PROPER USE OF AMMONIATED LOW-QUALITY FORAGES FOR THE WINTERING OF SPRING-CALVING BEEF COW HERDS IN THE INTERMOUNTAIN WEST

PROPER USE OF AMMONIATED LOW-QUALITY FORAGES FOR THE
WINTERING OF SPRING-CALVING BEEF COW HERDS IN THE INTERMOUNTAIN WEST

R.D. Wiedmeier\(^1\), D.R. ZoBell\(^2\), A.J. Young\(^1\), and D.L. Snyder\(^2\)
\(^1\)Department of Animal, Dairy and Veterinary Sciences
\(^2\)Department of Economics
Utah State University, Logan

Part I. Long-Term Use of Low-Quality Forages Such as Ammoniated Wheat Straw for the Wintering of Beef Cows (p. 1)
Part II. Practical Comments on the Processes Used to Properly Ammoniate Low-Quality Forages (p. 15)
Part III. Balancing Beef Cow Diets Using Ammoniated Low-Quality Forages and Economic Considerations (p. 20)

Part I. Long-Term Use of Low-Quality Forages Such as Ammoniated Wheat Straw for the Wintering of Beef Cows

Introduction

Low-quality forages (LQF) such as cereal straws or post-ripe hays are often used as economical feed sources for the wintering of beef cow herds. The ammoniation of such forages increases the digestibility and crude protein (CP) enough so that these forages can be used as the basis of beef cow diets, even during late gestation and early lactation if supplemented properly. Producers often contemplate the use of LQF to winter their cow herds during emergencies that reduce on-ranch forage supplies such as droughts, fires, floods, insect attack or various plant diseases, etc. In public-land states like Utah curtailment of grazing permits can also precipitate such emergencies. If winter feed supply is limiting the carrying capacity of some ranches, the proper use of LQF may be an economical method of increasing cow numbers, which is one method of reducing per cow fixed costs. Currently the corn-ethanol era has increased the value of forages to the extent that LQF may be a long-term option for the wintering of beef cow herds. However, the scientific literature is devoid of studies assessing the productivity of beef cows when LQF are the basis of their winter diets for several consecutive years. The objective of this study was to assess the effects of the long-term wintering of dry, pregnant spring-calving beef cows on their biological and economic productivity. Long-term in this study indicates a relatively large number of days per year (150 days/year) and for five consecutive years.

Materials and Methods

Twenty-four mature beef cows were used for this study. Due to the long duration of the study (five consecutive years) cows of four to five years of age at the beginning of the study were selected, hoping that most would remain on the study the entire duration. The cows were spring-calving (March-April) with a body weight of 1250 lbs. when in average body condition and in early gestation. The 24 cows were separated into six groups of four cows each so that each group was as similar as possible regarding breeding, age, body weight, and the average weaning weight of their calves prior to this study. Each group of cows was quartered each winter (December through April) in 12’ by 64’ pens constructed of steel livestock panels. Each pen was
equipped with a mound of wood shaving to bed the cows, a 3’ x 12’ steel feeder and a frost-free watering station with concrete apron. The same group of cows remained in the same pen and on the same winter diet each year of the study. Three cows had to be replaced during the course of the study. The replacements were as similar as possible to the cows replaced. Two cows were replaced for reproductive failure and one for physical unsoundness during the duration of the study.

The two winter diets compared were:

1. A full feed of medium-quality mixed grass hay (GH) typical of that used by cow-calf producers in the Intermountain West (67.5% neutral detergent fiber, 9.5% crude protein, dry matter basis).

2. A full-feed of ammoniated wheat straw (AWS) (76.5% neutral detergent fiber, 8.8% crude protein, dry matter basis) supplemented with alfalfa hay (AH) (51.5% neutral detergent fiber, 17.5% crude protein, dry matter basis). The amount of AH received was gradually increased through the wintering period as cows proceeded through late gestation and early lactation. During December and January each cow on the AWS diet received 4.62 lbs. and 6.16 lbs. of dry matter (DM) from AH, respectively. During February through April each cow received 8.14 lbs. of DM from AH.

The GH was harvested from the same sprinkler irrigated field each year of the study and was composed of approximately 50% endophyte-free tall fescue (Festuca arundinacea), 30% quackgrass (Agropyron repens) and 20% Kentucky bluegrass (Poa pratensis).

The wheat straw was harvested from one of two adjacent fields that were in a four-year rotation between alfalfa and hard red wheat. Straw was obtained from one of the fields the first three years of the study and from the adjacent field the last two years. For step-by-step procedures used to ammoniate the wheat straw along with practical suggestions, please proceed to Part II of this publication on page 15. For those wishing to study details of diet balancing techniques for beef cows being wintered on ammoniated wheat straw and associated economic considerations, please proceed to Part III of this publication on page 20.

Winter Feeding Management of the Cows on the Study (December through April):

a. Cows were fed once per day between 1500 and 1700 to help promote day-time calving.

b. The proper amount of GH was weighed out and delivered to the three pens (four cows/pen) assigned to that diet. The GH was fed as flakes from bales without processing to simulate practical feeding conditions. The cows were fed on an ad libitum bases receiving enough GH so only 1 to 3% of the previous day’s offering remained. If more than 1 to 3% remained, the present day’s offering was appropriately reduced. If the feed bunk was clean and dry, the present days offering was appropriately increased. Within three or four days, one could make fairly accurate predictions regarding how much forage should be offered. We have found that when feeding medium-quality forages and especially LQF, it is best to feed for these low levels of refusals. Otherwise the cattle quickly learned to sort out the chaff and leaves of the forage and leave the stems.

c. Vitamin-mineral supplements were formulated to rectify deficiencies associated with the two winter diet systems:
Table 1. Ingredient composition of vitamin-mineral supplements used to rectify deficiencies associated with the ammoniated wheat straw/alfalfa hay (AWS/AH) or grass hay (GH) winter diets.

<table>
<thead>
<tr>
<th>Ingredient, % of Dry Matter</th>
<th>AWS/AH</th>
<th>GH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground barley grain</td>
<td>61.57</td>
<td>68.61</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>12.72</td>
<td>-</td>
</tr>
<tr>
<td>Ground limestone</td>
<td>- -</td>
<td>6.59</td>
</tr>
<tr>
<td>Vitamin premix(^a)</td>
<td>8.20</td>
<td>8.20</td>
</tr>
<tr>
<td>Mineral premix(^b)</td>
<td>8.89</td>
<td>8.01</td>
</tr>
<tr>
<td>Salt</td>
<td>8.60</td>
<td>8.60</td>
</tr>
</tbody>
</table>

\(^a\) Vitamin A, 500000 IU/lb.; vitamin D, 50000 IU/lb.; vitamin E, 3000 IU/lb.
\(^b\) Zinc, 2727 mg/lb.; manganese, 2272 mg/lb.; copper, 909 mg/lb.; iodine, 91 mg/lb., selenium, 22.7 mg/lb., cobalt, 22.7 mg/lb.

Before receiving the daily allotment of GH, the cows were given **1.1 lb. of vitamin-mineral supplement/cow/day**. Due to the fact that this supplement was about two-thirds ground barley it was readily consumed within about two minutes.

d. The pens assigned to receive the AWS/AH diet also received 1.1 lbs./cow/day of the appropriate vitamin-mineral supplement first (Table 1). Then the appropriate amount of AWS was weighed and delivered to each pen. Ammoniated wheat straw was also fed as flakes directly from the bales without grinding or mixing to mimic practical feeding conditions. Lastly the appropriate amount of AH was weighed out and placed on top of the AWS. This allowed all cows in the pens equal access to the AH. If the AH was placed in the feeder first and then the AWS, we found that the cows would push the AWS out of the feeder to get to the AH. With the AH on top of the AWS there was no problem with cows pushing AWS out of the feeder.

**Measurements Taken During the Winter Feeding Period:**

a. Feed samples (GH, AWS, AH, vitamin-mineral supplement) were taken the last six days of each month from the daily ration delivered to each pen. Forage samples were taken with the aid of a core sampler. These samples were then composited and subjected to proximate analysis; DM, crude protein (CP), neutral detergent fiber (NDF), ether extract (EE), total ash (TA), and neutral detergent soluble carbohydrates (NDSC). As an estimate of the energy content of the feeds associated with the diets, **in vitro** dry matter digestibility (IVDMD) was also conducted on the composite samples by incubation with ruminal microorganism. In addition the acid insoluble ash (AIA) content of the feeds was estimated. The AIA represents the mineral portion of the feeds that is not digested and can therefore be used as an internal marker to estimate diet digestibility. The concentration of AIA increases in the feces of animals in proportion to diet digestibility. Consequently fresh fecal samples from each pen were also collected the last six days of each month and analyzed for AIA. These samples were collected at 0700 and 1500 each day of the collection period. As cattle raised from their beds they usually always defecated, allowing collection of fresh, uncontaminated samples. These samples were immediately dried in a forced-air oven set at 60°C for 72 hours or until weight stabilized. We felt that rectal grab sampling of feces at this frequency would have caused undue stress on the cows. This allowed an estimate of the amount of energy the cows were actually extracting from the diets. Table 2 is a summary of the proximate analysis of the forages used during the five years of the study.
Table 2. Proximate analysis and in vitro dry matter digestibility of forages used to winter beef cows through the five years of the study, % of dry matter.

<table>
<thead>
<tr>
<th>Item</th>
<th>CP&lt;sup&gt;a&lt;/sup&gt;</th>
<th>NDF&lt;sup&gt;b&lt;/sup&gt;</th>
<th>EE&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Ash&lt;sup&gt;d&lt;/sup&gt;</th>
<th>NDSC&lt;sup&gt;e&lt;/sup&gt;</th>
<th>IVDMD&lt;sup&gt;f&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALF&lt;sup&gt;g&lt;/sup&gt;</td>
<td>17.80</td>
<td>48.10</td>
<td>3.40</td>
<td>8.10</td>
<td>22.60</td>
<td>59.30</td>
</tr>
<tr>
<td>WS&lt;sup&gt;h&lt;/sup&gt;</td>
<td>3.20</td>
<td>78.40</td>
<td>2.34</td>
<td>7.12</td>
<td>8.94</td>
<td>41.17</td>
</tr>
<tr>
<td>AWS&lt;sup&gt;i&lt;/sup&gt;</td>
<td>9.71</td>
<td>73.80</td>
<td>2.20</td>
<td>6.70</td>
<td>7.59</td>
<td>48.40</td>
</tr>
<tr>
<td>GH&lt;sup&gt;j&lt;/sup&gt;</td>
<td>10.10</td>
<td>69.40</td>
<td>2.00</td>
<td>4.80</td>
<td>12.70</td>
<td>51.67</td>
</tr>
<tr>
<td></td>
<td>Year 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALF</td>
<td>17.50</td>
<td>51.40</td>
<td>3.00</td>
<td>8.90</td>
<td>19.20</td>
<td>57.89</td>
</tr>
<tr>
<td>WS</td>
<td>3.04</td>
<td>81.40</td>
<td>2.46</td>
<td>8.11</td>
<td>4.95</td>
<td>39.46</td>
</tr>
<tr>
<td>AWS</td>
<td>8.20</td>
<td>76.30</td>
<td>1.81</td>
<td>7.10</td>
<td>6.59</td>
<td>46.91</td>
</tr>
<tr>
<td>GH</td>
<td>9.42</td>
<td>71.30</td>
<td>2.36</td>
<td>6.42</td>
<td>10.50</td>
<td>48.27</td>
</tr>
<tr>
<td></td>
<td>Year 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALF</td>
<td>18.14</td>
<td>49.72</td>
<td>2.80</td>
<td>8.50</td>
<td>20.84</td>
<td>61.12</td>
</tr>
<tr>
<td>WS</td>
<td>4.13</td>
<td>80.14</td>
<td>2.04</td>
<td>7.63</td>
<td>6.06</td>
<td>41.89</td>
</tr>
<tr>
<td>AWS</td>
<td>9.20</td>
<td>75.64</td>
<td>1.85</td>
<td>6.24</td>
<td>7.07</td>
<td>47.78</td>
</tr>
<tr>
<td>GH</td>
<td>9.91</td>
<td>70.80</td>
<td>2.00</td>
<td>6.04</td>
<td>11.25</td>
<td>50.27</td>
</tr>
<tr>
<td></td>
<td>Year 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALF</td>
<td>17.23</td>
<td>52.33</td>
<td>2.75</td>
<td>9.13</td>
<td>18.56</td>
<td>57.01</td>
</tr>
<tr>
<td>WS</td>
<td>3.11</td>
<td>82.73</td>
<td>2.14</td>
<td>8.71</td>
<td>3.31</td>
<td>38.24</td>
</tr>
<tr>
<td>AWS</td>
<td>8.56</td>
<td>78.41</td>
<td>1.76</td>
<td>7.23</td>
<td>4.04</td>
<td>46.27</td>
</tr>
<tr>
<td>GH</td>
<td>10.30</td>
<td>68.74</td>
<td>2.32</td>
<td>5.92</td>
<td>12.72</td>
<td>51.91</td>
</tr>
<tr>
<td></td>
<td>Year 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALF</td>
<td>18.53</td>
<td>48.90</td>
<td>3.70</td>
<td>8.84</td>
<td>20.03</td>
<td>60.42</td>
</tr>
<tr>
<td>WS</td>
<td>3.87</td>
<td>80.01</td>
<td>2.52</td>
<td>7.71</td>
<td>5.89</td>
<td>39.08</td>
</tr>
<tr>
<td>AWS</td>
<td>10.16</td>
<td>74.42</td>
<td>1.95</td>
<td>6.92</td>
<td>6.55</td>
<td>48.12</td>
</tr>
<tr>
<td>GH</td>
<td>9.54</td>
<td>71.84</td>
<td>2.17</td>
<td>7.14</td>
<td>9.31</td>
<td>52.17</td>
</tr>
</tbody>
</table>

