</td>
<td>512</td>
<td>515</td>
<td>11.9</td>
</tr>
<tr>
<td>Final wt, lb</td>
<td>802i</td>
<td>848i</td>
<td>2.8</td>
</tr>
<tr>
<td>Daily gains, lb</td>
<td>2.53i</td>
<td>2.92i</td>
<td>.029</td>
</tr>
<tr>
<td>Supp. conversion</td>
<td>--</td>
<td>4.69</td>
<td>--</td>
</tr>
</tbody>
</table>

*Steers had free-choice access to Wheat Pasture Pro Mineral™ (Farmland Industries, Inc.).
*Steers were fed 4 lb/steer every other day.
*Based on supplement monensin concentration of 100 mg/lb.
*Calculated from supplement and mineral analysis.
*Weights included initial steers as well as steers added December 5, 1997.
*Calculated based on 127 and 113 grazing days, respectively, for Marshall and Stillwater locations.
*Supplement conversion, lb of supplement/lb of added weight gain.
*Means within a row with uncommon superscripts differ (P<.05).
Table 13. Effect of Ionophore on the incidence and severity of bloat\textsuperscript{a,b}

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>Monensin\textsuperscript{c}</th>
<th>Lasalocid\textsuperscript{c}</th>
<th>SE\textsuperscript{c}</th>
<th>Control vs Ionophore\textsuperscript{d}</th>
<th>Monensin\textsuperscript{c} vs Lasalocid\textsuperscript{c}</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of steers</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of steers that bloated*</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total steer days of bloat</td>
<td>40</td>
<td>4</td>
<td>33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean days of bloat/steer</td>
<td>10.0</td>
<td>1.0</td>
<td>8.3</td>
<td>2.25</td>
<td>.083</td>
<td>.049</td>
</tr>
<tr>
<td>Mean bloat score/steer</td>
<td>.88</td>
<td>.05</td>
<td>.77</td>
<td>.206</td>
<td>.097</td>
<td>.036</td>
</tr>
</tbody>
</table>

\textsuperscript{a}From March 15 to March 28, 14 days.

\textsuperscript{b}Bloat scores consist of: 0 = no visible signs of bloat; 1 = slight distention of left side; 2 = marked distention of left side; 3 = left and right sides distended

\textsuperscript{c}Standard error of least squares means.

\textsuperscript{d}P-value associated with orthogonal contrasts.

\textsuperscript{e}Steers given a bloat score greater than zero on one or more days.

**ENERGY SUPPLEMENTS TO STRETCH A SHORTAGE OF WHEAT PASTURE**

The 1991/92 wheat pasture year was very dry, and many pastures were extremely short of forage at the time of "traditional" turnout. In some of our pastures we had as little as 300 lb of forage dry matter per acre. While this was a problem, it did present us with an opportunity to compare some different types of energy supplements for stretching this severe shortage of wheat pasture. Our objective was to compare limited amounts (i.e., 1\% of mean body weight) of whole corn, dry-rolled corn or a 50/50 mix of pelleted wheat middlings/soybean hulls. The supplements were hand-fed 6 days/week. Our target gain for the cattle was 2 lb/day. Nine pastures were used in the study and initial stocking density was 3.5 acres/steer to provide an initial forage allowance of 1300 lb of forage DM/steer. Because of the very mild winter and continued growth of wheat forage, cattle of three pastures were distributed by treatment through the other six pastures on January 30, 1992 in an attempt to provide equal and lessor amounts of forage to all cattle. Forage availability in each of the pastures on January 21 was about 1500 lb DM/steer and greater than we would have liked for the initial objective of the trial. Forage growth after January 30 was excellent. Because wheat jointed so early, the cattle were removed on February 28. Performance of the steers is shown in Table 14.

<table>
<thead>
<tr>
<th>No. Pastures</th>
<th>Whole Corn</th>
<th>Dry-rolled Corn</th>
<th>Wheat midds/soybean hulls</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Steers</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Initial Weight, lb (12/5/91)</td>
<td>438</td>
<td>438</td>
<td>439</td>
</tr>
<tr>
<td>Final Weight, lb (2/28/92)</td>
<td>622</td>
<td>630</td>
<td>625</td>
</tr>
<tr>
<td>Daily Gain, lb (84 days)</td>
<td>2.17</td>
<td>2.25</td>
<td>2.19</td>
</tr>
</tbody>
</table>

*Increased to 14 on January 30.
*Increased to 18 on January 30.
*Add-on steers of January 30 were not included in calculation of mean daily gains.

Weight gain of all steers was about 2.2 lb/day during the 84-day trial, and was not different (P > .62) among treatments which is in general agreement with our other results where we have not observed a difference in gain between steers supplemented with a high-starch, corn-based supplement versus a high-fiber, byproduct feed-based supplement on wheat pasture. Steers consumed the whole corn much more readily than the rolled corn, and usually had slick bunks by mid-afternoon. Two steers fed rolled corn foundered and showed signs of lameness throughout most of the trial. Because of the small numbers of pastures and steers in this trial, this data should be considered only preliminary. However, from a feed and bunk management standpoint, the whole corn was clearly more desirable than the rolled corn.

The 1995/96 wheat pasture year presented us with another opportunity to evaluate a limit feeding program with whole shelled corn for steers on wheat pasture. Three pastures with 10 to 13 steers/pasture were used. Wheat forage standing crops on December 7 (date of turnout), January 17, and March 12 were 511, 376, and 251 lb DM/acre, respectively. Forage allowances on these same dates were 1024, 749, and 725 lb DM/steer. Steers had free-choice access to a high-calcium mineral mixture (footnote "a", Table 3). While our target level of intake of whole corn was 1% of body weight, the cattle did not achieve this level of intake until about January 17 or day 41. Corn intake was very consistent among pastures, and averaged .75% of body weight from December 7 to March 15 (98 days). Mean weight of the steers at the start of the trial was 540 lb, and they gained 1.86 ± 0.11 (std. dev.) lb/day.

SUMMARY

Supplementation of cattle grazing wheat pasture is of interest in order to (a) provide a more balanced nutrient supply and feed additives such as ionophores and bloat preventive compounds, (b) substitute supplement for forage where it is desirable to increase stocking rate in relation to grazing management and/or marketing decisions, and (c) substitute supplement for forage under conditions of low forage standing crops. Two different strategies for providing energy supplements to growing cattle on wheat pasture are presented. One strategy was to develop a
"small package" (i.e., target intake of 2 to 3 lb/day) self-limited monensin-containing energy supplement to provide a more balanced DOM:CP ratio in the total diet. The supplement very consistently increased daily gain approximately .50 lb, and increased profits by $15 to $31/steer depending on supplement cost and profit potential of the cattle. The milo-based supplement contained (as-fed basis) 4% fine mixing salt, 75 mg monensin/lb, and .75% magnesium oxide. Monensin itself limited intake, but MgO at concentrations up to 1.75% did not limit intake. Substitution of equal proportions of wheat middlings and soybean hulls for the ground milo did not affect consumption of the self-limited supplement. Modification of the formula for every-other-day hand-feeding resulted in similar improvements in weight gain as achieved with the self-limited supplement. An additional study using small numbers of rumen cannulated steers in a completely randomized design compared the effects of monensin or lasalocid versus no ionophore on wheat pasture bloat. Monensin decreased (P<.05) both the incidence and severity of bloat and was more efficacious for prevention of bloat than lasalocid. A second strategy was to feed two types of energy supplements (i.e., high-starch, corn-based supplement versus a high-fiber byproduct feed based supplement) at a level of .75% of body weight. Over the 3-year study, mean daily supplement consumption was .65% of body weight. This energy supplementation program increased daily gain by .33 lb and allowed stocking rate to be increased one-third. Type of supplement did not influence daily gain, supplement conversion, or the substitution ratio of supplement for forage. Supplement conversion was about 5 lb of as-fed supplement per lb of increased gain per acre, and was substantially less than conversions of 9 to 10 that have traditionally been used in evaluating the economics of energy supplementation programs for wheat pasture stocker cattle. Weight gain of steers placed on wheat pastures with very low initial standing crops (i.e., 300 lb DM/acre) but "stocked" so as to provide initial forage allowances of 1000 to 1300 lb DM/steer, and limit-fed whole shelled corn at a level of .75 to 1.0% of body weight have been about 2.0 lb/day during two separate wheat pasture years.
LITERATURE CITED


Grain Feeding and Acid-Resistant Escherichia coli

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Ithaca, NY 14853

Introduction

In the last few years, the term "E. coli O157:H7" has permeated our popular press, and the threat of this bacterium has had a negative impact on the cattle industry. Large amounts of hamburger have been recalled, and consumer confidence in beef has been eroded. Epidemiological studies indicate that a small, but significant, number of cattle carry this potentially fatal bacterium, and no method of eradication has yet been identified. However, recent work indicates that cattle diets can be modified to decrease the chance of food-borne E. coli infection. This strategy of dietary modification does not combat E. coli O157:H7 directly. When cattle are fed hay immediately before slaughter, the total E. coli population decreases, and the E. coli become more acid-sensitive. Acid-sensitive E. coli are more readily killed by the gastric juice of human stomach, and the risk if E. coli infection is decreased.

