2003
Plains Nutrition Council
Spring Conference

April 3-4, 2003
San Antonio, Texas

Publication No. AREC 03-13
Texas A&M Research and Extension Center
Amarillo
**About the Plains Nutrition Council**

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

**2002-2003 Officers**

David Yates, President  
Spencer Swingle, 1st Vice President  
Mike Brown, 2nd Vice President  
Ted McCollum III, Secretary/Treasurer
TABLE OF CONTENTS

Invited Presentations

Precision Nutrition – Opportunities and Limitations ................................................................. 1
   Dr. Andy Cole, USDA-ARS CPRL, Bushland, Texas

A nutritionist’s Perspective on the Updated Environmental Regulations Applicable to Beef Feedlots .................................................. 20
   Dr. Galen Erickson, University of Nebraska, Lincoln, Nebraska

TCFA Guidelines for Care and Handling of Feedyard Cattle .................................................... 27
   Mr. Ross Wilson and Ben Weinheimer, Texas Cattle Feeder’s Association, Amarillo, Texas

Ecology and Feedlot Epidemiology of E. coli O157:H7 ............................................................ 41
   Dr. Guy Loneragan, West Texas A&M University, Canyon, Texas

Prevalence of O157:H7 and Non-O157 Shiga Toxin-Producing Escherichia coli in Commercial
Beef Processing Plants, Dr. Mohammad Koohmaraie, USDA-ARS MARC, Clay Center, Nebraska ................................................................. 47

Lifetime Nutritional Effects on Feedlot Performance and Carcass Merit ...................................... 63
   Dr. Larry Berger, University of Illinois, Urbana-Champaign, Illinois

Net Feed Efficiency and its Commercial Applicability ............................................................. 79
   Dr. John Basarab, Western Forage/Beef Group, Lacombe Research Centre, Lacombe, Alberta

University Research Updates

Feedlot Research at Texas Tech University: Effects of Nutrition on Nutrient Excretion, Health and
Performance by Cattle
   Dr. Reed Richardson ............................................................................................................. 92

Research Update: Texas Agricultural Experiment Station at Amarillo, Texas ................................ 96
   Dr. Wayne Greene

Research Update: University of Nebraska, Lincoln, Nebraska ................................................ 101
   Dr. Galen Erickson

Abstracts

High moisture tempering of corn before flaking: Effects on bacterial contamination from house
flies and fecal shedding in finishing cattle. B.E. Depenbusch, J.S. Drouillard, R.K. Phebus,
A.B. Broce, C.M. Gordon, and J.J. Sindt, Kansas State University, Manhattan ......................... 105

Effect of purchasing bull vs steer calves on receiving performance and wheat pasture gain.
H. A. DePra, R. E. Peterson, D. R. Gill, and C. R. Krehbiel, Oklahoma State University .................. 105

Effects of Flax Supplementation and a Combined Trenbolone Acetate and Estradiol Implant on Circulating
Insulin-Like Growth Factor-1 (IGF-1) and Muscle IGF-1 mRNA Levels and Satellite Cell Activity in
Beef Cattle. J. D. Dunn*, J. P. Kayser, A. T. Waylan, E. K. Sissom, J. S. Drouillard and B. J. Johnson,
Kansas State University ............................................................................................................. 106
Effects of live cultures of *Lactobacillus acidophilus* (Strains NP45 and NP51) and *Propionibacterium freudenreichii* NP24 on performance, carcass and intestinal characteristics, and *Escherichia coli* 0157:H7 shedding of finishing beef steers. N.A. Elam¹, J.F. Gleghorn, J.D. Rivera¹, M.L. Gayean¹, P.J. Defoor², M.M. Brashears¹, and S.M. Younts-Dahl¹, ¹Texas Tech University, Lubbock; ²Clayton Livestock Research Center, Clayton ........................................ 107

Steroid hormone profiles and brain monoamine oxidase type A (MAO-A) activity of buller steers. M.P. Epp, D.A. Blasi, B.J. Johnson, and J.P. Kayser, Kansas State University, Manhattan .......................... 107

Combination of wet corn gluten feed and alfalfa hay in finishing diets: Effects on performance, feeding economics, and nitrogen balance. T.B. Farran¹, G.E. Erickson¹, T.J. Klopfenstein¹, C.N. Macken¹, R.U. Linquist². ¹University of Nebraska-Lincoln; ²Archer Daniels Midland Company................................. 108

Vaccination and Feeding a Competitive Exclusion Product as Intervention Strategies to Reduce the Prevalence of *Escherichia coli* 0157:H7 in Feedlot Cattle. J.D. Folmer¹, C.N. Macken¹, G.E. Erickson², S. Hinkley², R.A. Moxley², D.R. Smith², and T.J. Klopfenstein¹, University of Nebraska, Lincoln, ¹Animal Science, ²Veterinary Science........................................ 108

Effects of dietary crude protein level and degradability on serum urea nitrogen and efficacy of the metabolizable protein system. J. F. Gleghorn, N. A. Elam, M. L. Galyean¹, G. C. Duff², and N. A. Cole³, ¹Texas Tech University, Lubbock, ²University of Arizona, Tucson, ³USDA-ARS, Bushland................................. 109


The effects of dietary crude protein concentration and source on nitrogen absorption and retention by feedlot steers. A. Gueye¹, C. R. Richardson¹, J. H. Mikus¹, G. A. Nunnery¹, N. A. Cole², and L. W. Greene³ ¹Texas Tech University, Lubbock; ²USDA-ARS-CPRL, Bushland, TX; ³Texas Agricultural Experimental Station, Amarillo, TX ........................................... 111

Effects of Roughage Level and Min-Ad³ on Ruminal Metabolism and Site and Extent of Digestion in Beef Steers Fed a High-Grain Diet C. D. Keeler¹, C. R. Krehbiel¹, and J. J. Wagner², ¹Oklahoma State University and ²ContiBeef, LLC Lamar, CO .......................................................... 111

Effect of calcium source and concentration on blood acid-base status, circulating mineral concentrations, and apparent nutrient digestion and retention. E. A. Lauterbach, M. S. Brown, C. D. Drager, E. M. Cochran, and R. Brown, Division of Agriculture, West Texas A&M University, Canyon, TX .......................................................... 112