<sup>a</sup>Crude protein, total nitrogen x 6.25.

<sup>b</sup>Neutral detergent fiber, composed mainly of insoluble carbohydrates requiring microbial fermentation to be utilized.

<sup>c</sup>Ether extract, a crude estimate of the lipid content of feeds sometimes called crude fat.

<sup>d</sup>Ash, the total mineral or inorganic compound content.

<sup>e</sup>Neutral detergent soluble carbohydrates, composed of simple sugars, starches, and some soluble fiberous carbohydrates. All considered to be rapidly and extensively fermented in the rumen of cattle.

<sup>f</sup>In vitro dry matter digestibility or disappearance, measured by incubation of forages with ruminal microorganisms.

<sup>g</sup>Alfalfa hay

<sup>h</sup>Wheat straw prior to ammoniation

<sup>i</sup>Ammoniated wheat straw

<sup>j</sup>Grass hay

Note from Table 2 that after ammoniation there was a considerable increase in CP content of wheat straw. Also notice that the NDF content decreased. This is due partially to the dilution effect of the increased CP content and partially due to the solubilization of some carbohydrates associated with the NDF.

b. During the first week of each month the cows were weighed to note changes in body weight (BW). At the same time cows received a body condition score (BCS), which is a visual appraisal of the cows’ fat or energy reserves. We used a scoring system of 1 through 9 with a score of 1 being extremely
emaciated and physically weakened. A score of 9 represents extreme obesity. A score of 5 is considered average and functional in that cows will consistently reproduce if they have a BCS of 5 during the calving and breeding seasons. Three different persons assigned BCS to cows during the five years of the study, but all were trained by the same person. It is normally assumed that it is best to keep the cows away from feed and water 24 hours before weighing to equilibrate gastro-intestinal fill. This was not practical in this study due to concerns regarding abomasal impaction when hungry cow engorge on AWS. So we weighed the cows twice at 0800 and 1700 on the weigh dates. The average of these two weights was recorded.

c. The cows calved in the wintering pens. At birth the calf birth weight and sex were recorded. Then each calf received a calving ease score and a vigor score. The calving ease score was 1 or 2 with a score of 1 being an unassisted birth and 2 an assisted birth. The calf vigor scores were 1 through 3 with 1 indicating a calf that was up and nursing within 30 minutes. A vigor score of 2 indicated a calf up and nursing within 30 to 90 minutes, and a score of 3 indicated the calf required assistance to nurse. The time of day that calving took place was also recorded to ascertain if afternoon feeding increased the proportion of calving taking place during daylight hours.

d. For energy budgeting purposes we required an estimate of the milk production of the cows. This was accomplished using a calf weigh-suckle-weigh method. The day before cattle were scheduled to leave the wintering pens and moved to pastures, the calves were removed from their dams at 0600. Calves received no feed or water while removed from their dams. At 1800 the calves were weighed and then allowed to suckle their dams. As soon as suckling ceased the calf was immediately reweighed. The difference in calf weight before and after suckling was assumed to be due to milk ingested. The milk produced during this 12-hour period was doubled as an estimate of daily milk production.

Characteristics of the Pasture Grazed by Cow-Calf pairs May through October:

a. All cow-calf pairs grazed in common on flood meadow pastures approximately five miles west of the wintering pens.

b. The pasture consisted of three parcels of about 22 acres each. Cattle were rotated through these parcels at approximately 20-day intervals. After grazing the parcels were flood irrigated from a free-flowing artesian well. However, only about two-thirds was effectively irrigated due to the unevenness of the land. No commercial fertilizers were applied during the study. Using a clip plot method it was estimated that the pasture normally produced about 6500 lbs. of DM/acre/season leaving a three-inch stubble height. The predominant forage species on the pasture were Kentucky bluegrass (Poa pratensis), 30%; quackgrass (Agropyron repens), 25%; silver sedge (Carex praegracilis) 15%; reed canarygrass (Phalaris arundinacea), 10%; tall wheatgrass (Agropyron elongatum), 10%; intermediate wheatgrass (Agropyron intermedium), 10%. Drinking water was available in each parcel from free-flowing surface water from the artesian wells. Each parcel was equipped with a mineral supplementation station through which trace-mineralized salt was available at all times (Zinc, 3500 ppm; manganese, 2000 ppm; copper, 300 ppm; iron, 600 ppm; iodine, 110 ppm; selenium, 30 ppm; and cobalt, 50 ppm). Although the exact dates of grazing varied each year due to weather conditions, the grazing season lasted from 150 to 165 days.
Measurements taken during the Grazing Period:

a. To clear winter diets from the gastro-intestinal tract, the cattle were allowed to graze the pastures for seven days and were then weighed for an initial BW and BCS. Weighing always took place between 0500 to 0600.

b. The 24 cows associated with this study grazed in common with 25 other cow-calf pairs on these pastures during the grazing season. Two bull’s were placed with the cow-calf pairs the first week of June each year, one Hereford and one black Angus. The same two bulls were used years one and two of the study. Another set was used years three and four, and a third set was used the fifth year. The bulls used would be considered average regarding growth rate and mature size.

c. At the first weigh period seven days after being placed on pasture, the cows received vaccinations appropriate for the control of common reproductive and clostridial diseases. The calves were castrated and dehorned as needed and received vaccination for the control of respiratory diseases, clostridial diseases, and pinkeye. In addition each cow and calf received an ear tag for the control of external parasites. Control of internal parasites was not deemed necessary at the beginning of the grazing season.

d. After the initial weigh period, the cows and calves were weighed again the first week of August marking the approximate end of the first half of the grazing season. During this weigh period cows also received a BCS, cows and calves received booster vaccinations as needed, cows and calves received a new ear tag for the control of external parasites, cows and calves received a broad spectrum anthelmintic for the control of internal parasites, and the milk production of the cows was estimated. Cows and calves were brought to the working facility between 0500 and 0600. As the cows and calves were being weighed the calves were being separated from their dams and placed in four pens, six calves to a pen. Calves received no food or water while in these pens, but had access to shade. The cows were allowed to graze a small pasture adjacent to the working facility. At 1800 calves were weighed and immediately placed with their dam and allowed to suckle. Once suckling ceased calves were immediately weighed to determine 12-hour milk production. The doubling of the 12-hour milk production estimate was considered the daily milk production of the cows. This same procedure was used at the end of the grazing season, usually the second or third week of October. The last calf BW (October) was considered the actual weaning weight. Actual weaning weights were then adjusted to 205-day weights. Heifer calf weaning weights were increased by 5% so calf weaning weights were compared on a steer equivalent basis.
**Results and Discussion**

A. Table 3 shows the effect of the winter diets, either GH or AWS/AH on the BW change of the cows.

Table 3. Body weight change of dry, pregnant beef cows as affected by a winter diet of either grass hay or ammoniated wheat straw supplemented with alfalfa hay.

<table>
<thead>
<tr>
<th>Period</th>
<th>Winter Diet</th>
<th>SEM$^c$</th>
<th>P&gt;F$^d$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GH$^a$</td>
<td>AWS/AH$^b$</td>
<td></td>
</tr>
<tr>
<td>Initial BW,$^e$, lbs.</td>
<td>1212.4</td>
<td>1212.9</td>
<td>31.20</td>
</tr>
<tr>
<td></td>
<td>-----</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BW change, lbs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late gestation$^f$</td>
<td>77.4</td>
<td>81.0</td>
<td>1.63</td>
</tr>
<tr>
<td>Entire winter$^g$</td>
<td>-10.8</td>
<td>-8.4</td>
<td>2.20</td>
</tr>
<tr>
<td>Summer grazing I$^h$</td>
<td>4.2</td>
<td>4.6</td>
<td>2.64</td>
</tr>
<tr>
<td>Summer grazing II$^i$</td>
<td>1.8$^{m}$</td>
<td>10.3$^{l}$</td>
<td>2.86</td>
</tr>
<tr>
<td>Entire summer grazing$^j$</td>
<td>5.9$^{m}$</td>
<td>15.2$^{l}$</td>
<td>3.52</td>
</tr>
<tr>
<td>Entire year$^k$</td>
<td>-.9</td>
<td>.7</td>
<td>8.36</td>
</tr>
</tbody>
</table>

$^a$Mixed grass hay  
$^b$Ammoniated wheat straw supplemented with alfalfa hay  
$^c$Standard error of mean  
$^d$Probability greater than F score  
$^e$Body weight  
$^f$December through February  
$^g$December through April  
$^h$May through July  
$^i$August through October  
$^j$May through October  
$^k$November to next November  
$^{lm}$Means in the same row with different superscripts differ (p<.10)

Changes in cow BCS during the yearly production cycle due to the type of winter diet are presented in Table 4.
Table 4. Body condition score changes of beef cows as affected by a winter diet of either grass hay or ammoniated wheat straw supplemented with alfalfa hay.

<table>
<thead>
<tr>
<th>Period</th>
<th>Winter Diet</th>
<th>Winter Diet</th>
<th>SEM^c</th>
<th>P&gt;F^d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GH^a</td>
<td>AWS/AH^b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial BCS^c</td>
<td>5.17</td>
<td>5.42</td>
<td>.09</td>
<td>.06</td>
</tr>
<tr>
<td>BCS Change</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late gestation^f</td>
<td>-.10</td>
<td>-.11</td>
<td>.03</td>
<td>.90</td>
</tr>
<tr>
<td>Entire winter^g</td>
<td>-.17</td>
<td>-.12</td>
<td>.04</td>
<td>.46</td>
</tr>
<tr>
<td>Summer grazing I^h</td>
<td>-.02</td>
<td>.02</td>
<td>.03</td>
<td>.32</td>
</tr>
<tr>
<td>Summer grazing II^i</td>
<td>.09</td>
<td>.08</td>
<td>.05</td>
<td>.81</td>
</tr>
<tr>
<td>Entire summer grazing^j</td>
<td>.09</td>
<td>.08</td>
<td>.05</td>
<td>.83</td>
</tr>
<tr>
<td>Entire year^k</td>
<td>-.04</td>
<td>-.05</td>
<td>.09</td>
<td>.93</td>
</tr>
</tbody>
</table>

a Mixed grass hay  
b Ammoniated wheat straw supplemented with alfalfa hay  
c Standard error of mean  
d Probability greater than F score  
e Scoring system of 1 through 9: 1 = emaciated, 5 = average and functional goal, 9 = extremely obese.  
f December through February  
g December through April  
h May through July  
i August through October  
j May through October  
k November to next November

It is recommended that beef cows should gain 80 to 100 lbs. during the last trimester of gestation and also maintain a BCS of at least 5, which indicates that the diet is supplying adequate nutrition for fetal development without drawing from body reserves (BCS). Both diets supplied adequate nutrition for fetal development and cows calved with a BCS of at least 5 (5.07 for the GH diet and 5.31 for the AWS/AH diet, Table 4). Regardless of winter diet cows maintained functionally adequate BCS throughout the yearly production cycle (Table 4). The only difference in BW or BCS change that could be attributed to winter diet was associated with the summer grazing period. Cows wintered on the AWS/AH diet gained 9.3 lbs. more BW than those wintered on the GH diet (Table 3). Most of this BW gain happened during the last half of the grazing season. This small amount of BW could not be translated into a change in BCS. Although this gain in BW is small in magnitude, it is interesting that cows wintered on the AWS/AH diet consistently exhibited this characteristic over the five years of the study. It is difficult to ascertain why cows wintered on AWS/AH gained more BW during the second half of the summer grazing season compared to those wintered on GH. Pasture forages were definitely of lower quality during the second half of grazing season, especially on portions of the pasture that could not be irrigated. Perhaps cows wintered on the AWS/AH diet were better prepared to utilize these lower-quality pasture forages than those wintered on the medium-quality GH diet. Based on BW and BCS data both diets were supplying comparable amounts of nutrition.