E. coli O157:H7

E. coli is a normal inhabitant of the gastrointestinal tract of mammals, and most E. coli are harmless (Bettelheim, 1996). Pathogenic E. coli produce toxins that attack and sometimes destroy animal cells. E. coli O157:H7 produces two "Shiga" toxins, and these proteins are homologous to a toxin produced by Shigella, a closely related bacterium (Su and Brandt, 1995). Shiga toxins inhibit protein synthesis, and kidney cells are particularly susceptible. E. coli O157:H7 also produces hemolysins that rupture red blood cells. The ability of E. coli O157:H7 to cause disease is enhanced by a protein (Intimin) that allows it to attach tightly to intestinal cells (Kaper et al., 1998). The symptoms of E. coli O157:H7 include acute camps, vomiting, bloody diarrhea (Su and Brandt, 1995). If the infection is severe, the patient can develop kidney damage and dialysis is required (Neill, 1998). The incubation period is typically 1 to 4 days and the duration of the infection is typically 7 to 10 days. E. coli O157:H7 causes 40,000 infections and 250 deaths each year in the United States (Griffin, 1998).

Cattle and E. coli O157:H7

E. coli O157:H7 was isolated from the bloody feces of people that had consumed contaminated hamburger (Riley et al., 1983), and hamburger is still the most common source. Beef carcasses can be contaminated with cattle feces at slaughter (Armstrong et al., 1996). Fruits and vegetables have also been a source of E. coli O157:H7, and cattle
Manure is often used as a fertilizer. *E. coli* O157:H7 has been isolated from wild-life, but these animals had contact with cattle manure (Hancock et al., 1998). Based on these comparisons, cattle appear to be a natural reservoir for *E. coli* O157:H7. Mature cattle are unaffected by *E. coli* O157:H7, but only 1 to 3% of the cattle in the United States carry this bacterium (USDA:APHIS, 1997). Recent work indicated that 63% cattle on a dairy farm were infected, but the water supply was contaminated with cattle manure (Jackson et al., 1998).

Studies of feeding management have not been able to establish statistically significant and consistent links between feeding management and the incidence of *E. coli* O157:H7 in cattle. The presence of whole cotton seed meal decreased the “odds ratio” of cattle in feed lots and calves, but the mechanism of this action was not determined (Hancock et al., 1994; Garber, et al., 1995). A study by Hancock et al. (1994) indicated that the feeding of corn silage did not cause a statistically significant increase *E. coli* O157:H7 positive cattle, but later work by Herriott et al. (1998) indicated that “significantly higher prevalence of *E. coli* O157 was noted in herds that fed corn silage to heifers compared to herds that did not feed corn silage.”

A recent study (Dargatz, et al., 1997) indicated that barley increased the “likelihood” of feedlot cattle being positive for *E. coli* O157, but previous work was unable to establish a link with various grain sources (Hancock et al., 1994). Hancock et al. (1994) indicated that “computerized feeding,” a technology more common on large farms, was a contributing factor, but this effect was not fully explained. Calves that were “grouped” before weaning were more apt to be *E. coli* O157:H7 positive (Garber et al., 1995), and this effect may be related to an increased chance of transmission. Manure on pasture was cited as statistically significant factor for dairy and beef cattle (Hancock et al., 1994), but later work failed to corroborate a link between manure on pasture and *E. coli* O157:H7 (Hancock et al., 1997).

Cattle must sometimes be transported long distances to be slaughtered, and during this time feed is often not provided. Cattle given ruminal doses of *Salmonella* or *E. coli* did not shed these bacteria for long periods of time if they were fed, but shedding was detected if the animals were starved (Brownlie and Grau, 1967). Recent work by Cray et al. (1998) indicated that calves inoculated with *E. coli* O157:H7 were more apt to shed this bacterium if they were starved. Hovde and her colleagues (Kudva et al., 1995, 1997) examined effect of feed deprivation on *E. coli* O157:H7 shedding from inoculated sheep. There was a tendency for “*E. coli*-negative animals to become positive,” but these changes were not statistically significant. The impact of starvation on the ability of *E. coli* O157:H7 to persist in cattle has not been adequately explained. Rasmussen et al. (1993) noted that *E. coli* O157:H7 grew better in ruminal fluid from starved cattle than cattle fed regularly, but non-pathogenic strains behaved in a similar fashion.

Because relatively few cattle are carriers of *E. coli* O157:H7 at any one time, and *E. coli* O157:H7 does not usually persist, researchers have frequently used inoculation as an experimental protocol, but these models have never been validated. Zhao et al. (1998) indicated that calves previously inoculated with nonpathogenic, colicin-producing *E. coli* were less likely to shed *E. coli* O157:H7 than those given only *E. coli* O157:H7, and this result indicates that the natural flora can be a barrier. The epidemiology of *E. coli* O157:H7 in field surveys has also been confounded by the fact that animals are often given only a plus or minus score, and the actual numbers are rarely reported (Hancock et
I.aI., 1994; Garber, et al., 1995; Dargatz, et al., 1997). The type of ecological imbalance within the intestinal ecology that allows E. coli O157:H7 to gain a “foot-hold” has yet to be defined, but it is unlikely that any single dietary factor or management practice is solely responsible.

Grain Feeding and E. coli

Ruminants evolved as grazing herbivores, but the rate of fiber fermentation is usually slow. Grains ferment faster than fiber, and grain can be an extremely valuable supplement for domestic ruminants (Kotarski et al., 1990). Fattening beef cattle in the United States are often fed more than 80% grain. Starch is an inherently digestible substrate for ruminal bacteria, but the starch granules of cereal grains are encased in protein (French, 1973). Ruminal bacteria can quickly bore through the protein coat of some cereal grains (e.g., barley), but the starch granules of corn are coated by zein, a slowly degraded protein (McAllister et al., 1990). When cattle are fed raw corn, large amounts can escape ruminal fermentation and pass into the intestines (Waldo, 1973). Because ruminants do not secrete as much pancreatic amylase as simple-stomached species, starch passes to the colon where it is subjected to yet another fermentation (Harmon, 1991; Diez-Gonzalez et al., 1998).

E. coli does not compete well in the rumen (Hungate, 1966), and it is never a predominant ruminal bacteria. E. coli does better in the colon, and it can account for as many as 1% of the colonic bacteria (Bettleheim, 1996). E. coli does not utilize plant polysaccharides, but it can used maltose and malodextrains (Boos and Shuman, 1998) that are released by other starch-digesting bacteria. The impact of colonic starch fermentation on E. coli was until recently largely ignored, but feeding trails indicated that E. coli numbers were as much as 1000-fold greater when cattle were fed 90% grain as opposed to 100% hay (Diez-Gonzalez et al., 1998).

Acid-Resistant E. coli

Food consumed by man is collected in the gastric stomach prior to intestinal digestion (Figure 1), and the low pH of this compartment is a barrier to some, but not all, food-borne bacteria (Peterson et al., 1989). Waterman and Small (1998) concluded that gastric acidity was the "first line of defense against food-borne pathogens," and noted that "the ability of pathogens to resist pH corresponds to their infective dose." The role of stomach acid as a defense mechanism is supported by the observation that humans given oral doses of sodium bicarbonate were more susceptible to intestinal pathogens than patients not given bicarbonate (Cash et al., 1974).

Bacteria differ in their ability to grow and persist at low pH, and acid resistance a significant survival strategy. E. coli does not grow well at acidic pH values if fermentation acids are present, but it can survive a very low pH values if it first adapted. The extreme acid resistance of E. coli is triggered by fermentation acids, and in vitro results indicated that E. coli was as much as 1,000-fold more acid resistant if volatile fatty acids were added to the growth medium (Diez-Gonzalez and Russell, 1999). The ability of volatile fatty acids to induce the extreme acid resistance of E. coli is a pH
related function. Undissociated acid was much more effect in inducing extreme acid resistance, and the ratio of undissociated to dissociated acids increases as the pH declines. When cattle were fed 90% grain the colonic VFA concentration was greater than 75 mM and the pH was less than 5.5 (Diez-Gonzalez et al., 1998). Fecal grab samples that were taken from these animals had a large E. coli population and in vitro experiments indicated that these bacteria were highly acid-resistant. E. coli that were isolated and grown in the lab with low concentrations of volatile fatty acids became acid-sensitive, and this result indicated that the volatile fatty acids were “turning on” and “turning off” the extreme acid resistance of E. coli.

Hay Before Slaughter

Cattle fed 90% grain had large numbers of acid-resistant E. coli in their feces, but additional feeding trails indicated that this characteristic could be easily and quickly changed (Diez-Gonzalez et al., 1998). When animals were switched from 90% grain to 100% hay, the acid-resistant E. coli population declined, and after only 5 days acid-resistant E. coli were not longer detected.

Conclusions and Food Safety

The use of hay (or possibly ruminally degradable starch) to decrease total E. coli numbers and the extreme acid resistance of E. coli is an indirect method of combating E. coli O157:H7 that is analogous to modern warfare which kills all of the people rather than just the combatants. If the substrates available to E. coli are reduced and total E. coli numbers decline, one would also expect a decline in E. coli O157:H7. If the gut environment has a low concentration of undissociated volatile fatty acids and the extreme acid resistance of E. coli is not induced, one would expect E. coli O157:H7 to be more easily killed by human gastric juice. It is should also be stressed that the manipulation of cattle diets to prevent grain-dependent increases in the numbers and acid-resistance of E. coli, one factor is only one factor in the total risk assessment. It would not circumvent other food safety practices (sanitation, cooking, irradiation, etc).

References


Recent results from seven different research projects concerning nutrition and management of feedlot cattle are summarized in four categories below.