Effect of level of wet corn gluten feed on feedlot performance and economics in steam-flaked corn based finishing diets. C.N. Macken¹, G.E. Erickson¹, T.J. Klopfenstein¹, and R.A. Stock², ¹University of Nebraska, Lincoln, ²Cargill Inc., Blair, NE .......................................................... 112

Effect of cottonseed byproduct feeds on feedlot performance and carcass traits of finishing heifers C.E. Markham, C.R. Krehbiel, D.R. Gill, R.E. Peterson, and H.A. DePra, Oklahoma State University .................... 113

Effect of copper level and zinc level and source on finishing cattle performance and carcass traits. L.J. McBeth, C.R. Krehbiel, D.R. Gill, C.E. Markham, R.E. Peterson, R.L. Ball, C.K. Swenson, and S.S. Swanek, Oklahoma State University ........................................ 113

Nitrogen and phosphorus utilization by beef cattle fed three dietary crude protein levels with three levels of supplemental urea. K. W. McBride, L. W. Greene, N. A. Cole, F. T. McCollum III, and M. L. Galyean. TAES, Amarillo, TX, ARS, Bushland, TX, TTU, Lubbock, TX ........................................... 114
<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>gain and carcass characteristics</td>
<td>Good, E.R. Loe, M.J. Sulpizio, and T.J. Kessen. Kansas State University, Manhattan</td>
<td></td>
</tr>
<tr>
<td>Effects of starch-based versus fiber-based receiving diets on</td>
<td>C.J. Mueller and R.H. Pritchard, South Dakota State University, Brookings</td>
<td>115</td>
</tr>
<tr>
<td>nitrogen status and blood metabolites in lambs subjected to transit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>stress.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instrument versus manual sortation of feedlot steers and heifers.</td>
<td>R.E. Peterson1*, D.R. Gill1, C.R. Krehbiel1 and H.G. Doleza1, 1Oklahoma State University</td>
<td>115</td>
</tr>
<tr>
<td>and Excel Corporation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effect of Wet and Dry Distillers Grains Plus Solubles and</td>
<td>K.J. Vander Pol, G.E. Erickson, T.J. Klopfenstein, C.N. Macken, University of Nebraska</td>
<td>116</td>
</tr>
<tr>
<td>Supplemental Fat Level on Performance of Finishing Cattle.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Examination of the effects of Escherichia coli O157:H7 shedding on</td>
<td>J.D. Rivera, J.T. Richeson, N.A. Elam, M.M. Brashears, and M.L. Galyean. Department of</td>
<td>116</td>
</tr>
<tr>
<td>performance and carcass characteristics of beef cattle.</td>
<td>Animal and Food Sciences, Texas Tech University, Lubbock</td>
<td></td>
</tr>
<tr>
<td>characteristics of bulls and steers.</td>
<td>Ohio State University</td>
<td></td>
</tr>
<tr>
<td>Effect of processing methods on the characteristics of steam-flaked</td>
<td>J.J. Sindt*, J.S. Drouillard, S.P. Montgomery, and E.R. Loe. Kansas State University,</td>
<td>118</td>
</tr>
<tr>
<td>corn.</td>
<td>Manhattan</td>
<td></td>
</tr>
<tr>
<td>Expression in Adipose Tissue from Steers.</td>
<td>Morgan, F. J. White, and M. D. Ashworth, Oklahoma State University</td>
<td></td>
</tr>
<tr>
<td>non photoperiod sensitive Sorghum Sudangrass hybrids.</td>
<td>A&amp;M University Agricultural Research and Extension Center, Amarillo, Texas</td>
<td></td>
</tr>
<tr>
<td>lipoprotein lipase and glycogenin mRNA concentrations in finishing</td>
<td>State University, Manhattan</td>
<td></td>
</tr>
<tr>
<td>cattle.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparison of Dry and Liquid Protein Supplements Fed to Stocker</td>
<td>J. Weyers, Oklahoma State University</td>
<td>120</td>
</tr>
<tr>
<td>Cattle Consuming Low-Quality Native Grass: Performance, Digestibility,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and Rumen Kinetics.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physiological indicators of performance traits and net feed</td>
<td>M.B. White1, G.E. Carstens1, C.M. Theis1, L.J. Slay1, R.A. Hollenbeck1, T.H. Welsh, Jr.1,</td>
<td>120</td>
</tr>
<tr>
<td>Experiment Station, College Station, 2Uvalde, 3Overton, 4Amarillo and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5McGregor.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ZINPRO CORPORATION

The Leader in Trace Mineral Nutrition
Precision Feeding: Opportunities and Limitations\(^1, 2, 3\)

N. Andy Cole

USDA - Agricultural Research Service, Bushland, TX

Introduction

The effects of confined livestock operations (CAFOs) on the environment is a growing concern among many groups. In the past few years U.S. EPA instituted new air quality regulations on PM-10 and -2.5 particulates which could potentially lead to regulations on ammonia emissions from AFOs (USEPA, 1997) and new regulations (USEPA, 2003; TCEQ, 2002) that require the use of Comprehensive Nutrient Management Plans (CNMP) by CAFOs to “minimize impact on water quality and public health.” The CNMPs must address factors such as feed management, manure handling, and land application of manure. The Feed Management section of the CNMP must be designed to “Plan modifications of animal diets to reduce the amount of nutrients in manure” (NRCS, 2000). Thus, nutritionists will be called on to play an increasingly important and vital role in helping feedyards meet new environmental regulations.

Environmental Concerns / Background

The primary nutrients of “environmental” concern to feedyards are nitrogen and phosphorus. Phosphorus concerns revolve around potential contamination of surface and ground waters; whereas, N concerns revolve around both water (nitrates and nitrites) and air quality (ammonia, odors) issues.

Water quality. Feedyards with properly designed runoff retention ponds and(or) lagoons have little if any effect on surface or ground water quality near the feedyard. The potential for water contamination generally occurs after the manure leaves the feedyard and is used as a fertilizer on crops or pastures (Sharpley et al., 1999). Although specifics vary from state to state, under new regulations, once the soil P concentration reaches a specified concentration, manure must be applied at “agronomic rates” based on the P needs of the crop. When applied at P

\(^1\) Presented at the Spring Conference of the Plains Nutrition Council, San Antonio, TX, April 3-4, 2003.