B. Estimates of diet DM intake (DMI), DM digestibility (DMD), and digestible DM intake (DDMI) of the cow wintered on either the GH or AWS/AH diets are summarized in Table 5.
Table 5. Dry matter intake, dry matter digestibility, and digestible dry matter intake exhibited by beef cows being wintered on either a medium-quality grass hay diet or a diet composed of ammoniated wheat straw supplemented with alfalfa hay.

<table>
<thead>
<tr>
<th>Period</th>
<th>Winter Diet</th>
<th>SEMc</th>
<th>P&gt;Fd</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GHa</td>
<td>AWS/AHb</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>DMI, lbs./day</td>
<td>23.54</td>
<td>24.64</td>
</tr>
<tr>
<td></td>
<td>DMD, %</td>
<td>50.30</td>
<td>49.30</td>
</tr>
<tr>
<td></td>
<td>DDMI, lbs./day</td>
<td>11.84</td>
<td>12.15</td>
</tr>
<tr>
<td>January</td>
<td>DMI, lbs./day</td>
<td>25.74</td>
<td>26.84</td>
</tr>
<tr>
<td></td>
<td>DMD, %</td>
<td>50.70</td>
<td>50.30</td>
</tr>
<tr>
<td></td>
<td>DDMI, lbs./day</td>
<td>13.05</td>
<td>13.50</td>
</tr>
<tr>
<td>February</td>
<td>DMI, lbs./day</td>
<td>28.82</td>
<td>30.80</td>
</tr>
<tr>
<td></td>
<td>DMD, %</td>
<td>50.90</td>
<td>51.20</td>
</tr>
<tr>
<td></td>
<td>DDMI, lbs./day</td>
<td>14.67</td>
<td>15.77</td>
</tr>
<tr>
<td>March</td>
<td>DMI, lbs./day</td>
<td>28.16</td>
<td>30.58</td>
</tr>
<tr>
<td>April</td>
<td>DMT, lbs./day</td>
<td>28.60</td>
<td>29.70</td>
</tr>
</tbody>
</table>

a Mixed grass hay  
b Ammoniated wheat straw supplemented with alfalfa hay  
c Standard error of mean  
d Probability greater than F score  
e Dry matter intake  
f Dry matter digestibility, apparent  
g Digestible dry matter intake (dry matter intake x dry matter digestibility), an estimate of energy intake  
h Means in the same row with different superscripts differ (P<.10)

Table 6 summarizes our estimate of the energy (DDMI) requirements of the cows through the wintering period. At least 80% of cow diet cost is associated with supplying adequate energy.

Table 6. A summary of estimated digestible dry matter intake (energy) requirements of beef cows through the wintering period.

<table>
<thead>
<tr>
<th>Item</th>
<th>Digestible dry matter intake required, lbs./day</th>
<th>December</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance</td>
<td>8.10</td>
<td>8.10</td>
<td>8.10</td>
<td>9.90</td>
<td>9.90</td>
<td></td>
</tr>
<tr>
<td>Weather</td>
<td>1.80</td>
<td>1.80</td>
<td>2.03</td>
<td>1.58</td>
<td>0.68</td>
<td></td>
</tr>
<tr>
<td>Fetal development</td>
<td>1.87</td>
<td>3.10</td>
<td>4.83</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Lactation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4.32</td>
<td>5.13</td>
<td></td>
</tr>
<tr>
<td>Physical activity</td>
<td>0.23</td>
<td>0.23</td>
<td>0.23</td>
<td>0.23</td>
<td>0.23</td>
<td></td>
</tr>
<tr>
<td>Tissue again</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12.00</td>
<td>13.23</td>
<td>15.19</td>
<td>16.03</td>
<td>15.94</td>
<td></td>
</tr>
</tbody>
</table>

During the month of December, when most of the cows were beginning the last trimester of gestation, the DDMI requirement was about 12.00 lbs./day (Table 6). Both the GH and AWS/AH were supplying that amount of energy (Table 5). Cows fed the AWS/AH diet consumed 1.1 lbs./day more DM than those consuming the GH diet. However, cows fed the GH diet digested one percentage point more DM than those fed the AWS/AH diet. Consequently DDMI or energy intake was not different (P=.44).
During the month of January we estimated the DDMI requirement of the cows to be 13.23 lbs./day (Table 6). Cows consuming either diet were receiving similar and adequate amounts of energy (DDMI) during January (Table 5). During February, the last month before calving began, the energy requirement jumped to 15.19 lbs. of DDMI/day due to more inclement weather and a more rapidly growing fetus (Table 6). Although cows consuming the AWS/AH were consuming about 1.0 lb. more DM/day than those consuming GH, DDMI (energy) was not statistically different. Both groups of cows were receiving adequate energy from either diet during the late gestational period (Table 5).

The cows began calving and lactating in March. **Note from Table 6 that the maintenance energy requirement of cows increased by about 20% once they start lactating.** The physiology of the cow changes during lactation and maintenance energy is actually used less efficiently than during gestation. Also notice that fetal development during February requires just about as much energy as does milk production during March and April. These are important factors to consider when contemplating changing the time of year that you are going to calve your cows. Due to the fact that cows were calving during March and April and changing from gestating to lactating cows, it was not possible to accurately measure DMD. However, DMI during March and April was similar to that of February (Table 5). Since cows on either diet lost very little BW (Table 3) or BCS (Table 4) during the entire wintering period, it must be assumed the cows on either diet were extracting about 16.0 lbs. of DDMI from the diets.

<table>
<thead>
<tr>
<th>Cows consuming either the GH or AWS/AH diet were receiving similar and adequate amounts of energy during the wintering period from December through April. As a result both groups of cows were able to deliver a healthy calf and also maintain adequate BW and BCS.</th>
</tr>
</thead>
</table>

C. Since cows fed either the GH or AWS/AH diets during the wintering period performed adequately and similarly, one would not expect major differences regarding milk production, calving characteristics, or cow reproductive performance.
Table 7. The effects of wintering beef cows with diets composed of either grass hay or ammoniated wheat straw supplemented with alfalfa hay on cow milk production, calving characteristics, calf performance, and cow reproductive efficiency.

<table>
<thead>
<tr>
<th>Item</th>
<th>Winter Diet</th>
<th>SEM&lt;sup&gt;c&lt;/sup&gt;</th>
<th>P&gt;F&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow milk production&lt;sup&gt;2&lt;/sup&gt;, lbs./day</td>
<td>GH&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>12.85</td>
<td>.24</td>
<td>.92</td>
</tr>
<tr>
<td>August</td>
<td>11.44</td>
<td>.26</td>
<td>.82</td>
</tr>
<tr>
<td>October</td>
<td>8.01</td>
<td>.24</td>
<td>.71</td>
</tr>
<tr>
<td>Calving characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth weight, lb.</td>
<td>86.90</td>
<td>.75</td>
<td>.62</td>
</tr>
<tr>
<td>Calving ease&lt;sup&gt;i&lt;/sup&gt;, %</td>
<td>76.70</td>
<td>.13</td>
<td>.30</td>
</tr>
<tr>
<td>Daytime calving&lt;sup&gt;g&lt;/sup&gt;, %</td>
<td>83.30&lt;sup&gt;l&lt;/sup&gt;</td>
<td>.05</td>
<td>.0002</td>
</tr>
<tr>
<td>Calf weaning weight&lt;sup&gt;k&lt;/sup&gt;, lbs.</td>
<td>498.96</td>
<td>5.57</td>
<td>.64</td>
</tr>
<tr>
<td>Cow reproduction efficiency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postpartum interval&lt;sup&gt;l&lt;/sup&gt;, days</td>
<td>86.5</td>
<td>1.80</td>
<td>.61</td>
</tr>
<tr>
<td>Pregnancy rate&lt;sup&gt;i&lt;/sup&gt;, %</td>
<td>95.0</td>
<td>1.32</td>
<td>.33</td>
</tr>
<tr>
<td>Keep rate&lt;sup&gt;i&lt;/sup&gt;, %</td>
<td>91.7</td>
<td>1.93</td>
<td>.71</td>
</tr>
</tbody>
</table>

<sup>a</sup>Mixed grass hay  
<sup>b</sup>Ammoniated wheat straw supplemented with alfalfa hay  
<sup>c</sup>Standard error of mean  
<sup>d</sup>Probability greater than F score  
<sup>e</sup>Determined by calf weight-suckle-weigh method  
<sup>f</sup>Percent of cows not requiring any assistance to calve  
<sup>g</sup>Percent of cows calving during daylight hours  
<sup>h</sup>Calf weaning weights reported on a 205-day and steer equivalent basis  
<sup>i</sup>Days after calving required for cows to rebreed. Determined by consecutive calving dates.  
<sup>j</sup>Percent of cows conceiving during a 60-day breeding season  
<sup>k</sup>Percent of cows not culled during the five-year study  
<sup>l</sup>Means in the same row with different superscripts differ (P>.10)

1. Cows assigned to this study were of average milking ability for beef cows (Table 7). The type of winter diet had no effect on cow milk production (P=.92). Cows exhibited a typical lactation curve for beef cows with a 38% reduction in milk production from May to November.

2. The type of winter diet had no effect on the birth weight of the calves, the ease with which calves were born, or the weaning weight of the calves (Table 7), which is to be expected if cows are receiving similar nutrition during the yearly production cycle.

3. However, the type of winter diet did have a major impact on the time of day in which calving took place. Over 80% of the cows wintered on the AWS/AH diet calved during daylight hours (Table 7). Only about half of the cows wintered on GH calved during daylight hours. It has long been known that evening or night feeding of beef cows results in an increase in the proportion of cows calving during daylight hours when assistance is more readily available. The cows on this study were fed in the late afternoon and type of diet was a factor affecting daylight calving. The bulkiness of the AWS may have increased abdominal pressure, which in turn may have caused the fetus to initiate parturition that was conductive to daylight calving.
4. It is commonly known that beef cows must rebreed within 80 days of calving if they are going to produce a live calf each 365 days because the length of gestation is about 285 days. The winter diet can have a major impact on this production characteristic because if beef cows do not have a BCS of 5 to 6 at the time of calving and breeding, the postpartum interval to rebreeding will be extended. Cows receiving the GH or AWS/AH during the winter exhibited similar post-partum intervals to rebreeding (Table 7). The intervals were slightly longer than 80 days, which was likely due to the fact that some of the cows on this five-year study were 11 years old at the conclusion of the study. So extended postpartum intervals to rebreeding were likely a function of age. Since reproductive failure, either a failure to conceive or a failure to conceive within 80 days of calving, is the primary reason for culling beef cows, the type of winter diet also had no effect on keep/cull rates.