Protein Supplementation of Feedlot Cattle:
A finishing trail was conducted to determine the degradable intake protein (DIP) requirement of yearling steers fed a high-moisture corn diet. Two hundred fifty-two yearling steers (835 lb initial BW) were fed one of four diets for 108 days containing graded levels of urea (0, .4, .8, and 1.2% of diet DM). The finishing diet contained 82.5% high-moisture corn, 5% alfalfa hay, 5% cottonseed hulls, 2.5% molasses, and 5% dry supplement (DM basis). The high-moisture corn was 26% moisture, 9.6% CP (DM basis), and 66% DIP (% of CP). Dry matter intake (26.9 lb/d) was not affected by treatment. Daily gain ($P = .01$) and feed efficiency ($P = .03$) increased linearly with DIP level (urea concentration). Daily gains were 3.76, 3.79, 4.01, and 4.09 lb/d, respectively, and feed efficiencies were 7.19, 7.09, 6.62, and 6.54, respectively. Fat thickness also increased linearly ($P = .06$) with DIP level. Using the NRC (1996) model, all diets exceeded MP requirements by 120 g/d. The NRC model (level 1) predicted a requirement of 7.2% DIP (.2% urea), but gain and efficiency were linear up to approximately 9% DIP (DM basis) in this trial. The DIP requirement cannot be estimated, but may be greater than predicted by NRC for highly fermentable corn-based finishing diets. This increase is most likely a function of site of starch digestion compared with using TDN values for formulation.

Feeding Management Strategies for Feedlot Cattle
Two experiments evaluated programmed gain finishing systems on performance and carcass traits of finishing steers. In Exp. 1, 160 steer calves were assigned to one of four treatments: 1) ad libitum; 2) programmed to gain 2.8 lb/d for 70 d; 3) programmed to gain 2.5 lb/d for 35 d and 3.0 lb/d for 35 d; or 4) programmed to gain 2.5 lb/d for 50 d and 3.0 lb/d for 50 d. In Exp. 2, 245 yearling steers were assigned to one of five treatments: 1) ad libitum; 2 and 3) programmed to gain 2.33 lb/d for 21 or 42 d; or 4 and 5) programmed to gain 2.8 lb/d for 21 or 42 d. Diets contained 92.5% concentrate based on corn, wet corn gluten feed, and alfalfa hay. Feed intakes were adjusted every 14 (Exp. 1) or 7 days (Exp. 2). Following the programmed feeding periods, steers were allowed ad libitum access to feed. In Exp. 1, daily gain was reduced by all programmed feeding strategies compared with treatment 1. Feed efficiency and carcass traits were similar. Steers on treatment 1 were fed 154 days and programmed gain steers were fed 161 days. In Exp. 2, feed efficiency was similar among treatments. Steers on treatment 3 gained slower, had lighter carcasses, and less rib fat compared with other treatments ($P < .01$). Performance and carcass traits were similar among other treatments. Programming gain reduced ($P < .10$) the total amount of feed consumed in both trials. However, lack of a significant improvement in feed efficiency and numerical reductions in carcass weight may preclude any economical advantage from these programmed feeding strategies.

Eight ruminally fistulated steers were used in two concurrent 4 x 4 Latin squares to evaluate Rumensin® level and bunk management strategy on feeding behavior and ruminal pH.
Squares were different bunk management strategies: 24-hour access to feed, or feed access from 08:00 to 22:00 (clean bunk management). Within each square, steers were fed 0, 30, 30 changed to 40 on day 31, or 40 grams/ton Rumensin (90% air dry basis). Each period of the Latin square was 35 days in length with an imposed acidosis challenge on day 31. Steers were challenged by feeding 125% of day 30 intake, 4 hours late. Prior to the challenge, feeding Rumensin reduced (P < .05) the average meal size without reducing total intake. Steers fed using the clean bunk management strategy had increased intake rates, consumed fewer and larger meals per day spent less time eating, and had an increased ruminal pH variance compared with steers fed using the ad libitum system (P < .05). Following the acidosis challenge, Rumensin reduced the number of meals per day (P = .06) and tended (P = .12) to reduce rate of feed intake. Steers managed using the clean bunk management system had faster intake rates and reduced number of meals per day compared with the ad libitum system (P < .05). Feeding Rumensin reduced meal size and ruminal pH variance in steers fed using clean bunk management, but had little effect on steers fed using the ad libitum system following the challenge (interaction, P < .10). Rumensin affected consumption favorable for controlling acidosis, while cattle managed using our clean bunk management system appear to be at a greater risk for acidosis upsets compared with ad libitum feeding.

**Byproduct Utilization in Finishing Diets**

Sixty yearling steers were individually fed one of three finishing diets using Calen gates to compare distillers grains produced from corn or sorghum grain in finishing diets. The control diet (CON) was based on dry-rolled corn and contained 7.5% roughage. Corn (CD) or sorghum (SD) distillers grains were fed at 40% of the diet DM, replacing corn. Distillers grains were produced from either 100% corn or sorghum grain by a commercial ethanol plant. Compared with CON, steers fed CD or SD gained 10% faster (P < .01; 3.63 vs 4.03 lb/d) and were 8.2% more efficient (P < .01; 6.41 vs 5.88). Daily gain and feed efficiency were similar between CD and SD. Carcass weights were 31 lb heavier (P < .01) for steers fed CD or SD compared with CON. Compared with CON, feeding distillers grains increase 12th rib fat and yield grade (P < .10). The average NEg concentration of CD and SD was 34% greater than corn.

Two hundred eighty yearling steers were fed one of eight finishing diets for 116 days to evaluate performance and carcass traits as the composition of wet corn gluten feed was altered. Four blends of steep liquor, bran, and germ meal were evaluated. Steep liquor comprised up to 50% of the byproduct blends. Corn bran or a 50:50 combination of corn bran and germ meal replaced steep liquor. Wet corn gluten blends were fed at 30% of diet DM. Feed efficiency increased linearly (P < .05) as the dietary level of steep liquor increased in the wet corn gluten feeds produced. Additionally, when germ meal replaced 50% of the corn bran, feed efficiency was improved 7 to 10%.

**Implant Strategies for Finishing Steers**

Two hundred twenty-five steers (664 lb initial BW) were implanted with one of five implant strategies: Synovex® Plus™ on d 1 (SP1), 35 (SP35), or 70 (SP70), or Ralgro® d 1 and Synovex Plus d 70 (RSP), or Synovex® S on d 1 and 70 (SS). Steers were stepped up to a 92.5% concentrate and fed for 150 d. Daily gain (lb) of steers implanted with SP35 (4.08) was higher (P < .10) than steers implanted with SP70 (3.81) and SS (3.86), but similar to those implanted with SP1 (3.97) and RSP (3.97). Feed efficiencies were similar among implant strategies using Synovex Plus, but improved 3.7% (P = .01) compared with SS (6.06 vs 6.29).
Yield grade ($P = .03$), 12th rib fat thickness ($P = .05$), and maturity score ($P = .01$) were decreased linearly by delaying Synovex Plus. Steers implanted with SS had a higher yield grade ($P = .02$) and marbling score ($P = .10$) than other implant treatments. Percentage of Choice carcasses were unaffected by treatment; however, SP70 reduced the percentage of Choice carcasses by 10 units compared with the average of SP1, SP35, and RSP. Performance and carcass traits were similar for a single implant of Synovex Plus on d 1 or 35 or a reimplant program using Ralgro and Synovex Plus for steers fed 150 d. Delaying a single dose of Synovex Plus until d 70 appears to reduce daily gain, but maintains feed efficiency.
GRADUATE STUDENTS INVOLVED: G.M. Abdelrahim, T.C. Bramble, B.S. Clyburn, A. Gueye, C.L. Howard, M.A. Johnson, K.J. Sanders, H.H. Titi, K.W. Shuepbach, and K.F. Wilson

Results from research projects presented at this meeting and ASAS southern section meetings are outlined below. The most current research conducted in this laboratory has dealt with improving beef cattle performance through enzyme supplementation, use of mineral sources, processing techniques, and evaluation of corn hybrids.

1. In a metabolism trial the effects of extruded whole cottonseed (EWCS) as a supplemental protein source in high concentrate steer diets was evaluated using three steers (450 lb) in a 3 X 3 Latin square design. Three treatments were utilized in which EWCS composed 0, 50, or 100% of the supplemental protein source. Steers were fed iso-caloric diets, in which ether extract and NDF were held constant, by adjusting the amount of cottonseed hulls and vegetable fat in the diet in relation to ether extract and NDF supplied from EWCS in the 100% supplemental protein source diet. Dry matter intake, apparent digestibility, plasma urea nitrogen, plasma gossypol, VFA, or ruminal pH were not affected by treatment. It was concluded by this research that EWCS could be utilized in high concentrate diets to supply supplemental protein, and reduce the need for supplemental roughage and fat sources. (Poster to be presented.)

2. Addition of enzymes to growing and finishing cattle diets on average daily gain (ADG), feed intake (FI), feed : gain ratio (F:G) and carcass characteristics was examined using 175 steers (560 lb). The study was divided into three 56 d periods, with alfalfa and steam flaked corn comprising 50:40, 30:60 and 10:80 during each respective phase. During the first period steers receiving either fibrolytic or a combination of fibrolytic and amylolytic enzymes had higher ADG and lower F:G than control steers (2.74 and 2.90 versus 2.44 lb gain/hd/d; 7.14 and 7.10 versus 8.93 lb feed/lb gain). However, during the two subsequent periods when alfalfa levels were reduced and steam flaked corn levels were increased, no differences were detected for ADG or F:G. Amylolytic enzyme treatment increased ribeye area, and all enzyme treatments tended to improve quality grade. It was concluded from this experiment that the use of fibrolytic and amylolytic enzymes may prove beneficial for performance traits when overall dietary energy levels are low, and feeding of enzymes may produce steers that differ in carcass composition from steers not supplemented with enzymes. (Poster to be presented.)