\(^2\) All programs and services of the U.S. Department of Agriculture are offered on a nondiscriminatory basis without regard to race, color, national origin, religion, sex, age, marital status, or handicap. The mention of trade or manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion by USDA-Agricultural Research Service.

\(^3\) Appreciation is extended to David Hutcheson, Spencer Swingle, Chet Fields, Mike Galyean, Justin Gleghorn, Glenn Duff, Wayne Greene, Kevin McBride, Reed Richardson, and Ali Gueye for providing information and data used in this manuscript.
utilization rates, rather than N utilization rates, the quantity of farm land required to dispose of manure is increased by 5 to 10 fold.

**Air quality.** The major air quality concerns of feedyards vary with location, proximity to neighbors, etc; but, in general, are dust, odors, and ammonia. The recent NRC (2003) publication on air emissions from AFOs divides the importance of air emissions into those of Local/Property line concern and those of Global/National/Regional concern (Table 1). Ammonia was ranked as a major concern but a minor local concern; whereas, particulates and odors were considered insignificant from a global perspective but of significant major concern at the local level. Concerns with dust and odors revolve around “quality of life,” health, and litigation issues. Concerns with ammonia revolve around it’s designation as a PM-2.5 precursor. Depending upon weather conditions, pen surface conditions, and other factors, 20 to 70% of N fed may be lost to the atmosphere and ammonia concentrations range from 320 to 1,920 ppbv (Hutchinson, et al., 1982; Todd and Cole, unpublished data).

The NRC (2003) recommended that best control technologies be developed to control many of the emissions from CAFOs. They also recommended that technologies aimed at controlling emissions of ammonia and “greenhouse” gases be based on decreasing emissions per unit of production (ie. lb of food produced), rather than on a per farm basis. In contrast, they recommended that technologies to control emissions of local concern (dust, odors) be based on concentrations at the boundary line or the nearest occupied dwelling. However, many proposed regulations are not based on this premise.

**Nutritional “Opportunities” to Decrease Feedyard Effects on the Environment**

**General.** The term “precision feeding” has been coined to suggest that livestock can be fed with greater precision than currently practiced. In this context, precision feeding might be defined as “feeding livestock so that animal performance is not adversely affected but so that nutrient excretion to the environment is the smallest quantity possible.” Nutritional and management strategies have the potential to decrease the effects of feedyards on the environment and “precision feeding” is an excellent concept. However, it is still not clear how effectively it can be applied in the field. Many proposed methods have yet to be “proven” under real world conditions, some require additional management or equipment, and many need additional research and(or) modification.

Technologies may have positive effects on the environment by not only decreasing total nutrient excretion, but by altering the route of excretion. Based on in vitro (Cole et al., 2003) and simulated feedlot surface studies (Todd et al., 2003), the quantity of ammonia emitted from a feedyard surface may be affected by the concentration and source of dietary protein fed (Figure 1) and is highly correlated to the quantity of urinary N excreted ($r^2 = 0.72$: Cole, et al., 2003).

**Opportunity - decreasing dietary nitrogen concentrations.**

It has been suggested that many nutritionists overfeed protein (i.e. nitrogen) and that this leads to excess losses of N to the environment. Currently most consultants formulate finishing diets to contain 12.5 to 13.5% crude protein (CP: Galyean and Gleghorn, 2002). However, the CP and metabolizable protein (MP) requirements of finishing cattle are still not clear. The NRC(1984) values appear to be more “environmentally friendly” than NRC (1996/2000) values because the apparent requirements for CP are lower. However, the CP requirements presented in
the tables of the 1984 NRC publication were to meet the calculated requirements for 50% of a
given class of cattle. To meet the requirements of 84% of the cattle, the values had to be
multiplied by 1.14, and to meet the requirements for 100% of the cattle, the values had to be
multiplied by 1.28. In reality, the NRC (1996) values tend to lie between the 84 and 100%
values of NRC (1984).

Protein requirements determined in performance trials also tend to vary. Studies in
Kansas (Milton et al., 1997) and Nebraska (Shain et al., 1998) with dry rolled corn based diets
suggest the CP requirement is equal to or less than 11.5% of dietary DM. However, studies
(Cooper et al., 2002; Duff et al., 2002; Gleighorn, et al., 2003) with steam-flaked corn based diets
suggest the optimal CP concentration is close to 13.0% of DM. The difference in CP
requirements of cattle fed dry rolled corn- vs. steam flaked corn-based diets appears to be due to
greater requirement for degraded intake protein (DIP: Galyean, 1996; Cooper et al., 2002).

**Limitation - decreasing dietary nitrogen concentrations**

A number of factors limit the use of “Precision feeding” in finishing cattle diets: among
them 1) variability in animal requirements, 2) seasonal / climatic effects, 3) variability in tabular
values and actual composition of feed ingredients, 4) logistics. Additional factors such as the
low cost of urea-N, and as-yet undetermined ingredient associative effects also are important. In
short, most of these limitations revolve around the risk of adversely affecting animal health or
performance.

**Animal Variability.** Cattle feeders are normally faced with large variations in the genetics
of cattle within a single lot of cattle. Factors such as finished weight (ie. BW at 28% body fat),
BW gain potential, tolerance to weather extremes, etc. all affect the nutrient requirements of
individual animals within a lot.

As an example of the effect of animal growth potential on CP requirements, we
calculated the performance and N excretion of 100 steers fed diets formulated to meet the CP
requirements of 50%, 84%, or 100% of the animals in the pen (NRC,1984; Table 2). In addition,
assuming that animals could be individually fed based on their genetic potential for growth,
overall pen performance and N excretion were calculated (i.e., precision feeding of the bottom-
performing 50 steers, middle- 34 steers, and best-performing 16 steers). Restricting the dietary
CP concentration to meet the requirements of 50% of the cattle in the pen had adverse effects on
animal performance and did not decrease total pen N excretion. Feeding to meet the
requirements of 84% of the cattle, rather than 100%, had a slight adverse effect on animal
performance but a beneficial effect on calculated N excretion. As expected, precision feeding
provided the best performance and lowest N excretion but was not “attainable” in a real world
situation. Based on these calculations, diets need to be formulated to meet the requirements of at
least 84% of cattle in a pen. Feeding to meet the requirement of 100% of the cattle will
maximize performance and have modest effects on N excretion.