D. It is apparent from the cow production data presented above that cows wintered long-term on a diet based on AWS supplemented with AH will perform similarly and adequately compared to cows wintered on a more traditional grass hay diet. The major question remaining is in regard to if there is an economic advantage to wintering cows on diets based on AWS with some type of protein supplement such as AH. A simplified expression of the major factors controlling profitability on cow-calf operations is as follows:

\[
\text{Breakeven Price Needed for Saleable Calves} = \frac{\text{Annual Cow Cost}}{(\text{Weaning Weight of Calves, lbs.} \times \text{Weaning Percentage of Cows})}
\]

Another way of expressing the breakeven price needed for calves is sometimes called the Ranch Value of Calves: Weaning Weight or Sale Weight of Calves, lbs. × The Breakeven Price, $/lb.

The Profit/Loss of a cow-calf operation is then calculated as the difference between the Ranch Value of the Calves and the Market Value.

Example:

1. **Annual Cow Cost** (an individual cow’s share of all production costs), i.e., feed, cow depreciation, breeding, labor, taxes, etc.

   \[\$350/\text{cow/year}\]

2. **Weaning Weight of Calves**, Sale Weight would be a better term.

   \[550 \text{ lbs.}\]

3. **Cow Weaning Percentage**, the percent of the cows placed with bulls or subjected to a breeding program that actually Wean a Calf.

   \[88\%\]

4. **Calculation of Breakeven Price** needed per pound of calf.

   \[\$350 \div (550 \text{ lbs.} \times .88) = \$0.7231/\text{lb. of calf}\]
5. **Ranch Value of Calf**, $ required per calf to breakeven.

\[
550 \text{ lbs.} \times \$0.7231/\text{lb.} = \$397.73/\text{calf}
\]

So the cow-calf operator would have to receive $397.73/calf to just breakeven.

6. **Market Value of Calf**, $ per calf received from the marketing system. ($0.9742/lb. for example)

\[
550 \text{ lbs.} \times 0.9742/\text{lb} = \$535.81/\text{calf}
\]

7. **Profit/Loss per Calf**, simply the difference between the Market Value of the calves and the Ranch Value of the calves.

\[
\$535.81 - \$397.73 = \$138.08/\text{calf}
\]

So with the scenario used in this example calculation the return to management for this cow-calf operation was $138.08/calf.

With this brief explanation of beef cow-calf economics, Table 8 was constructed using data from this study To estimate Profit/Loss associated with the use of either GH or AWS/AH to winter beef cows.
Table 8. Economic analysis of profit/loss associated with cow-calf operation in which cows are wintered on either a grass hay diet or a diet based on ammoniated wheat straw supplemented with alfalfa hay.

<table>
<thead>
<tr>
<th>Item</th>
<th>Winter Diet System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GH&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total winter DMI&lt;sup&gt;d&lt;/sup&gt;, lbs./cow/year</td>
<td>4061</td>
</tr>
<tr>
<td>Winter feed costs&lt;sup&gt;e&lt;/sup&gt;, $/cow/year</td>
<td>135.46</td>
</tr>
<tr>
<td>Yearly grazing costs&lt;sup&gt;f&lt;/sup&gt;, $/cow/year</td>
<td>71.02</td>
</tr>
<tr>
<td>Yearly non-feed costs&lt;sup&gt;f&lt;/sup&gt;, $/cow/year</td>
<td>92.81</td>
</tr>
<tr>
<td>Weaning percentage&lt;sup&gt;g&lt;/sup&gt;, %</td>
<td>85.0</td>
</tr>
<tr>
<td>Calf weaning/sale weight&lt;sup&gt;h&lt;/sup&gt;, lbs.</td>
<td>499.4</td>
</tr>
<tr>
<td>Breakeven price needed for calves&lt;sup&gt;i&lt;/sup&gt;, $/lb.</td>
<td>.7091</td>
</tr>
<tr>
<td>Ranch value of saleable calves&lt;sup&gt;j&lt;/sup&gt;, $/calf</td>
<td>354.12</td>
</tr>
<tr>
<td>Market value of saleable calves&lt;sup&gt;j&lt;/sup&gt;, $/calf</td>
<td>426.76</td>
</tr>
<tr>
<td>Profit/Loss&lt;sup&gt;k&lt;/sup&gt;, $/cow/year</td>
<td>72.64</td>
</tr>
</tbody>
</table>

<sup>a</sup>Mixed grass hay, $58.93/ton or $0.0295/lb.
<sup>b</sup>Ammoniated wheat straw, $41.25/ton or $0.0206/lb.
<sup>c</sup>Alfalfa hay, 78.57/ton or $0.0393/lb.
<sup>d</sup>Dry matter intake December through April.
<sup>e</sup>(Forage consumed x $ value of forage) + vitamin-mineral supplement.
<sup>g</sup>2007 Utah Agricultural Statistics and Utah Department of Agriculture and Food Annual Report, Enterprise Cow Budget: Cow-Calf, page 116.
<sup>h</sup>Percent of cows exposed to bulls or breeding that wereaned a calf, Utah Average. During the project only two cows had to be culled for reproductive purposes, one on each diet. So we used the Utah average.
<sup>i</sup>Based on steer equivalent 205-day weight of calves on the project.
<sup>j</sup>(Annual Cow Cost, winter feed cost + grazing costs + non-feed cost) ÷ (Weaning Weight of Calves, lbs. x Weaning Percentage of Cows).
<sup>k</sup>Calf weaning/sale weight x breakeven value, $/lb.
<sup;l</sup>Calf weaning/sale weight x 10-year average market value, $/lb. Based on 10-year average market value of weaned calves (500 lbs.) 1995 through 2005, Utah Department of Agricultural and Food Market News, $.8545/lb.
<sup>m</sup>Market value of calves – Ranch value of calves.

Conclusions

1. Beef cows can successfully be wintered on diets based on ammoniated low-quality forages such as wheat straw if there is a proper amount of protein and vitamin-mineral supplementation for at least five consecutive years without any negative impacts on cow or calf productivity compared to a traditional medium-quality grass hay diet.

2. There is some evidence that indicates that cows wintered on low-quality forages will make superior use of low-quality forages available to them when they are grazing pastures or rangelands.

3. The afternoon feeding of LQF like the AWS/AH diet resulted in a much higher proportion of cows calving during daylight hours compared to a traditional medium-quality grass hay (83% versus 53%). Daylight calving increases the chance that cows will receive timely assistance when required.

4. The long-term use of ammoniated low-quality forages to winter beef cows will likely result in an improvement in profitability compared to wintering on traditional medium-quality grass hay. This
study reported a **17.5% increase in profitability** ($85.50/cow/year versus $72.64/cow/year) of a cow-calf operation mainly due to a reduction in the cost of winter feeding ($122.86/cow/winter versus $135.40/cow/winter).

**PART II. Practical Comments on the Processes Used to Properly Ammoniate Low-Quality Forage**

1. Straw was baled as soon after harvest as possible and as early in the morning as possible to incorporate as much dew as possible. The ammoniation process is enhanced when the straw is 12 to 15% moisture. Bales were medium-sized square bales, approximately 3’ x 3’ x 7’ long.

2. As soon as possible after baling the bales were placed in stacks three bales wide x four bales high x nine bales long. Thus the stacks were about 9’ wide x 12’ high x 63’ long, which is easily covered by a 40’ x 100’ sheet of black 6 mil polyethylene with a 3’ to 4’ lap on the ground all the way around the base of the stack. It is important that black polyethylene is used because the reaction is heat dependant and the black material will increase the temperature of the stack. As the stacks were being constructed a 1” (inside diameter) x 20’ long steel pipe was laid on top of the bottom layer of bales in the middle of the stack. Through this pipe anhydrous ammonia was infused into the stack.

3. Road base gravel was placed on top of the polyethylene lapped on the ground at the base of the stack about 8” to 12” deep. This was accomplished using a skid-steer loader. Care was taken during this process to insure that the polyethylene sheet was not tight over the stack. There should be enough slack in the polyethylene to allow expansion of the anhydrous ammonia as it is infused. Other materials can also be used to seal and anchor the polyethylene over the stack. It is suggested that the material should be dense and heavy. Some producers have used bags of crushed limestone or sandbags. Others have successfully used the wet mature and bedding mounds from their feedlots. Even heavy, wet bales of forage have been successfully used for this purpose.

4. Anhydrous ammonia was slowly infused into the stack through the 1” pipe. The amount infused is extremely important. Anhydrous ammonia is very expensive, so infusing too much is wasteful. If too little is infused the treatment will not be affective. Most scientific literature suggests that anhydrous ammonia is infused into a stack of LQF at a rate of **3.5% of the dry matter (DM)**. The stacks treated for this study contained 108 medium-sized square bales that weighed about 600 lbs. each. So on an as-fed basis the stacks contained about (108 x 600) 69800 lbs. of wheat straw. The bales we treated were about 12% moisture or 88% DM. Thus the stacks contained approximately (69800 x .88) **57024 lbs. of DM**. At 3.5% of the DM (57024 x .035), **1996 lbs. of anhydrous ammonia** was infused into each stack. We have found it best to infuse the anhydrous ammonia slowly by just cracking the valve. We normally infused the anhydrous ammonia over a 24-hour period. Infusing the anhydrous ammonia too quickly can cause excessive ammonia leakage and may result in failure of the polyethylene sheet. It is best to seek the advice of trained personnel from whom you are purchasing the anhydrous ammonia regarding safety procedures and proper operation of their delivery equipment. **Anhydrous Ammonia is dangerous.**

5. As the anhydrous ammonia is being infused into the stacks make sure you check for leaks. These are easily detected because of the strong ammonia smell. If the polyethylene sheet has been punctured, the holes should be taped immediately. A non-porous tape should be used. Our old standby duct tape is fair porous and we haven’t had much success using it. Farm supply stores that sell plastic silo
press bags and associated equipment usually sell a special tape for repairing silo press bags. This tape is excellent for repairs on stacks being ammoniated. This tape is usually 3” to 4” in width and we have successfully taped smaller polyethylene sheets together when we could not purchase large enough sheets. If ammonia is coming up from under the polyethylene sheet, a few shovels full of road base gravel over the leakage area is usually sufficient.

6. As the anhydrous ammonia diffuses through the stack it mixes with the water in the forage forming ammonium hydroxide, which increases the alkalinity (increased pH) of the forage. This increase in alkalinity causes changes in the chemical bonding in the forage that improves the ability of the microorganisms in the rumen of cattle to ferment the fibrous material. Thus the energy is substantially increased. The digestibility of wheat straw fed to cattle without a protein supplement is about 40% of the DM and the intake of a 1200 lb. mature beef cow would be about 12 lbs. of DM/day (12 ÷ .90 = 13.3 lbs. As-Fed). So a 1200 lb. beef cow would be able to consume only (12.0 x .40) 4.8 lbs. of digestible DM or energy per day. Although the energy requirement of beef cows varies greatly through a yearly production cycle, we often use 13.0 lbs. of digestible DM per day as an average energy requirement. If the wheat straw was properly ammoniated the DM digestibility would be increased to about 46% and the DM intake of a 1200 lb. beef cow would likely be increased to 17.5 lbs. without a protein supplement. Thus the digestible DM intake would be increased from 4.8 lbs./day to (17.5 x .46) 8.05 lbs./day. Although the energy intake was doubled via the ammoniation process, the energy requirement of the cows is still not being met, so supplementation is required. Ammoniated wheat straw is not a stand-alone feed source.

7. The ammoniation reaction is heat dependant. So we don’t recommend ammoniating LQF much past September in Utah and Southern Idaho. The black polyethylene sheet absorbs heat and aids in this process. We normally treated the wheat straw used in this study in August when the average daily temperature was 70-75°F (high 90°F low 60°F) ÷ 2. Under these conditions the ammoniation reaction usually requires only about 7 to 8 days since the temperature under the black polyethylene often reach over 160°F. After the reaction has been completed it is not reversible, so if the ammonia is lost from the stack after that time the LQF will remain treated. Once the average daily temperature drops to 40 to 45°F the ammoniation reaction will likely require 14 to 21 days to complete. As the average daily temperature drops to 30 to 35°F we feel that the ammoniation reaction cannot be completed.