3. Effects of feeding a direct feed microbial (Multiple Stabilized Enzymes -MSE, Natur’s Way Inc., Horton KS) on morbidity, mortality, performance and carcass characteristics were investigated utilizing 66 steers (490 lb). Antibiotics were included in control diets, and MSE replaced the ionophore-antibiotic combination in treatment diets. Addition of MSE reduced morbidity and health costs during the growing phase (70 d), while not affecting performance. During the finishing phase MSE increased daily gain, produced heavier carcasses, and decreased liver abscesses. Based on carcass characteristics and reduced morbidity and mortality MSE improved carcass value by 2.5% over steers receiving an ionophore-antibiotic treatment during
the growing and finishing phase. Results of this trial indicate that MSE reduced production costs and increase economic return when used in place of antibiotics in growing and finishing steer diets. (Poster to be presented.)

4. Addition of supplemental dietary organic chromium (Cr) was examined using performance data and carcass characteristics from 105 steers (650 lb). Two levels of high Cr yeast, 0.2 ppm and 0.4 ppm, were fed in a typical feedlot ration to supply approximately 1.8 and 3.1 mg Cr per head per day. Daily gain, feed intake, and feed efficiency were not affected by 0.2 ppm treatment; however, the 0.4 ppm treatment reduced daily gain and feed intake, while decreasing feed efficiency. Steers supplemented with 0.4 ppm Cr had larger ribeye areas, and decreased final yield grades, hot carcass weights and marbling scores. High Cr yeast improved carcass traits while not adversely affecting performance when fed at 0.2 ppm of feedlot diets. It was concluded from this trial that 0.2 ppm Cr supplementation improved carcass characteristics while not adversely affecting performance traits. (Poster to be presented.)

5. Effects of steam flaked corn hybrids grown in the same location on flake durability, crude protein, starch availability, and in vitro digestibility were investigated using a total of 10 commercial and experimental hybrids. Flake durability was not affected by hybrid, but electrical energy required to flake grain was affected by hybrid. Crude protein and starch availability content of corn hybrids increased following steam flaking with a corresponding decrease between steam flaked samples measured at 0 and 24 h post-flaking. In vitro digestibility was affected by hybrid at all h measured, however samples obtained 24 h post-flaking tended to have reduced digestibility when compared to samples obtained 0 h post-flaking. These results indicate that hybrid and post-flaking time prior to feeding may affect feedlot cattle performance.

6. Nutritional composition of high oil corn (HOC) fed at a commercial feedlot in Liberal, KS was determined. Results indicated that HOC had increased crude protein (8.84 versus 7.04%), crude fat (7.17 versus 2.88%), and ash (1.27 versus 0.88%) content as compared to the normal corn. Based on these results a finishing trial has been designed to investigate the effects of HOC inclusion in feedlot diets. The study in progress used the above HOC composition to formulate the finishing diets. The diets were made iso-nitrogenous and iso-caloric by increasing the tallow and urea content of the control diet. A limited number of research studies have been conducted with HOC in finishing beef cattle diets. Therefore, the impetus of this research project is to not only investigate the effects of HOC on feedlot performance and carcass characteristics but also determine the processing properties of HOC.
THE RELATIONSHIP BETWEEN RETROGRADE STARCH AS MEASURED BY STARCH AVAILABILITY ESTIMATES AND IN VITRO DRY MATTER DISAPPEARANCE OF STEAM-FLAKED CORN

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Introduction

Starch availability estimates are frequently obtained on samples of steam-flaked corn and milo as a means of assessing degree of processing and monitoring quality and consistency of the flaking process. The typical method of assessing starch availability involves incubating a ground sample of flaked grain with amyloglucosidase enzyme and either measuring glucose release directly or via gas production by yeast (Duff et al., 1994). Samples for analysis are usually taken soon after flaking, most often either just as the flaked grain leaves the rolls or once it is conveyed to a storage bin. Starch in steam-flaked grains can undergo retrogradation, or reassociation of starch molecules that have been separated during gelatinization (Rooney and Pflugfelder, 1986). The potential effect of starch retrogradation, as measured by decreases in enzymatic starch availability, on digestibility of flaked grains and subsequent animal performance has not been adequately characterized. We evaluated the in vitro dry matter disappearance (IVDMD) of samples from one lot of steam-flaked corn that differed in enzymatic starch availability, presumably as a result of starch retrogradation.

Experimental Procedures

Steam-flaked corn samples used in this study were obtained at a commercial feedlot. Corn was steamed for approximately 45 min before rolling to a bulk density of 29 pounds per bushel through either 18-inch x 36-inch or 24-inch x 48-inch rolls. Grain moisture content before rolling was approximately 21 to 22%. Samples were taken at two different locations in the process and sent to a commercial laboratory for measurement of enzymatic starch availability (glucose release). Roll samples were taken with a shovel directly beneath the rolls, whereas flaked grain was conveyed to a storage bin by a drag chain and leg conveyor, and Bin samples were taken as flaked grain exited the storage bin. Time in the bin was not recorded. Both Roll and Bin samples were allowed to sit at room temperature for 10 to 15 min to allow the steam to evaporate (flash) before packaging and sending the samples to the commercial laboratory for analysis.

The IVDMD of a composite of three Roll samples and a composite of six Bin samples was analyzed by incubating approximately .5 g of ground grain from each of the two composite samples for 4, 8, 12, 18, 24, and 48 h at in a 39°C water bath. Triplicate 50-mL tubes of each substrate and two blank cultures were used for each incubation time. Ruminal fluid had been obtained previously from four ruminally cannulated steers fed a high-concentrate diet, strained through cheesecloth, and frozen. Frozen ruminal fluid was thawed for approximately 6 h and then mixed (1 part ruminal fluid) with McDougall’s buffer (4 parts buffer) before being use. A 48-h incubation in acidified pepsin solution at 39°C followed the ruminal fluid-buffer incubation.
Results and Discussion

Enzymatic starch availability measured by the commercial laboratory averaged 55.3% (range 52 to 57%) for Roll samples and 33.3% (range 28 to 36%) for Bin samples (Table 1). Hence, the intent of the IVDMD procedure was to determine whether these differences in starch availability, presumably resulting from retrogradation of starch in Bin samples, would affect the ability or ruminal microbes to degrade starch.

The IVDMD data for various incubation times are shown in Table 1. These data were not analyzed statistically because we considered the triplicate incubation tubes per time/treatment combination to be analytical replicates rather than true experimental replicates. Nonetheless, these data provide descriptive information as to the effects of varying enzymatic starch availability measurements on IVDMD. No major differences in IVDMD were evident between Roll and Bin samples, despite the much greater enzymatic availability of Roll samples. Virtually identical IVDMD measurements were noted for each incubation time, except for 8 h, at which time Bin samples had a numerically greater IVDMD than Roll samples. Taken collectively, these IVDMD data provide no evidence that the lower enzymatic starch availability observed with Bin vs Roll samples had any impact on the ability of ruminal microbes to degrade the DM, and presumably starch, in these samples.

Assuming that the lower enzymatic starch availability noted with Bin samples reflected retrogradation of starch, our results suggest that formation of retrograde starch in steam-flaked corn samples has little effect on degradation of starch by ruminal microbes. It also is possible that the differences in enzymatic starch availability between the Roll and Bin samples merely reflect a failure of the analytical method to release starch enzymatically for subsequent measurement. The method typically involves a relatively short (often 1 h) incubation of flaked grain with an enzyme:buffer solution. Given that formation of retrograde starch might increase the durability of steam-flaked grains (Rooney and Pflugfelder, 1986), a short incubation period with enzyme and buffer may be inadequate to fully wet the sample and allow for necessary enzyme activity.

Summary and Conclusions

Our data suggest that differences in enzymatic starch availability resulting from when and where samples were taken after steam flaking had no effect on the degradation of steam-flaked corn dry matter in an in vitro culture system. Hence, these results suggest that such differences in enzymatic starch availability would be unlikely to affect animal performance. When enzymatic starch availability is used to monitor the quality and consistency of the steam-flaking process, care should be taken to obtain samples for analysis in a consistent manner over time.

Literature Cited


Acknowledgements

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Table 1. Enzymatic starch availability and in vitro dry matter disappearance (IVDMD) of steam-flaked corn samples obtained directly off the rolls (Roll) or after being conveyed to a storage bin (Bin)

<table>
<thead>
<tr>
<th>Item</th>
<th>Roll samples a</th>
<th>Bin samples b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch availability, %</td>
<td>55.3</td>
<td>33.3</td>
</tr>
<tr>
<td>IVDMD, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 h</td>
<td>21.79</td>
<td>20.32</td>
</tr>
<tr>
<td>8 h</td>
<td>27.66</td>
<td>34.51</td>
</tr>
<tr>
<td>12 h</td>
<td>43.16</td>
<td>45.98</td>
</tr>
<tr>
<td>18 h</td>
<td>67.58</td>
<td>68.47</td>
</tr>
<tr>
<td>24 h</td>
<td>84.01</td>
<td>84.35</td>
</tr>
<tr>
<td>48 h</td>
<td>93.09</td>
<td>96.81</td>
</tr>
</tbody>
</table>

aComposite of three samples.

bComposite of six samples.
BEEF CATTLE RESEARCH AT TEXAS A&M UNIVERSITY RESEARCH AND EXTENSION CENTER AT AMARILLO

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1Texas Agricultural Experiment Station, 2Texas Agricultural Extension Service, and 3West Texas A&M University

Introduction
Beef cattle research conducted at the Texas A&M University Research and Extension Center consist of studies in animal nutrition and environmental issues. Scientists and engineers in TAES and TAEX conduct this research. Current research efforts are as follows:

Use of Saccharomyces cerevisiae (BIOSAF®) in finishing diets.
Previous research from our laboratory shows that BIOSAF® increases gain of finishing cattle by 16% compared to controls. Other research conducted by graduate student Antonio Garcia shows that feeding .26% BIOSAF® improved feed conversion by 5% during a 102 day finishing period. A metabolism trial being presented by Mr. Garcia as a graduate student competition paper at this meeting shows that BIOSAF® may beneficial effects of controlling ruminal pH and improvement of mineral absorption and retention, especially P.