The protein requirements of cattle change as they approach their mature (or finished)
weight. Because cattle vary greatly in mature weight (and thus optimal finished weight), if they
are sorted based on initial weight, the CP requirement of cattle within a pen can vary greatly.
Ideally, for precision feeding to work, cattle should be sorted to pens based on a percentage of
their finished weight (or days required to reach finished weight or 28% body fat) rather than on
their actual starting weight. Unfortunately, this is easier said than done, especially in large
groups.
The interaction between body weight and CP requirements is demonstrated in Tables 3 to 5. In this trial 358 steers in five weight blocks were fed diets containing 11.5 or 13% CP (Duff et al., 2002) to a constant body fat end point. Only the light and heavy blocks are presented here. During the first 84 days on feed, increasing the CP concentration improved ADG and feed efficiency of both weight blocks of cattle (Table 3). From days 84 to finish, CP concentration did not affect performance of steers in either block (Table 4). Over the 126 to 154 day feeding period, dietary CP concentration did not affect ADG or feed efficiency of the light block of cattle but did affect performance of the heavy block (Table 5).

Seasonal /climatic variability. Animal performance varies with seasons (Figure 2). Thus, to precision feed cattle, factors such as the environment and season will need to be taken into account.

Feed Variability. A major factor limiting the use of precision feeding is feed and diet variability. The nutrient composition of feed ingredients and mixed diets can vary greatly from one load to another and even within a load. Many factors affect nutrient composition of diets including the nutrient composition of the ingredients, sampling errors, mixing errors, and laboratory errors.

Feed Sampling and Mixing: An analysis of a feed is only as good as the sample obtained. Feed and ingredient samples must be representative of the entire load or batch. This can sometimes be difficult, especially with some mixed diets, silages, and hays. Employees should receive training in proper procedures to obtain good feed and diet samples (AOAC, 1980; Pierce, 1994). For some mixed diets, an analysis profile of the individual ingredients may be more accurate than a sample of the mixed diet. Improper feed mixing can lead to large variations in the composition of feed within different portions of the batch. Efficiency of feed mixers vary with the type and change with wear. Therefore, mixers should be tested routinely to be sure that ingredients are mixed properly (ASAE, 1990; McCoy, 1994; Jones, 2001).

Chemical Analyses. Chemical analyses of feeds can vary from lab to lab and from method to method. In Table 6 are presented the analyzed CP concentrations of 5 diet samples sent to 3 different labs. The diet was formulated to contain 13.5% CP but analyzed CP concentrations ranged from 12.7 to 14.5%. Obviously, the difficulty in obtaining precise feed analyses, makes the formulation of diets more difficult.

Ingredient Variability: Feeds vary in nutrient composition because of growing conditions, time in storage, etc. The results in Figure 3 and Table 7 demonstrate the monthly and yearly variation in the composition of sorghum and corn samples at one feedyard. The cause of the monthly fluctuation in CP content is not clear since it was not consistent from year to year. The analyses of 110 diet samples from the same feedyard, formulated to contain 13.5% CP, are presented in Table 7 and Figure 4. The estimated ingredient CP concentrations used to formulate the diets were based on samples collected over the years and not values in NRC (1984; 1996). Although there was a considerable amount of variation in analyzed CP concentrations of the diets, the mean and median values were close to the formulated concentration. Over 75% of the samples contained at least 13.13% CP and only 10% had a CP concentration of less than 12.75%.

It can probably be assumed that day to day variation in nutrient concentration of feed ingredients received at a feedyard may be as great as the month to month variation noted in Figure 3. Because of the ability to recycle N and P between segments of the gut via the blood and saliva, ruminants appear to have some tolerance for even fairly large day-to-day variations in feed composition. For example, compared to feeding a constant 12% CP diet, intentionally
oscillating CP concentrations between deficient (10%) and excessive (14%) concentrations actually increased N balance of sheep (Cole, 1999) and tended to improve performance of steers (Cole, unpublished data).

**Tabular values.** One factor that limits the usefulness of feed analysis for formulating feedyard diets is that most ingredients are fed before a feed analysis can be obtained. Thus, some form of tabular value has to be used to formulate diets. The variability in these tabular values can be as great as the actual values (NRC, 1984, NRC, 1996, Dale, 2002; Preston, 2003). As noted in Table 7, if the nutritionist has a good history of the composition of feed ingredients, it is possible to formulate diets that meet the animals requirements at least 75 to 90% of the time.

**Balancing diets based on DIP / UIP.** CAST (2002) suggested that use of the MP system can decrease excess N losses compared to using a CP formulation system. Presently the DIP and UIP of most feed ingredients have not been determined experimentally. In addition, DIP and UIP values of feeds and their requirements are not constant and vary with other dietary and management factors. In general, the primary factor limiting the use of the MP system in the formulation of feedyard diets is the high UIP content of most commonly used feed grains. Using the NRC (1996/2000) Level 1 Model, Klopfenstein et al. (2002) noted the UIP requirements of cattle ranged from approximately 5.5% at 700 lb to 4% at 1,200 lb. In an 80% steam flaked corn diet, the corn will provide approximately 5.1 to 5.6% UIP. An 80% grain sorghum based diet will provide 5.3 to 7.2% UIP. Thus, in general, supplemental protein must be provided in finishing diets to supply DIP; and “excess” UIP-N in the grain, forage or supplement portions of the diet may supply an excess of N.

NRC (1996/2000) suggested the DIP requirement of finishing cattle fed dry rolled corn based diets was about 6.4% of diet DM. Galyean (1996) calculated that a value of about 9.4% was more appropriate for cattle fed steam-flaked-corn based diets because of greater ruminal fermentation. This value was later confirmed by studies in Nebraska (Cooper et al., 2002; Klopfenstein et al., 2002) which suggested DIP requirements varied with grain processing; averaging 6.8% for dry rolled corn, 10% for high moisture corn, and 9.5% for steam flaked corn based diets. Thus, based on these results, the required CP concentration of a steam flaked corn diet would be approximately 14% (4.6% UIP + 9.4% DIP). However, our studies suggest that CP concentrations of 13% are adequate for steers fed steam flaked corn diets and that concentrations of 14.5% may actually have adverse effects on performance (Duff et al., 2002; Gleghorn et al., 2003). Based on these results, it does appear that formulated CP and DIP concentrations of dry rolled corn based diets can be lower than those for steam flaked based diets.