8. Another advantage of the ammoniation process is that the crude protein (CP) of the LQF is increased, in most cases doubled. The CP of the wheat straw used in this study was about 4% of DM before ammoniation. After ammoniation the CP content of the ammoniated wheat straw (AWS) was about 8% of DM. However, it must be remembered that this increase in CP is totally attributed to non-protein nitrogen. We usually estimate that about 50% of the CP increase associated with the ammoniation process can be affectively used to meet the protein requirement of the cow. So although the CP content of the AWS was 8% of DM, we considered the affective CP content to be 6% of DM (4 + (4 x .50) = 6). If a supplement high in starches or simple sugars such as cereal grains or molasses is used with AWS, the CP added by the ammoniation process is probably used at about 75% efficiency. So the affective CP content would be 7% of DM (4 + (4 x .75) = 7).

9. We opened the stacks of AWS about three to four weeks before we contemplated feeding it to cows. This allows the excess ammonia to escape from the stack. Unfortunately only about 517 lbs. of the 1996 lbs. of anhydrous ammonia added to the stacks was fixed in the forage. About 1479 lbs. or approximately 74% was lost after the stacks were opened. For this reason it is best to avoid
ammoniating LQF close to areas of dense human population, especially hospitals, schools, rest homes, etc.

We started feeding the AWS the first week in December each year, so we opened the first stack to be fed the first week of November. One front face was opened by cutting and removing the polyethylene. **Be careful when cutting open the plastic sheet as ammonia fumes can be overpowering.** Never open the stacks when you are alone. By removing just one face and leaving the plastic on the top and three sides of the stack, the excess ammonia can dissipate while the stack remains protected from rain and snow. We gradually removed the polyethylene sheet as was needed when we removed the bales for feeding.

10. When a stack of ammoniated LQF is opened it can be quite a shock to see that the bright yellow forage has turned brown. Normally when we see feeds that have turned brown we think of heat damage. However, the browning associated with the ammoniation process is beneficial. The browner the color of the ammoniated LQF, the higher the digestibility and CP content.

11. Another beneficial factor associated with the ammoniation of LQF is that ammonia will neutralize many of the toxins associated with molds that can grow and proliferate in forages that have been stored at too high of a moisture content. Aflotoxin is a good example of a mold toxin associated with animal feeds that is neutralized by ammoniation. Whole cottonseeds that contain aflotoxin are often ammoniated to detoxify them.

12. Another very important item to remember when contemplating the ammoniation of forage is that the process is used to increase the digestibility and intake of **Low-Quality Forages, not medium or high-quality forages**. A producer may have some medium-quality grass hay, 9% CP and 50% DM digestibility. Would the ammoniation process increase the digestibility to 60% and the CP to 18%? The answer is maybe, but in some cases the ammoniation of medium or high-quality forages can result in **production of a toxic compound in the forages** that affects the central nervous system of cattle. As a result, the cows become hyperexcitable and run through fences, etc. The condition is called “Bonker Cow” in the Midwest. The condition results from the formation of a toxic compound when the **ammonia reacts with simple sugars in the forage**. Low-quality forages are nearly devoid of simple sugars so “Bonker Cow” is not a problem. The following review of the proximate analysis will help illustrate:

<table>
<thead>
<tr>
<th>Nutrient, % of DM</th>
<th>Wheat Straw</th>
<th>Medium-Quality Grass Hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>4.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Neutral detergent fiber</td>
<td>80.0</td>
<td>65.0</td>
</tr>
<tr>
<td>Crude fat</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Ash (mineral)</td>
<td>6.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Sub total</td>
<td>92.0</td>
<td>80.0</td>
</tr>
<tr>
<td>Soluble carbohydrate</td>
<td>8.0</td>
<td>20.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Note that the wheat straw is estimated to contain only 8.0% soluble carbohydrate, a very small portion of which is starches and simple sugars. The medium-quality grass hay is 20% soluble carbohydrate, a larger portion of which is simple sugars and starches. If this grass hay was ammoniated there would likely be problems. The cattle may not show central nervous system symptoms, but performance would be negatively affected. Several years ago, one of my graduate students conducted a study using
what he thought was low-quality grass hay. The hay was ammoniated and then used in the nutritional management of replacement beef heifers. To his surprise heifers fed the diets containing ammoniated grass hay exhibited performance inferior to that of heifers fed the same diets in which the grass hay was not ammoniated. The hay used in this study was of too high of quality for ammoniation. With cereal grain straws and stalks remaining after cereal grain harvest, ammoniation can proceed without concern regarding the formation of this toxic compound. However, with grass hays it is extremely important that a representative sample be taken and subjected to a proximate analysis. **If the Neutral Detergent Soluble Carbohydrate content is greater than 15% of DM, it would be best to avoid ammoniation.**

13. We are often asked if **low-quality legume hays** such as alfalfa or clover hay can be ammoniated to improve fiber digestibility. Apparently the chemical bonding associated with the fibrous carbohydrates of the cell wall of legume forages is different from that of cereal straws and stalks, and grass hays. Due to these differences in chemical bonding, the ammoniation of low-quality legume hays is **not effective.**

14. We are also often asked if it matters what size and/or shape of bales that are ammoniated. The answer to that question is **No. Any size or shape of bale can be effectively ammoniated.** There is some evidence that round bales are somewhat more affectively ammoniated than square.

15. If cattle have never consumed low-quality forages before it may require time before consumption will reach acceptable levels. Some cattle may never adapt to low-quality forages. We have noted a large amount of variation in the ability of cattle to adapt to low-quality forages. We have reported several factors that may affect this adaptability:

a. A properly formulated supplement used with the LQF or the ammoniated LQF will decrease the time needed for cattle to adapt and will also increase the number of cattle that will adapt.

b. The timing of supplementation can affect the rate at which cattle will adapt to LQF. When we supplemented cattle starting to consume LQF twice/day (7 a.m. and 7 p.m.) we noticed that it required more time for the consumption of LQF to increase compared to when they were supplemented only once/day. When supplemented twice/day some cows would wait for supplement rather than consume LQF.

c. We conducted a study several years ago in which we were wintering beef cows on ammoniated wheat straw supplemented with small amounts of alfalfa hay. All of the cows received the same amount of alfalfa hay each week, but how it was prorated varied. One group was supplemented daily. Another group was supplemented on Monday, Wednesday, and Friday each week. The last group received their entire weekly allotment on Friday only. **Superior performance was exhibited by cows on the Monday, Wednesday, Friday regimen.** With the daily supplemented group such a small amount of alfalfa hay was offered that timid cows received very little. Cows on the Friday only regimen received so much alfalfa hay that they wouldn’t start consuming ammoniated straw
again until Sunday morning. The intake of ammoniated wheat straw was much lower in the cows on the daily and Friday only regimens, which accounted for the poorer performance of the cows. Several studies have reported that supplementing cows fed LQF diets two or three times per week resulted in satisfactory cow performance with reduced labor costs.

d. Early calfhood exposure to LQF while the calves’ mothers are consuming LQF greatly enhances the adaptability of cattle to LQF. Apparently the mothers “taught” the calves that straw was feed and not bedding. This early imprinting can last for the entire life time of the cattle.

e. Recently we conducted an experiment that strongly indicated that if cows are fed LQF during the gestation period their resultant calves will exhibit improved utilization of LQF. Unfortunately we were not able to complete the study. This is a new area of nutritional research called fetal programming. It is likely that there will be more information on this subject in the future.

f. We have also noticed that having even a few cows that are well-adapted to LQF with cows that have not had previous experience with LQF will help “teach” the naïve cows to adapt to LQF.

g. The body condition score (BCS) or the degree of fatness of the cows will also affect the utilization of LQF. We have reported that beef cows with low BCS (2-3), which are very thin do not utilize LQF nearly as well as when they are average to high in BCS (5-7). So managing cow BCS is very important when beef cows are going to be wintered on LQF. During drought years when forage supplies become limiting and cows will likely be wintered on LQF, it may be best to early wean their calves so the cows will be better able to maintain or increase their BCS before the wintering period.
PART III. Balancing Beef Cow Diets Using Ammoniated Low-Quality Forages and Economic Consideration

In this section examples of proper supplementation of AWS diets along with diet balancing techniques and economic considerations are covered.

1. Economic considerations are also extremely important when contemplating the use of LQF or ammoniated LQF in the nutritional management of beef cattle. Consider the following examples:

   a. Due to a fire a rancher must purchase some off-ranch feeds to winter the cow herd.

   b. Medium-quality grass hay (9% CP, 50% digestible), can be delivered to the ranch for $95/ton or $.0475/lb.

   c. Medium-quality alfalfa hay (17% CP, 57% digestible) can be delivered to the ranch for $120/ton or $.06/lb.

   d. Wheat straw can be delivered to the ranch for $35/ton or $.0175/lb.

   e. Anhydrous ammonia can be delivered to the ranch for $725/ton or $.3625/lb. so the cost of ammonia to treat one ton of straw would be (2000 lbs./ton, as-fed x .88% DM x .035% anhydrous ammonia x $.3625/lb. anhydrous ammonia) $22.33/ton.

   f. A 40’ x 100’ sheet of black 6 mil polyethylene that will cover approximately 32.4 tons of straw or other LQF (108 medium-size square bales x 600 lbs./bale ÷ 2000 lbs./ton). The cost of black polyethylene sheets varies greatly. The cost of 40’ x 100’ 6 mil black polyethylene sheets averaged about $250/sheet during this study. So the cost of the polyethylene sheet for the ammoniation process was ($250 ÷ 32.4 ton) $7.72/ton.

   g. The cost of ammoniated wheat straw will be:

<table>
<thead>
<tr>
<th>Item</th>
<th>$/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat straw</td>
<td>$35.00</td>
</tr>
<tr>
<td>Anhydrous ammonia</td>
<td>$22.33</td>
</tr>
<tr>
<td>Black polyethylene</td>
<td>$ 7.72</td>
</tr>
<tr>
<td>Total Cost of Ammoniated Straw</td>
<td>$65.05/ton or $.0325/lb.</td>
</tr>
</tbody>
</table>

   h. What will be the least expensive method of wintering the beef cows?

   i. Estimate of the digestible DM (energy) (DDM) and crude protein (CP) requirements of the cows.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Late Gestation</th>
<th>Early Lactation</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDM lbs./d (energy)</td>
<td>13.47</td>
<td>15.72</td>
</tr>
<tr>
<td>CP, lbs./d</td>
<td>1.90</td>
<td>2.52</td>
</tr>
</tbody>
</table>
j. Cost of wintering cows on medium-quality grass hay (9% CP, 50% DDM).

**Late gestation:**
- 13.47 lbs. DDM (required) ÷ .50 = 26.94 lbs. hay DM
- 26.94 lbs. hay DM x .09 (9% CP) = 2.42 lbs. CP 1.90 lbs. required, OK
- 26.94 lbs. DM ÷ .90 (90% DM) = 29.93 lbs. hay x $.0475/lb. = $1.42/cow/day + vitamin-mineral supplement (VMS)

**Early lactation:**
- 15.72 lbs. DDM (required) ÷ .50 = 31.44 lbs. hay DM
- 31.44 lbs. hay DM x .09 = 2.83 lbs. CP 2.52 lbs. required, OK
- 31.44 lbs. DM ÷ .90 = 34.93 lbs. hay x $.0475/lb. = $1.66/cow/day + VMS

k. Cost of wintering cows on medium-quality alfalfa hay (17% CP, 57% DDM).

**Late gestation:**
- 13.47 lbs. DDM (required) ÷ .57 = 23.63 lbs. hay DM
- 23.63 lbs. hay DM x .17% (17% CP) = 4.02 lbs. CP 1.90 lbs. required, OK
- 23.63 lbs. DM ÷ .90 = 30.64 lbs. hay x $.06/lb. = $1.84/cow/day + VMS

**Early lactation:**
- 15.72 lbs. DDM (required) ÷ .57 = 27.58 lbs. hay DM
- 27.58 lbs. hay DM x .17 = 4.69 lbs. CP 2.52 lbs. required, OK
- 27.58 lbs. DM ÷ .90 = 30.64 lbs. hay x $.06/lb. = $1.84/cow/day + VMS

l. Cost of wintering cows on ammoniated wheat straw (AWS) (6% CP, 52% DM digestibility with a protein supplement) + medium-quality alfalfa hay (AH) (17% CP, 57% DM digestibility) supplement. **Remember, AWS is not a stand-alone feed source. A supplement is required.** The DM intakes and DM digestibilities used in the examples below are based on data from our experiment station. Also remember that as the level of supplemental good-quality protein increases, the digestibility and intake of AWS increases, to a point.