Use of AGRADO™ pre- and post-shipment in finishing steers.
This research is being conducted in cooperation with Dr. Beth Kegley at the University of Arkansas. Eighty steers were transported to the University of Arkansas animal research facility in Fayetteville and fed a control or 150 ppm AGRADO™ diets for a 42 day preconditioning period. Following preconditioning, cattle were shipped to the TAES/USDA-ARS research feedlot in Bushland, TX and fed either a control or 150 ppm AGRADO™ in a 2X2 factorial arrangement with the preconditioning treatments. Preliminary results from this study suggest that AGRADO™ fed pre-shipment improved ADG during the first 28-d of the receiving period.

Implanting cattle grazing short grass prairie pastures during the winter to determine performance on grass and subsequent feed yard gain.
Seventy-two crossbred steers were implanted with Revalor-G® or not implanted. Steers were allowed to graze dormant native range for 77 d at Bushland, TX. At the end of the grazing period, steers were relocated to the TAES/USDA-ARS research feedlot, implanted with Synovex-S®, and reimplanted on d 83 of the finishing period with Revalor-S®. Steers were slaughtered on d 130. During the grazing period, ADG was higher (P=.0008) for the implanted than for the control steers (.57 vs .43 kg/d). During the feedlot phase, ADG, feed intake and carcass characteristics were not different (P>.10) between the implanted and control steers. We have previously shown that implanting with zeranol improved phosphorus retention by 18% during the peak pay-out of the implant. We have shown that implanted animals have a greater maturation of bone by increasing bone-breaking strength. We suspect the retention of phosphorus is from an increased phosphorus deposition in bone. We are currently conducting a study to determine if implanting cattle on pasture has any effect on phosphorus retention in the feedyard.
Trace mineral solubility in a free-choice mineral supplement treated with petrolatum.

A laboratory procedure was conducted in cooperation with Farmland Industries to determine the trace mineral solubility in a free-choice mineral supplement. The mineral supplement was formulated by Farmland and treated with or without petrolatum. Ruminal fluid (100 ml) or water was added to each erlenmeyer flask. Zero, 1, 2, 4, 8 or 10 g of treated and untreated mineral supplement was incubated in each flask. Addition of petrolatum did not affect the solubility of Zn, Mn or Fe in ruminal fluid (P > .10). Copper and Na solubility in ruminal fluid was less (P < .0082) when petrolatum was included in the supplement compared to the non-treated control. However, Cu solubility was greater when petrolatum was incubated in water compared to controls. Mn solubility was less when petrolatum was included in the water incubations. These differences could be related to characteristics of specific mineral salts added to the supplement and an interaction with proteins and microorganisms found in ruminal fluid.

Effect of Stocking Density on Emissions of Fugitive PM$_{10}$ from Cattle Feedyards.

This research is being conducted by B.W. Auvermann, A. Romanillos and J. M. Sweeten. Dust emissions from corral surfaces are driven primarily by the interaction of moisture conditions and cattle activity. Most of the quantitative evaluations of dust-suppression techniques have focused on the use of sprinklers or tanker trucks to increase moisture in the corral surface. A commercial-scale evaluation of the use of stocking density to modify moisture dynamics during dry weather patterns is being tested to reduce emissions of fugitive particulate matter. Fugitive dust emissions have not been included in the emissions inventory for cattle feedyards, but the State of Washington has recently moved to include them, raising the specter of major permitting difficulties, emissions fees and other regulatory burdens for all but the smallest feedyards (<2000 head capacity). This research shows that doubling the stocking density from a 150 ft$^2$/hd to 75 ft$^2$/hd has the potential to reduce PM$_{10}$ emissions by as much as 20%. If these preliminary results are confirmed over the duration of the project, stocking density manipulation should be a candidate for Best Available Control Technology (BACT) for fugitive PM$_{10}$. In the event fugitive emissions are included in the inventory for feedyards, this management tool will help to reduce the regulatory burden associated with feedyard dust.

Effect of pre-transit Micotil™ and posttransit dust exposure on body weights and rectal temperature of market stressed cattle.

One hundred and twenty stressed feeder steers were transported from Tennessee and used in a simulated dust storm trial. Housing animals in a tent designed to contain the dust produced the simulated storm. Cattle were assigned to either a control or Micotil™ injection pre-transit and one of the following dust treatments: 1) control, 2) exposure to dust tent for 2 h, and 3) dust exposure for 2 h, in a 2 X 3 factorial arrangement of treatments. Upon arrival at the feedlot, dust exposure treatments were delivered on d 0 day of arrival, 1, 2, and 3. Body weights and rectal temperatures were taken on d 0, 1, 2, 8, 15, 22, 28 and 49. There was a significant interaction of posttransit dust exposure and pretransit Micotil™ treatment for body weight on d 8, 15 and 22. Steers treated with Micotil™ and subsequently exposed to dust had higher (P<.03) body weight than those that did not receive Micotil but exposed to dust (196, 200, 214 vs 185, 187, 193 kg for d 8, 15, and 22, respectively). Other dust treatments (control and tent exposure) and Micotil™ treatment groups were similar (P>.05) for all other days of the study. Rectal temperature of all dust and Micotil™ treatment groups were also similar (P>.05) for all time periods of the study.
Performance of grazing calves supplemented with copper proteinate pre- or post-shipping to a feedlot.

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Eighty-four Angus and Brangus sired steers were used to determine the effects of feeding copper proteinate (AllTech BioCopper) before shipping or during the feedlot receiving period. Steers were weaned in October of 1997, at weaning the calves were processed including treatment for internal and external parasites, vaccinated with a 7-way Clostridial antigen and IBR-PI3-BVD-BRSV. The calves were then fed hay and 2 lb/hd/d of a high-protein supplement. On February 19, 1998, the calves were weighed after a 16-h shrink, implanted with Component-S, separated by treatment, and placed on 12 2-acre bermudagrass pastures interseeded with wheat/rye/ryegrass. From February 19 to April 16, the cattle were fed 2 lb/hd/day of corn, containing a commercial mineral premix, 3 times per week. On April 16, the cattle were weighed after a 16-h shrink and copper supplementation began. Corn supplements fed three times per week (prorated to be 2 lb/hd/d) contained a commercial mineral mix, supplied 200 mg rumensin and either had no additional copper or .165% BioCopper. Nineteen ppm supplemental copper (copper sulfate) was supplied by the mineral premix to the control calves, and 165 ppm additional was fed to BioCopper calves.

On May 15, the calves were weighed, after a 16-h shrink shipped to a local receiving yard, commingled with calves purchased from a local auction, and held on hay and water until May 17. The steers were then shipped from southwest Arkansas to the CLRC (approximately 630 miles, 14-h transit). Steers arrived at 0730 and were processed including: branding, treatment for internal and external parasites, vaccinated with a 7-way Clostridial antigen, and IBR-PI3-BVD-BRSV, implanted with Ralgro, rectal temperature was determined, and sorted into treatment pens. Treatment pen assignments were the same as pasture assignments. All cattle were fed a 70% concentrate diet throughout the 42 day receiving period and observed daily for bovine respiratory disease. After the initial weight at the feedlot, weights were taken unshrunken on days 14, 28, and 42 of the feedlot receiving period before the morning feeding.

Treatments were applied as a completely randomized design using a 2 X 2 factorial arrangement of treatments. Factors included receiving the copper proteinate during the grazing period and receiving the copper proteinate during the feedlot receiving period. Pen was considered the experimental unit for all calculations. Least square means and predicted differences were used to separate the effect of copper treatments. Cattle weights were heavier for BioCopper calves on April 16, so that BW was used as a covariate in subsequent statistical analysis.

There was no significant interaction between grazing or feedlot copper supplementation so only main effects are discussed. Beginning BW of the grazing calves was 630 lbs, BioCopper calves tended to be heavier (688 vs 680 respectively, p<.11) and daily gains higher (2.00 vs 1.74, p<.11) than control calves by the end of the grazing period. At the end of the feedlot receiving period, BioCopper calves were 14 pounds heavier than control calves (926 vs 912, p<.05) and ADG was numerically higher (5.70 vs 5.56, p=.34). No differences were found in rectal temperature, or morbidity during the 42 day feedlot receiving period. Feed efficiency and DMI was not affected by copper addition (3.8 vs 3.8, p>.89, 21.3 vs 21.6 lb/d, p>.79).
Effects of corn and decreasing levels of soybean meal on intake and digestion of prairie hay by beef steers.