The ability of cattle to recycle N complicates the use of the MP system because net N recycling to the rumen will decrease the requirement for DIP. The NRC (1996/2000) Level 1 Model assumes no net recycling of N. However, because increasing dietary DIP percentage did not increase performance of steers; current data (Duff et al., 2002; Gleghorn et al., 2003) could be interpreted to suggest that there is net recycling of N to the rumen even with diets containing 13 to 14.5% CP (Figure 5).

**Opportunity - phase feeding of protein**

Because nutrient requirements change with the physiological state of an animal, for many years it has been proposed that dietary protein concentrations of beef cattle finishing diets can be decreased as time on feed increases (Preston; 1982; Erickson, 1998). Previous results were based
on dry rolled corn diets and(or) moderate implanting strategies. Our results with steam-flaked corn diets (Duff et al., 2002; Gleghorn, 2003) suggest the dietary CP concentration can be decreased from about 13% to 11.5% (or possibly lower) during the last 40 to 60 days of feeding without adversely affecting performance (Tables 4 and 5).

Our in vitro studies (Cole et al., 2003) suggest that ammonia emissions (per animal) increase as days on feed increases; primarily due to increased urinary N excretion (Figure 1). Thus, decreasing dietary CP concentration during the later part of the feeding period could have a greater effect on ammonia emissions than decreasing CP concentrations earlier in the feeding period.

Limitation - phase feeding of protein

There are a number of obstacles to overcome in using phase feeding systems in commercial feedyards; some are logistic (additional supplements and diets, etc.) rather than nutritional. To date, phase feeding studies have been conducted with dry rolled corn diets. Because ammonia may act as a systemic buffer, studies need to be conducted with diets that produce a greater acid load on the animal. The economic practicality of phase feeding under current feeding and management situations is equivocal as is the potential effect on digestive disturbances (Galyean, 1996). In addition, it is not known if phase feeding will “work” if dietary CP or MP concentrations are decreased earlier in the feeding period (precision feeding).

Opportunity - decreasing intake of P and other minerals

Limiting P intake. According to NRC (1996/2000) most feed grains contain at least 0.32% P. Thus, if fed at 80% of the diet, the basal P content of finishing diets should be 0.25% or more. Phosphorus from protein supplements or liquid feeds will increase this further. Erickson et al. (1999) noted that performance of yearling steers and calves was not adversely affected by feeding diets with P concentrations as low as 0.14%. Thus, it appears that supplemental P is generally not required in finishing diets.

Limitation - decreasing intake of P and other minerals

Sorghum grain and corn samples obtained at a commercial feedyard routinely had P concentrations lower than NRC (1996/2000) tabular values with concentrations as low as 0.19% (Table 5). On average, they contained 0.25 to 0.28% P and concentrations were greater than 0.23% at least 75% of the time.

Although Erickson et al. (1999), suggested that the P requirement of finishing cattle is below 0.2% of dietary DM, the diets fed were “unique.” In contrast, NRC (1996/2000) suggests finishing cattle weighing 660 to 1320 lb require 15 to 26 g of P per day. This is equivalent to 0.2 to 0.3% of dietary DM assuming a feed intake of 20 to 24 lb/day (CAST, 2002).

A number of excellent by-product feeds are currently available to nutritionists. Unfortunately, many of these have a relatively high P concentration which leads to higher P in the manure. Because of new manure application regulations (USEPA, 2003; TCEQ, 2002) this additional manure P is a potential problem for feedyards that have limited farmland on which to apply the manure. However, in yards with ample access to farmland, the use of these high-P by-products should be less of a concern.
Other Potential Opportunities and Catch-22s

Opportunities. As previously noted, the NRC (2003) publication recommended that emissions of ammonia, methane, and nitrous oxide be based on a per unit of production basis, rather than on a per CAFO basis. Thus, factors which increase production efficiency, such as the use of ionophores and growth promoting implants, probably also decrease ammonia emissions per unit of gain. Implants also decrease P excretion (Niemann, et al., 2002) and urinary N excretion. Thus, they probably decrease ammonia emissions per unit of weight gain. New feed additives, nutritional regimens, and management techniques have the potential to decrease CAFO effects on the environment.

Adding a “manure removable cost” to the cost of feeds may be beneficial in limiting the use of feeds that may produce environmental problems. For example, if manure must be applied to land based on its P content, then manure with a higher P content will have to be hauled greater distances and the manure becomes less valuable as a fertilizer. In addition poorly digested feeds can have dramatic effects on the quantity of manure produced and thus the quantity that must be transported off-site.

Many producers can receive monies through the USDA Environmental Quality Incentives Program (EQIP) to implement and improve waste management facilities, etc. Some potentially useful nutritional and management regimens probably require modifications or additions to current facilities such as feed mills. Although specifics of this program are still not clear, it might be appropriate to attempt to receive EQIP funds to modify feed mills so that improved nutritional management can be achieved.

Some Catch 22s. Gaseous emissions of ammonia, odors, etc. are all controlled by a balance of microbial activity on the feedyard (or pond) surface: significant interactions can occur. Making drastic changes in nutrition or management in order to decrease emissions of one component (ammonia for example) can potentially lead to increased emissions of other components (nitrous oxide for example).

The feeding of urea, rather than oil seed meals, potentially increases urinary N excretion and ammonia emissions (see Figure 1). However, it also decreases the quantity of P in the diet and manure.

Conclusion

The general public is demanding that everyone - and that includes agriculture - be held accountable for their impact on the environment. This could mean big changes for American agriculture and the livestock industries in particular. Basing arguments on good science, sound logic, and rational economics may not be enough. Today, and in the future, we will need to balance animal production with environmental risks. “Safety margins” in diet formulation may have to be decreased. At the present time the biggest “cushion” available is probably toward the end of the feeding period - the time period when we can probably have the greatest effect on nutrient excretion and gaseous emissions. The use of many technologies such as phase feeding and precision feeding are limited at the present time. However, nutritionists and scientists need to work together to modify and develop technologies that can be used in the future to meet new regulations and to balance animal performance, risk, and environmental concerns.
References


ASAE. 1990. Standards S303.2 and S380. IN Standards of the American Society of Agricultural Engineers, St. Joseph, MI.