**Late gestation:**
- 22.0 lbs. AWS DM (full feed) x .52 = 11.44 lbs. DDM
- 3.56 lbs. AH DM x .57 = 2.03 lbs. DDM
- Total DDM (energy) intake = 13.47 lbs. DDM 13.47 lbs. required, OK

- 22.0 lbs. AWS DM x .06 = 1.32 lbs. CP
- 3.56 lbs. AH DM x .17 = .61 lbs. CP
- Total CP intake = 1.93 lbs. CP 1.90 lbs. required, OK
Late gestation (continued):

22.0 lbs. AWS DM ÷ .90 (90% DM) = 24.44 lbs. AWS
3.56 lbs. AH DM ÷ .90 = 3.96 lbs. AH

22.0 lbs. AWS x $.0325/lb. = $ .7943/cow/day

3.96 lbs. AH x $.06/lb = $.2376/cow/day

Total cost of diet: $1.03/cow/day + VMS

Early lactation:  (Since more protein is being supplied the intake and digestibility of AWS is increased.)

24.0 lbs. AWS DM (full feed) x .54 (54% digestible) = 12.96 lbs. DDM
4.85 lbs. AH DM x .57 (57% digestible) = 2.76 lbs. DDM

Total DDM (energy) intake = 15.72 lbs. DDM/day 15.72 lbs. required, OK

24.0 lbs. AWS DM x .06 = 1.44 lbs. CP
4.85 lbs. AH DM x .17 = .82 lbs. CP

Total CP = 2.26 lbs. CP/day 2.52 lbs. required, Deficient

Although this diet supplies enough energy (DDM) it is deficient (2.52 – 2.26) .26 lbs. CP/day. Consequently we’ll have to feed more AH:

.26 lbs CP needed ÷ 17 (17% CP) = 1.53 lbs. AH DM/day.

So we’ll have to add 1.53 lbs. of AH DM to the diet to provide adequate CP.

24.0 lbs. AWS DM x .54 = 12.96 lbs. DDM
6.38 lbs. AH DM (4.85 + 1.53) x .57 = 3.64 lbs. DDM

Total DDM (energy) intake = 16.60 lbs. DDM/day

24.0 lbs. AWS DM x .06 = 1.44 lbs. CP
6.38 lbs. AH DM x .17 = 1.08 lbs. CP

Total CP intake = 2.52 lbs. CP/day 2.52 lbs. required, OK

24.0 lbs. AWS DM ÷ .90 = 26.67 lbs AWS
26.67 lbs. AWS x $.0325 lb. = $.8667/cow/day
6.38 lbs. AH DM ÷ .90 = 7.09 lbs. of AH
7.09 lbs. AH x $.06/lb = $.4254/cow/day

Total cost of diet: $1.29/cow/day + VMS

Remember, that although this diet provides just enough CP, it provides excess energy, (16.60 – 15.72) .88 lbs. DDM/day, which means this diet is costing more than necessary. We could use the Simultaneous Equation method to balance this diet for exact amounts of CP and Energy:

Let X = lbs. of AWS needed and Y = lbs. of AH needed.

.54 X + .57 Y = 15.72 lbs. DDM
.06 X + .17 Y = 2.52 lbs. CP

.54 ÷ .06 = 9.0 adjustment factor
Multiply the CP equation above by the adjustment factor:

\[(.06)(9.0) X + (.17)(9.0) Y = (2.52)(9.0) \text{ lbs. CP} \]
\[.54 X + 1.53 Y = 22.68 \text{ lbs. CP} \]

Subtract the adjusted CP equation from the DDM equation:

\[.54 X + .57 Y = 15.72 \text{ lbs. DDM} \]
\[.54 X + 1.53 Y = 22.68 \text{ lbs. CP} \]
\[0 - .96 Y = -6.96 \]
\[Y = 7.25 \text{ lbs. AH DM} \]

Lastly, plug 7.25 in place of Y in either equation and solve for X (lbs. of AWS):

\[.54 X + (.57)(7.25) = 15.72 \]
\[.54 X + 4.13 = 15.72 \]
\[.54 X = 11.59 \]
\[X = 21.46 \text{ lbs. AWS DM} \]

Check:

\[.54 \times 21.46 + .57 \times 7.25 = 11.59 + 4.13 = 15.72 \text{ lbs. DDM, OK} \]
\[.06 \times 21.46 + .17 \times 7.25 = 1.29 + 1.23 = 2.52 \text{ lbs. CP, OK} \]

21.46 lbs. AWS DM ÷ .90 (90% DM) = 23.84 lbs. AWS
23.84 lbs. AWS x $.0325/lb. = \$7749/lb./cow/day
7.25 lbs. AH DM ÷ .90 (90% DM) = 8.06 lbs. AH
8.06 lbs. AH x $.06/lb = \$4836/lb./cow/day

Total cost of diet \$1.26/cow/day + VMS

Notice that this diet is only \$(1.29 - $1.26) \$.03/cow/day less. But over a long winter this can add to a substantial amount.

m. Summary of Diet and Cost Options Associated with Wintering Beef Cows on Purchased Off-Ranch Feeds.

<table>
<thead>
<tr>
<th>Diet</th>
<th>Gestation $/Cow/Day</th>
<th>Lactation $/Cow/Day(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-quality grass hay</td>
<td>1.42</td>
<td>1.66</td>
</tr>
<tr>
<td>Medium-quality alfalfa hay</td>
<td>1.58</td>
<td>1.84</td>
</tr>
<tr>
<td>Ammoniated wheat straw + medium-quality alfalfa hay supplement</td>
<td>1.03</td>
<td>1.26</td>
</tr>
</tbody>
</table>

\(^a\)These costs do not include vitamin-mineral supplementation.
n. Dietary Cost Savings (%) Associated with Using an Ammoniated Wheat Straw + Medium-Quality Alfalfa Hay Diet (AWS/AH) to Winter Beef Cows Compared to Medium-Quality Grass Hay (GH) or Medium-Quality Alfalfa Hay (AH).

<table>
<thead>
<tr>
<th>Diet Comparison</th>
<th>Production Period</th>
<th>Late Gestation % Savings</th>
<th>Early Lactation % Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWS/AH versus GH</td>
<td></td>
<td>27.46b</td>
<td>24.10b</td>
</tr>
<tr>
<td>AWS/AH versus AH</td>
<td></td>
<td>34.81</td>
<td>31.52</td>
</tr>
</tbody>
</table>

Cost of vitamin-mineral supplementation not included in comparison.

Given the conditions outlined in this example the use of an ammoniated wheat straw diet supplemented with small amounts of medium-quality alfalfa hay to winter beef cows resulted in considerable savings, (24 to 34%) compared to the use of medium-quality grass hay or medium-quality alfalfa hay. Costs and circumstances change with each ranch and through time. Notice that these calculated savings are higher than those actually measured in the study in Part I, which were based on 2005 prices. The values used in these examples are more reflective of corn-ethanol era prices.

o. In the example above alfalfa hay was used as the protein/energy supplement for the AWS diet. Many times alfalfa hay is the cheapest source of supplemental protein and/or energy. However, this is not always the case. During different years and in different geographic locations the use of many other feedstuffs could result in considerable savings. We thought it would be good at this point to review the process we use to select protein/energy supplements for low-quality forage diets such as AWS. The three major considerations regarding the selection of a protein supplement for low-quality forage diets like AWS are (1) Price, (2) Delivery System Needed, and (3) Consistency of Supply.

Probably the most important of these three factors is price. The following Cost per Unit of Nutrient Table illustrates how we can compare and select a protein supplement based on cost/unit of protein and energy:

<table>
<thead>
<tr>
<th>Protein Supplement</th>
<th>Cost Delivered, $/ton</th>
<th>% CP</th>
<th>$/unit CP</th>
<th>% DDM</th>
<th>$/unit DDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>150.00</td>
<td>17</td>
<td>8.82b</td>
<td>57</td>
<td>2.63b</td>
</tr>
<tr>
<td>Corn distiller dried grains</td>
<td>220.00</td>
<td>28</td>
<td>7.85c</td>
<td>86</td>
<td>2.56d</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>440.00</td>
<td>44</td>
<td>10.00d</td>
<td>82</td>
<td>5.36f</td>
</tr>
<tr>
<td>Cottonseed meal</td>
<td>405.00</td>
<td>41</td>
<td>9.88e</td>
<td>80</td>
<td>5.06g</td>
</tr>
</tbody>
</table>

The table above indicates that Corn Distillers-Dried Grains, a major by-product of the ethanol industry, is by far the cheapest source of protein and energy.
When setting up a Cost per Unit of Nutrient Table such as the one above it is important that all feeds are compared on an equal basis: all costs and nutrient concentrations must be either on an as-fed or dry matter basis, all costs must be on the same basis ($/ton, $/cwt, $/lb.), all nutrient concentrations must be on the same basis (%, Mcal/kg, Mcal/lb., mg/kg, etc.). Also remember to add any processing costs that would be necessary to deliver the supplement such as grinding/mixing or pelleting.

p. In the previous example alfalfa hay was used as a protein/energy supplement for the AWS diet. In the example below corn distillers dried grains (CDDG) will be used as the protein/energy supplement instead of alfalfa hay, 28% CP and 86% DDM. Due to these higher concentrations, less will have to be fed. This will leave more “room” in the diet for AWS. In this example we’ll say the CDDG can be delivered to the ranch for $220/ton or $1.100/lb. We’ll use the Simultaneous Equations method above to balance for CP and DDM (energy):

**Late gestation:**

Let X = amount of AWS needed  
Let Y = amount of CDDG needed

\[
.52 \times X + .86 \times Y = 13.47 \text{ lbs. DDM} \\
.06 \times X + .28 \times Y = 1.90 \text{ lbs. CP} \\
.52 \div .06 = 8.6667 \text{ adjustment factor}
\]

Multiply the CP equation by the adjustment factor:

\[
(.06 \times 8.6667) \times X + (.28 \times 8.6667) \times Y = (1.90 \times 8.6667) \\
.52 \times X + 2.43 \times Y = 16.47
\]

Subtract adjusted CP equation from DDM equation:

\[
.52 \times x + .86 \times y = 13.47 \\
.52 \times x + 2.43 \times y = 16.47 \\
0 - 1.57 \times y = -3.00
\]

\[
Y = 1.91 \text{ LBS. CDDG DM}
\]

Plug 1.91 in place of Y in either equation and solve for X (lbs. AWS needed).

\[
.52 \times X + (.86)(1.91) = 13.47 \\
.52 \times X + 1.64 = 13.47 \\
.52 \times X = 11.83 \\
X = 22.75 \text{ lbs. AWS DM}
\]

Check:

\[
22.75 \text{ lbs. AWS} \times .52 \text{ (52% digestible)} = 11.83 \text{ lbs. DDM} \\
1.91 \text{ lbs. CDDG} \times .86 \text{ (86% digestible)} = 1.64 \text{ lbs. DDM} \\
\text{Total DDM intake/cow/day} = 13.47 \text{ lbs. DDM} \quad 13.47 \text{ lbs. required, OK}
\]
22.75 lbs. AWS x .06 (6% CP) = 1.37 lbs. CP
1.91 lbs. CDDG x .28 (28% CP) = .53 lbs. CP
Total CP intake/cow/day = 1.90 lbs. CP 1.90 lbs. required, OK

22.75 lbs. AWS DM ÷ .90 (90% DM) = 25.28 lbs. AWS x $.0325/lb. = $0.8215
1.91 lbs. CDDG DM ÷ .90 (90% DM) = 2.12 lbs. CDDG x $.1100/lb. = $0.2334
Total cost/cow/day $1.06/cow/day + VMS

Early lactation:

Let X = amount of AWS needed
Let Y = amount of CDDG needed
Digestibility of AWS was increased to 54% because the amount of protein given was increased.