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An 8 x 8 latin square experiment with 2 x 4 factorial arrangement of treatments was designed to determine the effects of supplemental corn fed with decreasing amounts of SBM on intake and digestion of prairie hay. A Corn+SBM supplement was fed in a preliminary trial to determine hay intake and OM digestibility (HOMD) to be used in formulating diets. Eight ruminally cannulated steers (701 lb) were fed ad lib prairie hay with 0% (NOCRN) or .75% (CORN) BW cracked corn, each with four incrementally decreasing levels of supplemental DIP (.13, .10, .07, .04 %BW). Diets were formulated by balancing total diet DIP to TDN for the CORN+.13 diet and decreasing supplemental DIP as a %BW for the remaining CORN treatments. The NOCRN supplements contained equal DIP as a %BW as each respective CORN supplement. Supplement DM intake was equalized within NOCRN (2.69 lb/(steer*day)) or CORN (7.21 lb/(steer*day)) treatments with cottonseed hulls. Decreasing DIP in CORN treatments resulted in a linear ($P < .01$) decrease in hay OM intake (HOMI; 11.57, 11.71, 11.09, 8.93 lb/d) with a quadratic ($P < .01$) response (14.88, 14.44, 13.82, 8.18 lb/d) in NOCRN treatments. Feeding CORN+.04 increased ($P < .01$) HOMI (8.93 vs 8.18 lb/d) over NOCRN+.04. A cubic ($P < .01$) response to decreasing DIP was observed in HOMD (49.3, 41.9, 45.8, 29.5%) in CORN supplements while no trend ($P > .49$) was found in NOCRN treatments (55.1, 56.2, 54.5, 58.0%). Supplementation with CORN+.04 depressed ($P < .01$) HOMD (29.5 vs 58.0%) compared to NOCRN+.04. Decreasing DIP resulted in a linear ($P < .01$) decrease in total digestible OMI (TDOMI; 12.15, 10.85, 10.78, 8.16 lb/d) in CORN treatments with a quadratic ($P < .01$) effect (10.47, 10.03, 9.13, 5.86 lb/d) in NOCRN treatments. Supplementation with CORN+.04 increased ($P < .01$) TDOMI (8.16 vs 5.86 lb/d) compared to NOCRN+.04. Balancing total diet DIP to TDN appeared to overcome negative associative effects typically found when low-quality forages are supplemented with large quantities of low-protein, high-starch feeds.

Keywords: Protein, Starch, Fiber digestion
Effect of Degree of Grain Processing on Serum Metabolic Hormone Profiles and Performance by Finishing Steers


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Two experiments were conducted to determine the effect of degree of grain processing on serum metabolite, insulin, and growth hormone (GH) concentrations and feedlot performance. Corn was processed by either dry rolling to approximately 0.54 kg/L bulk density (42 lbs/bu) or steam flaking to a bulk density of 0.36 or 0.26 kg/L (28 and 20 lb/bu, respectively). Degrees of processing were selected to generate final products with 25, 50, or 75% enzymatically available starch. Available starch averaged 27.2, 53.2, and 77.7% of total starch for dry-rolled corn and 0.36 kg/L and 0.26 kg/L steam-flaked corn, respectively, through d 84. In Exp. 1, 29 steers were housed in individual outdoor pens (2.4 m x 6.1 m) and adapted to a 90% concentrate diet over 21 d. Whole blood and serum were collected before feeding and at 4 and 8 h after feeding on days 0, 7, 14, 21, 28, 84, and 140. Daily DMI decreased linearly (P < .01) as degree of processing increased, whereas daily water intake did not differ (P > .61) among treatments. Average daily gain, ADG:DMI, and hot carcass weight increased quadratically (P < .02) with increasing degree of processing. Packed cell volume, and serum glucose and lactate dehydrogenase were not influenced (P > .15) by degree of processing. For hormone data, ME intake on the day of sample collection was evaluated as a covariate. Serum insulin (2.49, 2.95, and 1.80 + 0.3 ng/mL) and GH (16.1, 12.4, and 14.4 + 1.1 ng/mL) responded quadratically (P < .04) on d 28 as degree of processing increased. Serum insulin tended to decrease quadratically (P = .057) on d 140. In a second experiment, 216 steers were blocked by BW (18 pens; 12 hd/pen) and assigned to treatments used in Exp. 1. Through d 56, DMI did not differ (P > .16) among treatments, whereas ADG and ADG:DMI increased linearly (P < .04) with increasing degree of processing. Results suggest that degree of processing may influence serum insulin and growth hormone concentrations of feedlot cattle.
Effects of Multiple Stabilized Enzymes on performance of steers during receiving and subsequent high concentrate feeding.
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Seventy-two crossbred steers (221 kg) were used in two completely randomized design experiments to evaluate the effects of supplementing diets with Multiple Stabilized Enzymes (MSE) on morbidity, mortality, performance, and carcass characteristics. Steers were randomly assigned to one of two treatments: ionophore-antibiotic combination (control) or MSE. Diets were formulated to be iso-nitrogenous and iso-caloric containing steam-flaked grain sorghum and cottonseed hulls with 0% MSE (control) and 0.10% MSE. The MSE premix was hand added on top of the other dietary ingredients before mixing and conveying to the pens. Twelve pens of six steers were used, and pen was the experimental unit. Steers were kept in partially slotted floor pens and fed once per d ad libitum via an automated feed delivery system in fence-line bunks. Steers were weighed individually and recorded on 28 d intervals and fed a receiving diet for 70 d, rerandomized and fed a finishing diet for 141 d. No differences (P > .10) were detected for blood cortisol levels taken on 0 and 56 d of the receiving study. Average daily gain (ADG), dry matter intake (DMI), and feed efficiency (FE) were not affected by treatment (P < .10) during the receiving period. Steers receiving MSE during the finishing period had an increase (P < .10) in rate of gain, heavier (P < .07) hot carcass weights and an increase (P < .10) in final yield grade. However, no differences (P > .10) were detected in ribeye area between treatment groups. MSE steers had 45% less (P < .10) liver abscesses. Value of the carcasses, in dollars, was calculated based on hot carcass weight, final yield grade, and quality grade. Steers receiving the MSE treatment had a 2.5% numerical increase in carcass value compared to the steers receiving the ionophore-antibiotic treatment. MSE is a commercially available enzyme-microbial feed supplement that may improve weight gain, feed efficiency, and decrease liver abscesses. These data clearly illustrate an economic benefit from the inclusion of MSE in the diet.

Key words: Ionophore, Multiple Stabilized Enzymes, Steers
Impact of prenatal dietary copper level on cellular and humoral immunity of newly weaned calves.

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To examine the effects of prenatal dietary Cu on immunocompetence of calves, Simmental cows were fed one of four diets containing 0, 20, 40 or 80 ppm Cu (all diets contained high levels of S and Mo) during the last trimester of gestation. From birth to weaning, all cows were fed a mineral supplement devoid of Cu. We have previously reported (Branum et al., 1998) that 56-d-old calves from 80-Cu cows had enhanced cellular-, but lower humoral-immune responses than calves from 0-Cu cows. Because all calves at weaning were determined to be Cu deficient (liver Cu = 23 ± 4 ppm DM), calves were stratified by liver Cu and reassigned to one of three postweaning dietary Cu treatments (n = 14) containing 0, 10 or 50 ppm added Cu (1:1 mix of CuSO4 and Availa CuO). Liver biopsies were obtained on days 0, 14, 28, 42 and 75. Cell-mediated immunity (CMI) was assessed on days 14, 28, 42 and 54 by measuring skin-swelling responses to intradermal injections of phytohemagglutinin. To assess humoral immune responses, weekly serum neutralizing (SN) antibody titers for BVD, BRSV, IBR and PI3 were measured following vaccinations on days 14 and 28 with a 4-way modified-live viral vaccine. We have previously reported (Davis et al., 1998) that 50-Cu calves had higher (P < .05) CMI responses on days 28, 42 and 54, higher SN titers (P < .05) to BRSV, but lower (P < .06) SN titers to PI3 compared to 0-Cu calves. We have subsequently determined that prenatal Cu treatments as well as postweaning Cu treatments affected immunocompetence of the calves. Prenatal dietary Cu treatment affected CMI responses, independent of postweaning Cu treatment or liver Cu status, with calves from 40-Cu cows having higher (P < .01) responses than calves from 0-Cu cows on d 14, 28, 42 with CMI responses of calves from 20- and 80-Cu cows being intermediate. In contrast, average SN IBR and BRSV titer concentrations were higher (P < .05) for calves born to 0-Cu cows compared to calves from 40- and 80-Cu cows, with calves from 20-Cu cows being intermediate. These results suggest that higher prenatal dietary Cu levels, as well as higher postweaning dietary Cu levels, enhance cellular-, but not humoral-immune responses in early weaned calves.

Six crossbred steers (mean wt 355.7 kg) of similar genetics were used in a replicated 2 X 2 Latin square design to determine mineral balance and ruminal fluid pH when fed .26% BIOSAF® (Saccharomyces cerevisiae 8 X 10^9 CFU/g). BIOSAF® was substituted for .26% of the corn in a feedlot finishing diet. During each period, the steers were group fed (11.4 kg head^-1 d^-1) the control or BIOSAF® diets containing 80% steam rolled corn, 10% cottonseed hulls, and 10% protein-mineral supplement for a 21-d diet adjustment period. Following the diet adjustment period, steers were fed 9.08 kg/d and housed in metabolism stalls for a 7-d stall adjustment period and a 7-d collection period. Mineral intake, excretion (fecal and urine), apparent absorption, and retention were determined. On the last day of the collection period, a ruminal fluid sample was obtained via rumenocentesis and pH was measured. Apparent absorption and retention of Ca were increased (P=.0307) 8% with the addition of BIOSAF®. There was no difference (P=.9566) in apparent P absorption; however, P retention as a percentage of absorbed P was increased (P=.0584) by BIOSAF® (67.7 vs 52.6 %). BIOSAF® increased (P=.0013) apparent Na absorption (10.7 vs 8.4 g/d) and (P=.0074) retention (4.3 vs 1.1 g/d). Steers fed BIOSAF® had a greater (P=.0069) apparent Mn absorption (147 vs 70 mg/d) and (P=.0002) retention (146 vs 69 mg/d). There were no differences in absorption or retention of N, K, Mg, Fe, Zn, and Cu when either of the diets were fed. BIOSAF® increased (P=.0176) ruminal fluid pH (6.47 vs 5.48). The results of this research indicates that BIOSAF® has a positive effect on Ca and P utilization in feedlot steers and may be valuable in reducing P excretion in concentrated animal feeding operations.