Http://www.nhq.nrcs.usda.gov/Programs/ahcwd/CNMPTG.pdf


Appendix - Some Statistical Terms

(1). Skewness - A measure of deviation from a normal distribution. If low values are bunched close to the mean but high values extend far from the mean, this value will be positive. If the lower tail is extended, the value will be negative.

(2). Kurtosis - A measure of deviation from a normal distribution. For a normal distribution this value is 3. If the ratio exceeds 3 there is usually an excess of values near the mean.

(3). Mean - the weighted average.

(4). Mode - the most frequent value.

(5). Median - the point at which half the values are greater than and half the values are less than.

(6). Standard deviation - A measure of the spread or variation in individual measurements. With a normal distribution, over 2/3 of values will lie within 1 SD of the mean and 95% will lie within 2 SDs of the mean.

(7). Coefficient of variation - the standard deviation divided by the mean.

(8) 75% quartile (or percentile) - 25% of values are greater than this value.

(9) 25% quartile (or percentile) - 25% of the values are less than this value.
Table 1. NRC (2003) air quality concerns from CAFOs

<table>
<thead>
<tr>
<th>Emission</th>
<th>Global effect</th>
<th>Local effect</th>
<th>Concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₃</td>
<td>Major</td>
<td>Minor</td>
<td>Atmospheric deposition, Haze</td>
</tr>
<tr>
<td>N₂O</td>
<td>Significant</td>
<td>Insignificant</td>
<td>Climate change</td>
</tr>
<tr>
<td>NOₓ</td>
<td>Significant</td>
<td>Minor</td>
<td>Haze</td>
</tr>
<tr>
<td>CH₄</td>
<td>Significant</td>
<td>Insignificant</td>
<td>Climate change</td>
</tr>
<tr>
<td>VOCs</td>
<td>Insignificant</td>
<td>Minor</td>
<td>Quality of life</td>
</tr>
<tr>
<td>H₂S</td>
<td>Insignificant</td>
<td>Significant</td>
<td>Quality of life</td>
</tr>
<tr>
<td>PM-10</td>
<td>Insignificant</td>
<td>Significant</td>
<td>Haze</td>
</tr>
<tr>
<td>PM-2.5</td>
<td>Insignificant</td>
<td>Significant</td>
<td>Health, Haze</td>
</tr>
<tr>
<td>Odor</td>
<td>Insignificant</td>
<td>Major</td>
<td>Quality of life</td>
</tr>
</tbody>
</table>

Table 2. Effects of feeding to meet the CP requirements of 50% (9.9% CP), 84% (11.3% CP), 100% (12.8% CP), or of performance groups (precision fed): 100 head of 880 lb., large frame steers (NRC, 1984)

<table>
<thead>
<tr>
<th>Item</th>
<th>50%</th>
<th>84%</th>
<th>100%</th>
<th>Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ration cost, $ / ton</td>
<td>108</td>
<td>110</td>
<td>112</td>
<td>109</td>
</tr>
<tr>
<td>N intake, lb/d</td>
<td>34.8</td>
<td>39.8</td>
<td>45.1</td>
<td>37.4</td>
</tr>
<tr>
<td>N excreted, lb/d</td>
<td>27.9</td>
<td>31.9</td>
<td>36.1</td>
<td>29.9</td>
</tr>
<tr>
<td>ADG, lb</td>
<td>2.73</td>
<td>3.39</td>
<td>3.52</td>
<td>3.52</td>
</tr>
<tr>
<td>Feed/gain</td>
<td>8.00</td>
<td>6.49</td>
<td>6.25</td>
<td>6.25</td>
</tr>
<tr>
<td>Cost of gain, $/cwt</td>
<td>43.20</td>
<td>35.70</td>
<td>35.00</td>
<td>34.06</td>
</tr>
<tr>
<td>Days to 1280 lb</td>
<td>146</td>
<td>118</td>
<td>114</td>
<td>114</td>
</tr>
<tr>
<td>N excreted, lb/pen</td>
<td>4,073</td>
<td>3,764</td>
<td>4,115</td>
<td>3,409</td>
</tr>
</tbody>
</table>
Table 3. Variation in average daily gain of steers fed finishing diets formulated to contain 11.5 or 13% CP during the first 84 days on feed (Duff et al., 2002; Gleghorn et al., 2003)

<table>
<thead>
<tr>
<th>Item</th>
<th>Light weight block</th>
<th>Heavy weight block</th>
<th>Total or overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11.5%</td>
<td>13%</td>
<td>11.5%</td>
</tr>
<tr>
<td>Mean</td>
<td>4.18</td>
<td>4.52</td>
<td>4.36</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.57</td>
<td>0.66</td>
<td>0.59</td>
</tr>
<tr>
<td>Maximum</td>
<td>5.05</td>
<td>6.36</td>
<td>5.76</td>
</tr>
<tr>
<td>90%</td>
<td>4.84</td>
<td>5.30</td>
<td>5.14</td>
</tr>
<tr>
<td>75%</td>
<td>4.60</td>
<td>4.95</td>
<td>4.81</td>
</tr>
<tr>
<td>Median</td>
<td>4.26</td>
<td>4.49</td>
<td>4.30</td>
</tr>
<tr>
<td>25%</td>
<td>3.81</td>
<td>4.05</td>
<td>4.05</td>
</tr>
<tr>
<td>10%</td>
<td>3.54</td>
<td>3.70</td>
<td>3.55</td>
</tr>
<tr>
<td>Minimum</td>
<td>2.55</td>
<td>3.52</td>
<td>3.28</td>
</tr>
<tr>
<td>BW d 84, lb</td>
<td>1067</td>
<td>1092</td>
<td>1234</td>
</tr>
</tbody>
</table>

Table 4. Variation in average daily gain of steers fed finishing diets formulated to contain 11.5 or 13% CP from days 84 to finish (Duff et al., 2002; Gleghorn et al., 2003)