\[.54 X + .86 Y = 15.72 \text{ lbs. DDM}\]
\[.06 X + .28 Y = 2.52 \text{ lbs. CP}\]

\[.54 ÷ .06 = 9.0 \text{ adjustment factor}\]

Multiple CP equation by adjustment factor

\[(.06 \times 9.0) X + (.28 \times 9.0) Y = (2.52 \times 9.0)\]
\[.54 X \quad + \quad 2.52 Y = 22.68\]

Subtract adjusted CP equation from DDM equation

\[.54 X + .86 Y = 15.72\]
\[.54 X + 2.52 Y = 22.68\]
\[0 \quad -1.66 Y = -6.96\]

\[Y = 4.19 \text{ lbs. CDDG DM}\]

Plug 4.19 in place of Y in either equation and solve for X (lbs. of AWS needed).

\[.54 X + (.86)(4.19) = 15.72\]
\[.54 X + 3.60 \quad = 15.72\]
\[54 X \quad = 12.12\]

\[X = 22.44 \text{ lbs. AWS DM}\]

Check:

22.44 lbs. AWS x .54 (54% digestible) = 12.12 lbs. DDM
4.19 lbs. CDDG x .86 (86% digestible) = 3.60 lbs. DDM
Total DDM intake/cow/day = 15.72 lbs. DDM 15.72 lbs. required, OK

22.44 lbs. AWS x .06 (6% CP) = 1.35 lbs. CP
4.19 lbs. CDDG x .28 (28% CP) = 1.17 lbs. CP
Total CP intake/cow/day = 2.52 lbs. CP 2.52 lbs. required, OK
With the prices illustrated in the Cost/Unit of Nutrient Table above these AWS/CDDG diets would be an inexpensive method to winter the beef cows. However, one final consideration: **How will we deliver the CDDG to the cows?** With alfalfa hay we can use the same equipment and method of delivery used to deliver the AWS. The CDDG is in a meal or granular form. We have spoken with producers who have simply spread the correct amount of CDDG on a clean meadow from behind a pickup either from bags or by augering from a box in the back of a truck. The cattle do a fairly affective job of licking up most of the CDDG with little waste. Some producers have even spread it on the snow with minimal wastage. However, during windy periods this method is quite wasteful. Another method we have used is the formulation of a **Free-Choice Salt Meal**. With cattle plain white salt can be used to limit the intake of highly palatable supplements like CDDG:

<table>
<thead>
<tr>
<th>% Supplement</th>
<th>% Plain, White Salt</th>
<th>Lbs. of Supplement Intake, 1200 lbs. cow</th>
</tr>
</thead>
<tbody>
<tr>
<td>60%</td>
<td>40%</td>
<td>1.5</td>
</tr>
<tr>
<td>70%</td>
<td>30%</td>
<td>3.0</td>
</tr>
<tr>
<td>80%</td>
<td>20%</td>
<td>5.0</td>
</tr>
<tr>
<td>90%</td>
<td>10%</td>
<td>7.5</td>
</tr>
</tbody>
</table>

- The correct mixture can be placed in a feeder and the cattle are allowed free-choice access.
- The figures above are “ball park” estimates. Actual amounts consumed will depend on the type of supplement used, the amount of salt in the drinking water, etc. A nutritionist, veterinarian, or extension specialist can help “fine tune” these formulas.
- A few do’s, don’t, and cautions regarding the use of salt meals:
  1. If your soil is already too high in salt it would be best to avoid this delivery method.
  2. Always use **Plain, White Salt**, not iodized salt or trace-mineralized salt for mixing, which would result in toxic intake of some minerals.
  3. Make sure the salt meals are placed in **weather proof feeders**. If the salt meals get wet they could be ruined. If the wind velocity is high, tons of salt meal could be lost in just one day.
  4. Make sure the salt meal feeding station is close to **plenty of fresh, clean drinking water (600 ft.)**. The excess salt being consumed by the cattle will be excreted through the urine, which requires an ample supply of good-quality drinking water. Placing the salt meal station two or three miles from water could result in the death of some cattle due to salt poisoning.
  5. Don’t mix too much salt meal at a time in case adjustments in the formula are necessary.

- Also keep in mind that delivering the CDDG in a salt meal will likely **increase the cost** due to mixing cost and the added cost of the salt.
• If you use a salt meal to deliver a supplement it is best to formulate vitamin and mineral supplements within the salt meal. If you use a salt meal and then depend on trace-mineralized salt blocks to insure adequate trace mineral intake, the salt meal will cause the cattle to totally avoid use of the salt blocks.

q. Another option that can be considered regarding supplements for beef cows consuming AWS diets is that of cereal grains. With the advent of the corn-ethanol era the price of many cereals has been elevated to the point that they are precluded from use as supplements. However, if prices soften somewhat cereal grains can be successfully used as energy/protein supplements for cattle consuming LQF like AWS. However, it’s very important that we review the effects of supplements high in starches and sugars like cereal grains on LQF utilization by cattle:

1. Cereal grain supplements usually reduce the DM intake of LQF and the more cereal grain fed the larger the magnitude of this reduction.

2. Cereal grain supplements usually reduce the DM digestibility of LQF and the more cereal grain fed the larger the magnitude of this reduction.

3. Cereal grains that are high in starches that ferment relatively rapidly in the rumen of cattle are more detrimental to LQF utilization than other cereal grains. For example soft white wheat contains a high concentration of starches that ferment rapidly in the rumen. Corn contains about the same amount of starch, but corn starch is fermented much more slowly than soft white wheat starch. Generally the starches associated wheat are fermented the most rapidly in the rumen of cattle, followed by barley starch, and lastly the starches of corn and sorghum. Of the cereal grains oats are usually considered to be the lowest in starch content, and oat starch is considered moderate regarding ruminal fermentation rate.

4. How cereal grains are processed can also affect the ruminal fermentation rate of starches and thus reductions in LQF intake and digestibility. Feeding cereal grains whole of course will result in the slowest ruminal fermentation rate of starch. However, only corn can affectively be fed whole. Unprocessed small grains such as wheat, barley, oats, and sorghum are not masticated well by cattle and much will transit the gastro-intestinal tract unscaved. Heavy processing like pelleting and steam flaking greatly increases the rate and extent of starch fermentation. Of the processing methods, grinding is usually considered to increase starch fermentation moderately and course grinding and cracking the least. So the processing method of cereal grains should be considered when they are to be used as supplements for cattle consuming LQF like AWS.

5. When cereal grains are used as supplements for cattle consuming ammoniated LQF like AWS, the CP added to the forage during the ammoniation process is used more efficiently than when a protein supplement is used:

\[
\text{with a protein supplement} \\
4\% \text{ original } \text{CP} + (4\% \text{ added CP } \times 0.50) = 6\% \text{ CP}
\]

\[
\text{with a cereal grain supplement} \\
4\% \text{ original } \text{CP} + (4\% \text{ added CP } \times 0.75) = 7\% \text{ CP}
\]
This is due to a synchrony that exists between the added non-protein nitrogen and the starches of cereal grains.

6. The following table shows the approximate reductions in AWS intake and digestibility associated with increasing levels of cereal grain supplementation:

<table>
<thead>
<tr>
<th>Cereal grain DM intake, % BWa</th>
<th>Resultant AWS DM intake, % BW</th>
<th>Resultant AWS DM digestibility, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>.42</td>
<td>1.83</td>
<td>47.0</td>
</tr>
<tr>
<td>.63</td>
<td>1.75</td>
<td>46.0</td>
</tr>
<tr>
<td>.84</td>
<td>1.58</td>
<td>45.0</td>
</tr>
</tbody>
</table>

*Percent of animal body weight.

The following example illustrates the use of ground barley grain (GBG) as a supplement for beef cows being wintered on an AWS diet. For this example the value of GBG was set at $220/ton or $.1100/lb. The GBG used in this example is considered to be 13% CP and the DM digestibility to be 90%.

With example diets previous to this we used the simultaneous equation method to balance the diets. However, with some feed combinations it is impossible to put a diet together that provides exactly the minimal requirements for energy (DDM) and CP. Check the simultaneous equations below using AWS supplemented with GBG:

Let X = amount of AWS needed  
Let Y = amount of GBG needed.

According to the table above, at low cereal grain intake (.42% of body weight) AWS DM digestibility should be around 47%.

\[
.47X + .90Y = 13.47 \text{ lbs. DDM} \\
.07X + .13Y = 1.90 \text{ lbs. CP}
\]

\[
.47 \div .07 = 6.714 \text{ adjustment factor}
\]

Multiple CP equation by adjustment factor:

\[
(.07 \times 6.714)X + (.13 \times 6.714)Y = (1.90 \times 6.714) \\
.47X + .873Y = 12.76
\]

Subtract adjusted CP equation from the DDM (energy) equation.

\[
.47X + .90Y = 13.47 \\
.47X + .873Y = 12.76 \\
.027Y = .71
\]

Y = 26.30 lbs. GBG
Obviously this cannot be correct, 26.30 lbs. of GBG will provide (26.30 x .90) 23.67 lbs. DDM (13.47 required) and (26.30 x .13) 3.42 lbs. CP (1.90 lbs. required)

We wanted you to know that the simultaneous equation method is a good diet balancing tool, but it does not “always” work.

Using the table above, at a low level of cereal grain intake (.42% body weight) the cows should consume about 1.83% of body weight of AWS, which should be about 47% digestible.

**Late gestation:**

1200 lbs. cow body weight x .0183 (1.83%) = **21.96 lbs. AWS DM**
21.96 lbs. AWS DM x .47 (47% digestible) = 10.32 lbs. DDM
13.47 lbs. DDM required - 10.32 lbs. DDM = 3.15 lbs. DDM deficient
3.15 lbs. of DDM will have to be supplied by GBG.
3.15 lbs. DDM ÷ .90 (90% digestible) = **3.50 lbs. GBG DM**

How much CP is supplied by 21.96 lbs. AWS DM and 3.50 lbs. GBG DM?

21.96 x .07 (7% CP) = 1.54 lbs. CP
3.50 x .13 (13% CP) = .46
Total CP intake = 2.00 lbs. 1.90 required, OK

21.96 lbs. AWS DM ÷ .90 (90% DM) = 24.40 lbs. AWS x $ .0325 = $**.7930**
3.50 lbs. GBG DM ÷ .90 (90% DM) = 3.89 lbs. GBG x $ .1100 k= **$.4279**
Total cost/cow/day $**1.22/cow/day** + VMS

**Early lactation:**

Since the nutrient requirements are higher during lactation more GBG will likely have to be fed. From the table above, at moderate cereal grain intake (.63% of body weight) AWS DM intake will likely be about 1.75% of body weight and its DM digestibility will likely be about 46%.