Key words: Mineral, Steers, Yeast
IMPACT OF IMPLANTS AND MONENSIN ON WEIGHT MAINTENANCE OF LIMIT-FED STEERS

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Limited research has suggested that trenbolone acetate implants and monensin may decrease energy requirements for maintenance whereas estrogenic implants may increase energy requirements for maintenance. To test these ideas, 192 medium frame British crossbred steer calves (646 lb) were limit fed a 50% concentrate diet (NE\textsubscript{m} = 80, NE\textsubscript{g} = 49 Mcal/cwt) at a level equal to their estimated maintenance requirements (8.2 lb feed daily) for 56 days. After recovering from transport stress, all steers were stratified by weight and assigned randomly to 32 pens (six/pen). Eight pens were assigned to each of four implant regimens: none, 14 mg estradiol 17\beta, 140 mg trenbolone acetate, or 14 mg estradiol 17\beta plus 140 mg trenbolone acetate. Within each implant regimen, four pens were fed diets with no added monensin whereas the other four pens received the same diet with 33 ppm monensin added. Calves were weighed weekly and feed supply was adjusted to achieve zero weight gain. Steers receiving TBA alone or in combination had greater \((P < .01)\) weight retention or weight gain than other steers by day 7; this difference remained and expanded throughout the trial. A favorable weight retention response to estrogen first became evident \((P < .04)\) on day 28. At day 56, control steers had gained 19.6 lb (for an ADG of .35 lb); TBA implants had increased weight beyond that of control steers at day 56 by 22.5 lb \((P < .001)\) whereas estrogen implants had increased weight at day 56 beyond that of control steers by 7.6 lb \((P < .03)\). No interaction between TBA and estrogenic implants was detected; effects were additive. An advantage in weight maintenance also was detected \((P < .06)\) starting on day 21 for cattle fed diets containing monensin, so that by day 56 steers receiving monensin averaged 7.2 lb heavier \((P < .04)\) than steers not receiving monensin. Analysis of feces indicated that coccidiosis was not a problem with any of the steers. No interaction between implants and monensin was detected, though the response to monensin appeared greater for implanted than non-implanted steers. No differences \((P > .39)\) were detected in hip height among treatments either initially or on day 56, but mean height increased by 1.26 inch during the trial. Fat thickness, .074 inch at 56 day as determined via ultrasound, was not significantly altered \((P > .64)\) by diet or implant regimen. These data suggest that the depression in weight gain associated with adaptation to monensin may be due to metabolic changes and not merely due to reduced feed intake. Results support the idea that monensin feeding decreases the amount of energy required for weight maintenance. Being immediate and dramatic, TBA implants presumably are altering the partitioning of nutrients; perhaps through altering metabolism, e.g., reducing protein turnover or enhancing lipid mobilization, reducing the quantity of energy expended for weight maintenance. Overall, these results indicate that, in contrast to a common belief, even with very low daily gains (.35 lb), weight maintenance of limit-fed steers can be enhanced by either estrogenic or TBA implants and by including monensin in the diet.

(Key words: Hormonal implants, Ionophores, Energy, Maintenance)
Effects of Feeding Vitamin D$_3$ on Feedlot Performance and Carcass Characteristics of Beef Cattle.

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Supplementing the diet with Vit. D can improve tenderness of beef cuts but may depress feed intake. Three trials were conducted to examine responses to high levels of Vit. D on intake and carcass characteristics. In trial 1, Vit. D was supplemented at 0, 5, 7.5, 15 or 75 million IU (MIU)/steer daily with 20 steers (360 kg) per treatment. Depressions in DMI were detected (P<.05) after 2 d with 75 MIU, at 4 d with 15 MIU, at 5 d with 7.5 MIU, and at 6 d with 5 MIU added Vit. D suggesting that when total Vit. D intake on previous days exceeds about 30 MIU, feed intake will be reduced. In trial 2, Vit. D was included in a pellet included with the diet so that at 11 kg daily feed intake, each steer would receive either 0, 2.5, 5 and 7.5 MIU/steer daily with 20 steers (445 kg) per treatment. Depressions in DMI were detected (P<.05) after 12 d with both 5 and 7.5 MIU and at 20 d with 2.5 MIU added Vit. D indicating that these steers tolerated 50 to 60 MIU before DMI was reduced. In trial 3, we examined effects of Vit. D on blood Ca, carcass traits, Warner Bratzler Shear force values, and pH (0, 3, 12, and 24 h post-harvest) of three different muscles: Longissimus, Gluteus medius and Biceps femoris with 24 steers (560 kg) per treatment. Treatments included no Vit. D supplementation or 6 million IU (MIU) daily for either 4 or 6 d pre-harvest. Hot carcass weights decreased (P<.05) an average of 6.4% due to feeding of Vit. D. Shear force was decreased (P<.05) with Vit. D feeding for Longissimus and Gluteus medius steaks 10.4% and 6.4% respectively. An effect of duration of feeding Vit. D on pH on all muscles measured was detected with pH at 0, 3, and 12 h postmortem being greater for steers being fed Vit. D for 6 d than for those fed Vit. D for 4 d; the response was reversed at 24 h with pH being lower with steers fed Vit. D for 6 d. Blood Ca was increased (22.6%; P<.05) as a result of feeding Vit. D (P<.05). Results indicate that intakes of Vit. D exceeding 25 to 50 MIU will depress feed intake. However, possibly through increasing blood and tissue Ca concentrations, it improved tenderness of some but not all muscles measured.

(Key words: Vitamin D, Intake, Beef, Tenderness)
Effect of dietary chromium supplementation on growth and carcass characteristics of feedlot steers.
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The objectives of this research were to determine the effects of supplemental chromium (Cr) during growing and finishing periods on steer feedlot performance and carcass characteristics. One hundred and five English and continental crossbred steers (295 kg) were used to evaluate the effects of 0.2 ppm and 0.4 ppm chromium supplementation. Steers were initially implanted with Synovex-S, vaccinated, and adjusted to a high concentrate diet over a 35 d growing period. Steers were randomly allotted to the following dietary treatments 1) control (CON; basal diet), 2) basal diet with 0.2 ppm Cr supplementation (Cr 0.2), and 3) basal diet with 0.4 ppm Cr supplementation (Cr 0.4). A completely randomized design with seven steers per pen and five pens per treatment were used in this experiment. Diets were mixed and fed once per d on an ad libitum basis, and formulated to be iso-caloric and iso-nitrogenous using cottonseed meal, urea and steam flaked grain sorghum. Chromium was supplied as high chromium yeast and ground grain sorghum premix added to the diet at either 0.25% or 0.50% in replacement for steam flaked grain sorghum. All steers were fed a growing diet for 35 d followed by a finishing diet for 161 d. Individual animal weights were recorded on d 0, 14 and 28 and repeated every 28 d through d 196 with final pen weights recorded on d 208 prior to shipping to a commercial packing plant. Neither control steers nor treatment steers experienced any significant health problems throughout the entire trial. Dry matter intake was not affected (P > .05) by dietary treatment, however steers fed CON and Cr 0.4 had numerically lower DMI than steers fed Cr 0.2 diet (8.22 and 7.80 versus 8.96 kg/d). Daily gain was greater (P < .05) for steers fed CON and Cr 0.2 than steers fed Cr 0.4 diet (1.11 and 1.16 versus 0.96 kg/d). Gain to feed ratio was greatest (P < .05) for steers fed CON and Cr 0.2 compared to Cr 0.4 diet (135 and 130 versus 119 g gain/kg feed). Carcass characteristics were determined from live weight with a 4% pencil shrink using the Excel grid system. Steers receiving Cr 0.2 diet had heavier (P < .05) carcass weights, while Cr 0.4 steers had lightest carcasses with CON steers being intermediate (315, 276 and 302 kg, respectively). Ribeye area was greatest (P < .05) for Cr 0.4 diet and lowest for CON diet, with Cr 0.2 diet being intermediate (81.6, 77.9 and 81.4 cm2, respectively). Marbling score was reduced (P < .05) by Cr 0.4 diet, compared to CON and Cr 0.2 diet (395 versus 472 and 446). Dressing percentage was increased (P < .05) by CON and Cr 0.2 diet compared to Cr 0.4 diet (63.37 and 63.65 versus 62.16). Final yield grade was increased (P < .05) by CON and Cr 0.2 diet and decreased by Cr 0.4 diet (2.53 and 2.32 versus 1.56). Feeding Cr failed to improve growth performance and gain to feed, however, Cr did improve many economically important carcass characteristics when the spread between Choice and Select is small, or when cattle are sold on a grid system which emphasizes hot carcass weight, ribeye area, and final yield grade.

Key words: Steers, Chromium, Carcass characteristics
The effects of extruded whole cottonseed as a supplemental protein source in high concentrate diets for growing beef steers.

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The primary objective of this study was to evaluate the effects of feeding extruded whole cottonseed (EWCS) as a supplemental protein source in high concentrate diets fed to growing beef steers. A Latin-square design was utilized with three ruminally cannulated Hereford steers averaging 295 kg. Steers were housed in individual metabolism crates equipped with feeders and an automatic water system. Each collection period consisted of a 10 d adaptation period, 5 d total feed and fecal collection period followed by a 3 d ruminal content and blood collection period. During the 10 d adaptation period steers were fed ad libitum. During the collection period, steers were fed 90% ad libitum once each day at 0900 h. Samples were taken before 0900 h each morning. Treatments were designed to investigate the ability of EWCS to replace cottonseed meal (CSM) in high concentrate diets. Three dietary treatments were formulated (A, B, and C) in which the natural supplemental protein source was adjusted using CSM and EWCS. Treatment A contained 100% CSM, treatment B contained 50% CSM and 50% EWCS, while treatment C contained 100% EWCS, as their respective natural supplemental protein sources. Diets were formulated to be iso-caloric and iso-nitrogenous (13% CP) using steam flaked grain sorghum, CSM, EWCS, and vegetable fat which met or exceeded NRC (1996) requirements for growing beef steers. Dietary NDF and ether-extract levels were held constant using cottonseed hulls (CSH) and vegetable fat. With increasing level of CSM, CSH and vegetable fat were increased in the diet to offset the higher levels of NDF and ether-extract found in EWCS. No differences ($P > .05$) were detected for dry matter intake (DMI), apparent digestibility, plasma urea nitrogen, nitrogen balance, plasma gossypol, volatile fatty acids, or ruminal pH. These data indicate that substituting EWCS for CSM does not alter rumen fermentation. Furthermore, EWCS does not appear to have adverse effects on metabolism and could be used as a supplemental protein source for CSM. Therefore, EWCS can be included in high concentrate diets as a replacement for CSM and a partial replacement for vegetable fat and CSH.