<table>
<thead>
<tr>
<th>Item</th>
<th>Light block</th>
<th>Heavy block</th>
<th>Total or overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11.5%</td>
<td>13%</td>
<td>11.5%</td>
</tr>
<tr>
<td>Mean</td>
<td>3.26</td>
<td>2.90</td>
<td>3.44</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.70</td>
<td>0.66</td>
<td>0.75</td>
</tr>
<tr>
<td>Maximum</td>
<td>4.26</td>
<td>4.48</td>
<td>5.14</td>
</tr>
<tr>
<td>90%</td>
<td>4.03</td>
<td>3.68</td>
<td>4.45</td>
</tr>
<tr>
<td>75%</td>
<td>3.68</td>
<td>3.26</td>
<td>3.90</td>
</tr>
<tr>
<td>Median</td>
<td>3.26</td>
<td>2.93</td>
<td>3.53</td>
</tr>
<tr>
<td>25%</td>
<td>2.97</td>
<td>2.51</td>
<td>2.86</td>
</tr>
<tr>
<td>10%</td>
<td>2.66</td>
<td>2.07</td>
<td>2.55</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.57</td>
<td>1.63</td>
<td>2.14</td>
</tr>
<tr>
<td>Days</td>
<td>59</td>
<td>59</td>
<td>42</td>
</tr>
</tbody>
</table>
Table 5. Variation in final overall performance of steers fed finishing diets formulated to contain 11.5 or 13% CP (Duff et al., 2002; Gleghorn et al., 2003)

<table>
<thead>
<tr>
<th>Item</th>
<th>Light weight block</th>
<th>Heavy weight block</th>
<th>Total or overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11.5%</td>
<td>13%</td>
<td>11.5%</td>
</tr>
<tr>
<td>Number</td>
<td>30</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td>Init. BW, lb</td>
<td>716</td>
<td>712</td>
<td>869</td>
</tr>
<tr>
<td>Days fed</td>
<td>154</td>
<td>154</td>
<td>126</td>
</tr>
<tr>
<td>Average daily gain, lb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>3.76</td>
<td>3.81</td>
<td>4.05</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.49</td>
<td>0.49</td>
<td>0.51</td>
</tr>
<tr>
<td>Maximum</td>
<td>4.43</td>
<td>5.12</td>
<td>5.11</td>
</tr>
<tr>
<td>90%</td>
<td>4.29</td>
<td>4.39</td>
<td>4.68</td>
</tr>
<tr>
<td>75%</td>
<td>4.10</td>
<td>4.08</td>
<td>4.32</td>
</tr>
<tr>
<td>Median</td>
<td>3.87</td>
<td>3.75</td>
<td>4.04</td>
</tr>
<tr>
<td>25%</td>
<td>3.48</td>
<td>3.54</td>
<td>3.81</td>
</tr>
<tr>
<td>10%</td>
<td>3.16</td>
<td>3.13</td>
<td>3.29</td>
</tr>
<tr>
<td>Minimum</td>
<td>2.17</td>
<td>2.91</td>
<td>3.00</td>
</tr>
<tr>
<td>Final BW, lb</td>
<td>1295</td>
<td>1295</td>
<td>1379</td>
</tr>
<tr>
<td>Carcass wt, lb</td>
<td>813</td>
<td>827</td>
<td>847</td>
</tr>
<tr>
<td>Dressing %</td>
<td>62.8</td>
<td>63.9</td>
<td>61.4</td>
</tr>
</tbody>
</table>
Table 6. Variation in crude protein analysis of five diet samples obtained at unloading from a feed truck (diets formulated to contain 13.5% CP)

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Lab 1</th>
<th>Lab 2</th>
<th>Lab 3</th>
<th>Mean</th>
<th>Std dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.3</td>
<td>14.2</td>
<td>14.1</td>
<td>14.2</td>
<td>0.10</td>
</tr>
<tr>
<td>2</td>
<td>13.4</td>
<td>14.0</td>
<td>13.0</td>
<td>13.5</td>
<td>0.50</td>
</tr>
<tr>
<td>3</td>
<td>13.2</td>
<td>14.5</td>
<td>13.0</td>
<td>13.6</td>
<td>0.81</td>
</tr>
<tr>
<td>4</td>
<td>13.6</td>
<td>14.4</td>
<td>12.7</td>
<td>13.6</td>
<td>0.85</td>
</tr>
<tr>
<td>5</td>
<td>13.5</td>
<td>13.9</td>
<td>12.8</td>
<td>13.4</td>
<td>0.56</td>
</tr>
<tr>
<td>Average</td>
<td>13.6</td>
<td>14.2</td>
<td>13.1</td>
<td>13.7</td>
<td></td>
</tr>
<tr>
<td>Std dev.</td>
<td>0.42</td>
<td>0.25</td>
<td>0.56</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>CV,%</td>
<td>3.1</td>
<td>1.8</td>
<td>4.3</td>
<td>4.45</td>
<td></td>
</tr>
</tbody>
</table>

Table 7. Variation in composition (% DM) of sorghum, corn, and diets at a commercial feedyard over 8 years (diet formulated to contain 13.5% CP; no supplemental P was added).

<table>
<thead>
<tr>
<th>Item</th>
<th>Crude protein,%</th>
<th>P,%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sorghum</td>
<td>Corn</td>
</tr>
<tr>
<td>Number of samples</td>
<td>69</td>
<td>32</td>
</tr>
<tr>
<td>Mean</td>
<td>11.15</td>
<td>9.25</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>1.05</td>
<td>1.14</td>
</tr>
<tr>
<td>Maximum</td>
<td>13.29</td>
<td>12.31</td>
</tr>
<tr>
<td>90%</td>
<td>12.40</td>
<td>10.51</td>
</tr>
<tr>
<td>75% quartile</td>
<td>11.80</td>
<td>9.58</td>
</tr>
<tr>
<td>Median</td>
<td>11.32</td>
<td>9.06</td>
</tr>
<tr>
<td>25% quartile</td>
<td>10.73</td>
<td>8.55</td>
</tr>
<tr>
<td>10%</td>
<td>9.49</td>
<td>8.30</td>
</tr>
<tr>
<td>Minimum</td>
<td>8.29</td>
<td>6.84</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.63</td>
<td>1.08</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>0.22</td>
<td>2.05</td>
</tr>
</tbody>
</table>
Figure 1. In vitro ammonia emissions from manure of steers fed diets containing 11.5, 13.0, or 14.5% crude protein (A) or fed diets in which supplemental N was from urea, cottonseed meal or a blend (50:50 on a N basis) of urea and cottonseed meal (B) (Cole et al., 2003).
Figure 2. Variation in average daily gain of pens of cattle in a feedyard over a 9 year period.
Figure 3. Variation in crude protein concentration of grain sorghum (A) and corn (B) samples obtained at a commercial feedyard over a 5 year period.
Figure 4. Variation in crude protein concentration of a finishing diet (A) formulated to contain 13.5% CP (samples obtained monthly over a 9-year period) and distribution of crude protein concentrations in feed grain and diet samples (% of samples with designated CP concentration - rounded to nearest 0.5%)