1200 lbs. cows x .0175 (1.75% of BW) = **21.00 lbs. AWS DM**
21.0 lbs. AWS DM x .46 (46% digestible) = 9.66 lbs. DDM

15.72 lbs. DDM required - 9.66 lbs. from AWS = 6.06 lbs. DDM that must come from GBG
6.06 lbs. DDM ÷ .90 (90% digestible) = **6.73 lbs. GBG DM**

21.00 lbs. AWS DM x .46 = 9.66 lbs. DDM
6.73 lbs. GBG DM x .90 = 6.06 lbs. DDM
Total DDM intake 15.72 lbs. DDM 15.72 required, OK

21.00 lbs. AWS DM x .07 (7% CP) = 1.47 lbs. CP
6.73 lbs. GBG DM x .13 (13% CP) = .88 lbs. CP
Total CP intake 2.35 lbs. CP 2.52 required, X **Deficient**

CP provided is slightly deficient (2.52-2.35) **.17 lbs.**
We’ll have to feed enough GBG to supply the needed .17 lbs. CP. We can’t feed any extra AWS to help rectify this CP deficiency because it is already at maximum intake.

\[
.17 \text{ lbs CP needed ÷ .13 (13% CP)} = 1.31 \text{ lbs. GBG DM}
\]

\[
6.73 + 1.31 = 8.04 \text{ lbs. of total GBG DM needed}
\]

21.00 lbs. AWS DM x .46 = 9.66 lbs. DDM
8.04 lbs. GBG DM x .90 = 7.24 lbs. DDM

Total DDM intake = 16.90 lbs. DDM 15.72 lbs. DDM required, OK

21.00 lbs. AWS DM x .07 (7% CP) = 1.47 lbs. CP
8.04 lbs. GBG DM x .13 (13% CP) = 1.05 lbs. CP

Total CP intake = 2.52 lbs. CP 2.52 lbs. CP required, OK

21.00 lbs. AWS DM ÷ .90 (90% DM) = 23.33 lbs. AWS
23.00 lbs. AWS x $.0325 = $.7583
8.04 lbs. GBG DM ÷ .90 = 8.93 lbs. GBG
8.93 lbs. GBG x $.1100/lb. = $.9827

Total Cost/cow/day = $1.74/cow/day + VMS

The major problem with this early lactation diet is that it is too expensive because it contains more energy (DDM) than necessary. Also, the increased amount of GBG fed would likely result in a decrease in AWS intake and digestibility. We use GBG as a source of protein (CP) and as with most energy feeds like cereal grains, the cost per unit of protein is relatively high. To illustrate that point, study the unit/cost of CP table below:

<table>
<thead>
<tr>
<th>Feed Supplement</th>
<th>Cost, Processed and Delivered, $/ton</th>
<th>% CP</th>
<th>$/unit of CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn distillers dried grains</td>
<td>220.00</td>
<td>28</td>
<td>7.85(^a)</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>440.00</td>
<td>44</td>
<td>10.00(^b)</td>
</tr>
<tr>
<td>Ground barley grain</td>
<td>220.00</td>
<td>13</td>
<td>16.92(^c)</td>
</tr>
</tbody>
</table>

\(^a\) \$220.00 ÷ 28 = 7.85
\(^b\) \$440.00 ÷ 44 = 10.00
\(^c\) \$220.00 ÷ 13 = 16.92

Notice that the cost of CP is 2.15 times higher if it comes from GBG compared to CDDG. There will likely be considerable saving if we use CDDG to rectify the CP deficiency rather than by just adding more GBG.

From the example above, a full feed of AWS (21.00 lbs. DM) will provide 9.66 lbs. DDM and 1.47 lbs. of CP. This means the GBG – CDDG mix will have to provide (15.72 – 9.66) 6.06 lbs DDM and (2.52 – 1.47) 1.05 lbs. CP. Let’s try the simultaneous equations to see if we can determine exactly how much GBG and CDDG we will need to supply these nutrients:
Let \( X = \) the amount of GBG needed.
Let \( Y = \) the amount of CDDG needed.

\[ .90 X + .86 Y = 6.06 \text{ lbs. DDM} \]
\[ .13 X + .28 Y = 1.05 \text{ lbs. CP} \]

\[ .90 \div .13 = 6.923 \] is the adjustment factor

Multiply the CP equation above by the adjustment factor:

\[ (.13 \times 6.923) X + (.28 \times 6.923) Y = (1.05 \times 6.923) \]
\[ .90 X + 1.938 Y = 7.269 \]

Subtract the adjusted CP equation from the energy (DDM) equation:

\[ .90 X + .86 Y = 6.06 \]
\[ .90 X + 1.938 Y = 7.269 \]
\[ 0 - 1.078 Y = -1.209 \]
\[ Y = 1.12 \text{ lbs. CDDG} \]

Plug 1.12 in place of \( Y \) in either the equation and solve for \( X \):

\[ .90 X + (.86 \times 1.12) = 6.06 \]
\[ .90 X + .9632 = 6.06 \]
\[ .90 X = 5.0968 \]
\[ X = 5.66 \text{ lbs. GBG} \]

So the least expensive diet for early lactation will consist of:

\begin{itemize}
  \item \textbf{21.00 lbs. DM from AWS}
  \item \textbf{5.66 lbs. DM from GBG}
  \item \textbf{1.12 lbs. DM from CDDG}
\end{itemize}

Check:

\[ 21.00 \text{ lbs. AWS DM} \times .46 = 9.66 \text{ lbs. DDM} \]
\[ 5.66 \text{ lbs. GBG DM} \times .90 = 5.09 \text{ lbs. DDM} \]
\[ 1.12 \text{ lbs. CDDG DM} \times .86 = .97 \text{ lbs. DDM} \]
\[ \text{Total DDM intake} = 15.72 \text{ lbs. DDM} \]
\[ 15.72 \text{ lbs. required, OK} \]

\[ 21.00 \text{ lbs. AWS DM} \times .07 (7\% \text{ CP}) = 1.47 \text{ lbs. CP} \]
\[ 5.66 \text{ lbs. GBG DM} \times .13 (13\% \text{ CP}) = .74 \text{ lbs. CP} \]
\[ 1.12 \text{ lbs. CDDG DM} \times .28 (28\% \text{ CP}) = .31 \text{ lbs. CP} \]
\[ \text{Total CP intake} = 2.52 \text{ lbs. CP} \]
\[ 2.52 \text{ lbs. required, OK} \]
Calculate cost of balanced diet:

\[
\begin{align*}
21.00 \text{ lbs. AWS DM} & \div 0.90 (90\% \text{ DM}) = 23.33 \text{ lbs. AWS} \\
23.33 \text{ lbs. AWS} & \times \$0.0325/\text{lb.} = \$0.7583 \\
5.66 \text{ lbs. GBG DM} & \div 0.90 (90\% \text{ DM}) = 6.29 \text{ lbs. GBG} \\
6.29 \text{ lbs. GBG} & \times \$1.100/\text{lb.} = \$6.919 \\
1.12 \text{ lbs. CDDG} & \div 0.90 (90\% \text{ DM}) = 1.24 \text{ lbs. CDDG} \\
1.24 \text{ lbs. CDDG} & \times \$1.100/\text{lb.} = \$1.364
\end{align*}
\]

Total cost of diet $1.59/cow/day + VMS

This is compared to $1.74/cow/day for the AWS/GBG diet above, a $(1.74 - 1.59) \$0.15/cow/day savings.

One might ask why didn’t we supply the entire DDM requirement with CDDG and over feed CP? The answer is that GBG is a cheaper source of DDM:

<table>
<thead>
<tr>
<th>Feed</th>
<th>Cost, Processed and Delivered, $/ton</th>
<th>% DDM</th>
<th>$/unit DDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground barley grain</td>
<td>220.00</td>
<td>90</td>
<td>2.44(^a)</td>
</tr>
<tr>
<td>Corn distillers dried grains</td>
<td>220.00</td>
<td>86</td>
<td>2.56(^b)</td>
</tr>
</tbody>
</table>

\(^a\)220 \div 90 = 2.44
\(^b\)220 \div 86 = 2.56

r. For the sake of comparison let’s summarize all of the late gestation and early lactation diets below in table form.

Summary of Cost options to winter the beef cows on purchased off-ranch feeds:

<table>
<thead>
<tr>
<th>Diet</th>
<th>Late Gestation $/cow/day</th>
<th>Early Lactation $/cow/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-quality grass hay</td>
<td>1.42</td>
<td>1.66</td>
</tr>
<tr>
<td>Medium-quality alfalfa hay</td>
<td>1.58</td>
<td>1.84</td>
</tr>
<tr>
<td>Ammoniated wheat straw (AWS) + medium-quality alfalfa hay supplement</td>
<td>1.03</td>
<td>1.26</td>
</tr>
<tr>
<td>AWS + corn distillers dried grains (CDDG) supplement</td>
<td>1.06</td>
<td>1.32</td>
</tr>
<tr>
<td>AWS + ground barley grain GBG/CDDG</td>
<td>1.22</td>
<td>1.74</td>
</tr>
<tr>
<td>AWS + GBG/CDDG supplement</td>
<td>---</td>
<td>1.59</td>
</tr>
</tbody>
</table>

By going through the agony of all of the calculations above, one can select the least expensive diet of purchased off-ranch feeds that can be used to winter beef cows. Of course most computerized diet balancing programs can accomplish these computations in seconds.

s. It is important to remember that mineral and vitamin supplementation has not been described in the example diets above. It’s also important to remember that LQF like AWS are extremely low in phosphorus and most of the trace minerals relative to cow requirements. In addition LQF are almost devoid of fat-soluble vitamin like vitamin A and E. The ammoniation process does not add to or enhance the availability of vitamins or minerals. In fact it may diminish the availability of magnesium. It is very important that these deficiencies be addressed. We have been associated with producers who have developed otherwise excellent supplementation programs for their cows consuming LQF only to fail due to the lack of .5 mg of selenium.
The vitamin-mineral supplementation program needed depends on the type and amount of protein/energy used. Some protein/energy supplement can rectify many of the vitamin-mineral deficiencies associated with LQF. As an example let’s say that the phosphorus requirement of a beef cow is .04 lbs./cow/day. Using the alfalfa hay supplemented diet during late gestation described above, calculate the amount of phosphorus provided by the AWS and the AH:

<table>
<thead>
<tr>
<th>Feed</th>
<th>DM fed, lbs./day</th>
<th>Phosphorus content, % of DM</th>
<th>Phosphorus Provided, lbs./day</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWS</td>
<td>22.00</td>
<td>.05</td>
<td>.011</td>
</tr>
<tr>
<td>AH</td>
<td>3.56</td>
<td>.22</td>
<td>.008</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>.019</td>
</tr>
<tr>
<td>Amount required</td>
<td></td>
<td></td>
<td>.040</td>
</tr>
<tr>
<td>Amount needed from VMS</td>
<td></td>
<td></td>
<td>.021 lbs./day</td>
</tr>
</tbody>
</table>

However, if we use the CDDG protein/energy supplement there is a different amount of phosphorus supplementation needed:

<table>
<thead>
<tr>
<th>Feed</th>
<th>DM fed, lbs./day</th>
<th>Phosphorus content, % of DM</th>
<th>Phosphorus Provided, lbs./day</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWS</td>
<td>22.75</td>
<td>.05</td>
<td>.011</td>
</tr>
<tr>
<td>CDDG</td>
<td>1.91</td>
<td>.80</td>
<td>.015</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>.026</td>
</tr>
<tr>
<td>Amount required</td>
<td></td>
<td></td>
<td>.040</td>
</tr>
<tr>
<td>Amount needed from VMS</td>
<td></td>
<td></td>
<td>.014 lbs./day</td>
</tr>
</tbody>
</table>

It is best to consult a nutritionist, veterinarian, or extension specialist to aid you in the formulation of a proper vitamin-mineral supplement for cows consuming LQF diets with various types of protein/energy supplements. Often it is difficult to buy a vitamin-mineral supplement when we see the price/ton. However, it’s important to remember that what counts is the cost/head. Normally vitamin-mineral supplementation costs only pennies/head/day, $.03 to $.07/cow/day. For example the diet about is deficient .014 lbs. of phosphorus/day. A common source of supplemental phosphorus in Dicalcium Phosphate, which is about 18.5% phosphorus and cost about $450/ton or $.225/lb. How much dicalcium phosphate would be needed to supply the .014 lb. deficiency, and what would it cost?

\[
.014 \text{ lbs. P needed} \div .185 (18.5\% \text{ P}) = .076 \text{ lbs./day}
\]
\[
.076 \text{ lbs./day} \times .225/\text{lb.} = .0171/\text{cow/day}
\]

My Grandpa always used to say “Just because it works on paper doesn’t always mean that it is going to work in practice. But if you can’t make it work on paper, it definitely is not going to work.” That is the reason we conducted the study reported in Part I of this bulletin.
Utah State University is committed to providing an environment free from harassment and other forms of illegal discrimination based on race, color, religion, sex, national origin, age (40 and older), disability, and veteran’s status. USU’s policy also prohibits discrimination on the basis of sexual orientation in employment and academic related practices and decisions.

Utah State University employees and students cannot, because of race, color, religion, sex, national origin, age, disability, or veteran’s status, refuse to hire; discharge; promote; demote; terminate; discriminate in compensation; or discriminate regarding terms, privileges, or conditions of employment, against any person otherwise qualified. Employees and students also cannot discriminate in the classroom, residence halls, or in on/off campus, USU-sponsored events and activities.

This publication is issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Noelle E. Cockett, Vice President for Extension and Agriculture, Utah State University.