Key words: Steers, Extruded Whole Cottonseed, Cottonseed meal
Effect of AgradoTM on the Health and Performance of Transport-Stressed Heifer Calves
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Six hundred ninety mixed breed heifer calves (196 kg average initial BW) were used to determine the effect of adding AgradoTM, an antioxidant produced by Solutia, St. Louis, MO., to the receiving ration on rate and efficiency of gain, and response to medical treatments. Heifers were blocked by weight within 7 truckloads of cattle and randomly assigned to one of two diets (0 or 150 ppm added Agrado) within each weight block with eight pens of 10 to 16 head per load. All cattle, purchased at sale barns in Oklahoma and Arkansas by order buyers, were given free choice access to a moderately high energy receiving diet (51 Meal NEg / cwt) consisting of 32% soybean hulls, 27% corn, 16% wheat middlings, and 10% cottonseed hulls. Health and performance were monitored for 42 days following arrival. Diets were supplemented with 15 IU vitamin E/kg and either 0 or 150mg AgradoTM/kg. Cattle were observed for signs of morbidity daily and frequency, duration, and extensiveness of medical treatments were recorded. Morbid heifers fed supplemental AgradoTM required fewer medical treatments for recovery (1.2 vs 1.0; P<.05) indicating that AgradoTM may reduce medical cost. No significant effects of Agrado supplementation on rate and efficiency gain during these 42-day receiving trials were detected.

Key words: AgradoTM, shipping stressed cattle, feedlot.
Combination of cellulase and amylase enzyme mixtures on performance of feedlot steers.
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The objective of this study was to evaluate the effects of enzymatic treatment of diet components on steer performance in terms of average daily gain (ADG), feed intake (FI), feed: gain ratio (F:G) and carcass characteristics. One hundred and seventy-five crossbred steers (604 lb) were randomly divided by weight into five treatment groups with five pens of seven steers per treatment. The five treatments were 1) control (no enzyme), 2) cellulase liquid, 3) cellulase liquid + Digest C liquid (combination liquid), 4) Digest C liquid, and 5) cellulase dry + Digest dry (combination dry). Steers were fed a steam flaked corn and alfalfa hay based diet on an ad libitum basis. The liquid form enzyme treatments were sprayed on the hay or corn components for each pen immediately prior to mixing the complete diet, while those in the dry form were mixed with ground corn and added to the diet via a premix. The study was divided into three 56-day phases with alfalfa hay and corn at approximately 50:40, 30:60, and 10:80 for each respective phase. Each phase was summarized and analyzed as a separate experiment. Enzymes were used in the diets at levels of 5 ounce/ton of alfalfa hay and 6 ounce/ton of corn. Liquid enzymes were mixed with 1% moisture as a carrier for digest-C and 2% for cellulase before spraying. Steers were weighed every 28 days and FI, ADG and F:G ratio were calculated on a pen basis for each 56-day phase. Steers were implanted with Synovex S at the initiation of the study. The first 56 days showed that, except for Digest-C treatments, direct fed enzymes improved (P< .05) ADG and F:G ratio, with no effect on FI. Even though enzyme treated groups were numerically better than the control group, no differences (P>.05) were observed during the second 56-day period. Enzyme treatments did not have an effect on ADG or F:G ratio during the last 56 days, however they reduced (P< .05) the amount of feed consumed. These results indicate that enzyme treated diets can improve the performance of feedlot cattle. Carcasses were sold on a basic standard grade and yield grid system which includes hot carcass weight, final yield grade, and quality grade at EXCEL Packing Plant, Plainview, TX. Steers receiving the Digest-C liquid treatment had larger (P<.05) ribeye areas than the control and the combination dry treatment. The cellulase liquid and the combination liquid treatments resulted in somewhat larger ribeye areas as compared to the control but were not different (P>.05). All enzyme treatments resulted in somewhat heavier hot carcass weights but were not different (P>.05) from the control. There were no differences (P>.05) across final yield grades. However, distribution of carcasses across the four quality grades favored the enzyme treatments. Overall, the carcass characteristics were informative and indicate that steers fed these enzymes may have carcasses that are somewhat different in composition.

Key words: Cellulase, Enzyme, Performance
The effects of dietary cation-anion balance and varying calcium concentrations in the diet on the serum calcium of feedlot steers.

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Previous research shows that high cellular Ca levels at slaughter increase tenderness. A study was conducted with 12 crossbred steers to develop feeding strategies to increase circulating Ca levels. Steers were fed in a single pen equipped with Calen gate feeders and used in a 4 X 4 Latin square design experiment. Dietary treatments were two dietary cation-anion (DCAB) diets (-30 and +5 meq/100g) and two Ca feeding strategies in a 2 X 2 factorial arrangement. The Ca feeding strategies were .45 % Ca throughout each 28 d period or .45 % Ca for 7 d, followed by .1% Ca for 14 d and then .9 % Ca for 7 d during each period. The diet contained steam rolled corn (75.9 %), cottonseed hulls (15.4 %), and a protein-mineral supplement (8.7 %). Serum samples were taken on d - 1, 14, 21, 22, 24, 26, and 28, and ruminal fluid pH was collected on d 14 and 28 for each of the last three feeding periods. Steers fed -30 DCAB diets had a lower ruminal pH on d 28 (P<.05) when compared to steers fed +5 DCAB (5.63 vs 6.02, respectively), and tended to have lower ruminal fluid pH on d 14 (P= .059). In addition, average daily feed intake was 22.9 % greater on d 1-7, 38.5 % greater on d 8-21, and 34.2 % greater on d 22-28 (P<.05) for steers fed the +5 DCAB diet compared to the -30 DCAB diet. Serum inorganic P was greater on d 14 (P<.05) for steers fed the -30 DCAB compared to those fed the +5 diet (10.26 vs 8.71 mg/dl). Serum ionized Ca was greater (P<.05) on d 28 for steers fed +5 DCAB compared to those fed -30 DCAB (9.22 vs 7.21 mg/dl). Steers fed the alternating levels of Ca had a higher serum Ca (8.87 vs 7.56 mg/dl) on d 28 compared to those fed .45% Ca throughout the period (P<.05). The results of this study indicate that feeding a -30 DCAB may alter the acid-base balance of the animal causing subclinical acidosis. The findings also indicate that alternating Ca levels over the last 28 d of the finishing period may help to increase the serum Ca levels of feedlot steers.

Key Words: Tenderness, Calcium, Dietary Cation-Anion Balance
Performance and carcass measurements of cattle with varying degrees of pulmonary lung lesions at slaughter.

Upon slaughter, respiratory tracts were collected from 371 steers consigned to the Ranch to Rail North program to evaluate the possible effects pulmonary lung lesions have on cattle performance. A veterinary pathologist performed necropsies and lungs were scored based upon lobular involvement, lesion type, and the amount of total lung volume effected. For purposes of analysis, lung scores were compiled into one of seven categories (0=no lesions, 6=most severe) depending upon lesion involvement. Pull status (non-pulled vs. pulled) within categories were analyzed using the chi-procedures. Within the cattle having no lesions (category=0, n=32), thirty one-percent had been pulled and treated at least once, however there were no differences between pulled and non-pulled animals (p=.12). Of the animals having mild (categories 1 and 2, n=170) and moderate lesions (categories 3 and 4, n=121) pulls were lower in groups 1 and 4 (p<.05), while 35.9 and 51.2% had been pulled and treated, respectively. Within the most severe lung score classifications (categories 5 and 6, n=48) 70.8% of the cattle were pulled, and pulls were significantly higher in category 6 (p<.05). As lung lesion category increased (0-6) percentage of steers pulled increased also (31, 34, 38, 40, 61, 57, and 84%, respectively). Performance traits, medical history and carcass characteristics were examined using general linear models. Lung category was analyzed as the primary independent variable but when appropriate initial weight was included as a covariate. Days on feed were greatest for category 5 (199) but were not different than categories 4, 1, and 6 (p>.05), while animals in category 2 were on feed for the shortest length of time (182, p<.05). Daily gain was less for steers in categories 1, 4, 5, and 6 (mean=1.29kg, p<.05) and highest for animals in categories 0, 2, and 3 (mean=1.37kg, p<.05). Category 6 had the highest frequency of pulls (p<.05), while pulls were not different in categories 0, 1, 2, 3, 5 (p>.05). Steers in category 6 had the highest medical cost (mean= $40.35/hd, p<.05), while categories 6 and 4 (mean= 3.9 and 3.1d/hd, respectively) had the greatest number of hospital days (p<.05). Marbling scores increased as lung severity decreased and were highest for categories 2, 0, 1, 3 (mean=179.73, p<.05), however calculated yield grades were not different between lung categories (mean=2.6, p>.05). These results indicate that at each lung lesion category there were cattle that had never been treated. These findings further accentuate the need for a more objective means of determining health status of animals in finishing yards.