![Graph A](image1)

![Graph B](image2)
Figure 5. Effects of supplemental CP source and concentration on steer performance during the first 28 days on feed (A) or over the entire feeding period (B) (Duff et al., 2002, Gleghorn et al., 2003)
A Nutritionist's Perspective on the Updated Environmental Regulations Applicable to Beef Feedlots

Galen Erickson

Introduction

On December 15, 2002, regulations governing concentrated animal feeding operations (CAFO) were updated, published in the federal register on February 12, 2003, and will become effective on April 14, 2003. These new requirements were an update to the Clean Water Act and were accomplished because of a 25 year need and numerous federal suits filed against US EPA by environmental groups. The philosophy of this update is to regulate medium (300-999 head) to large (>1000 head capacity) operations. Across species, roughly 15,500 CAFO will be regulated, accounting for >60% of the manure according to US EPA. It is unclear how this percentage was calculated. Based on feedlot cattle, which is presumably the least intensive of all livestock, I would predict much greater control of manure nutrients. The logic is that more cattle are marketed from medium to large operations and therefore more manure is produced from medium to large operations despite the very large number of small operations. For example, in Nebraska, approximately 4380 out of 5100 feedlots are less than 1000 head. However, 93.8% of the cattle marketed were from feedlots greater than 1000 head capacity (NASS, 2002). Presumably, 93.8% of the manure is from these cattle. This is an important point for environmental groups interested in regulating large operations, but not small operations. An argument could be made that small operations (<300 head) may be more detrimental. The current prediction by EPA that 60% of manure nutrients will be regulated with the new regulation may be underestimated. This prediction implies that 40% of manure nutrients are unaccounted for and is pessimistic.

My summary of the new regulations is based on the 100 page document, printed in the Federal Register and summaries presented at the following meetings. This rule can be accessed at: http://www.epa.gov/npdes/regulations/cafo_fedrgstr.pdf.


Summary References:
Overview of the revised CAFO regulations. Mark Matthews, US EPA Region 7, presented at the 2003 Nebraska Beef Feedlot Roundtable, Grand Island, NE; February 18, 2003

CAFO Regulation

The regulations still require feedlot operations to control all runoff from areas where livestock manure is stored, or produced. This permit is termed an NPDES (National Pollutant Discharge Elimination System) permit, which essentially requires retention of all runoff from a feedlot except events greater than a 25 year, 24 hour storm. A change that may affect some feedlots is

1 Correspondence: C220 Animal Science, P. O. Box 830908; Lincoln, NE 68583-0908; ph: 402 472-6402; email: geericks@unlnotes.unl.edu
that no exemption is now available for feedlots with capacity greater than 1000 head. In the past, if no discharge was likely either because of distance to surface water, or layout, then feedlots may be offered an exemption from the permit.

Numerous other additions were included in the new regulation. Land application areas receiving manure are now regulated. This requires manure sampling and nutrient analysis, setback distance from wells and surface water when manure is spread, soil sampling and nutrient analysis of fields receiving manure, and "best management practices" (BMP) for land application of manure and pond effluent. If manure is marketed, then transfer records need to be maintained. In general, more record keeping is required, particularly for nutrient management, and records must be retained for 5 years. Another major change is an annual report, submitted to the respective State Agency that governs environmental regulations. In Nebraska, this agency is the Department of Environmental Quality. Nutrient management plans and annual reporting will be discussed in more detail, as these are the largest changes and have the most "opportunity" for nutritionists.

**Nutrient Management Plans & Reporting**

Nutrient management planning is a major change to current regulations. The requirements are not just management of total runoff water, but encompass adequate runoff storage, nutrient content of runoff, and use of effluent nutrients. Mortality management has been discussed in this area, but the regulation is unclear how these nutrients are part of the plan. Perhaps most important, the manure amounts, manure nutrient content, and distribution of manure nutrients must now be monitored. The distribution of nutrients will be evaluated based on site maps, acres available, and soil testing. States still have some flexibility on whether manure application is based on N or P, but language suggests that most states should adopt a P-based application system using either "agronomic rate", P index, or a P soil test with some threshold. This is a contentious issue because agronomic rate is poorly defined, a suitable P index which accounts for slope, moisture, soil type, etc. has not been developed for many areas, and one soil test may not be appropriate. But, the goal is the same: limit the amount of P loading in soil to minimize the impact of manure P reaching surface water once land applied. In Nebraska, the Bray P test is used as a measure of available P in soil. The six inch core cannot contain more than 150 mg/kg (ppm) of Bray P.

The importance of the N:P ratio in manure has been discussed in recent years. The issue that N is lost during manure accumulation and storage results in manure N:P ratios of 1:1 to 3:1. However, most crops contain a ratio of >5:1, which suggests that manure cannot be applied to meet the entire N needs of the crop. Methods that increase the N:P ratio in manure will be advantageous in the future. As you can deduce, increasing the N:P ratio requires increasing N and/or decreasing P in manure.

The last major change is the annual reports, submitted to the respective state agency. These reports require: number of cattle that were fed, amount of manure and wastewater generated, amount of nutrients generated, amount of manure and nutrients transferred if marketed, land application areas and amount of nutrients applied, and acres in the operation's nutrient management plan as well as the acres used the past 12 months or the year of that report.

Numerous challenges exist with the new regulations. States are implementing the programs and have some flexibility. While advantageous to set requirements at a local level, differences from state to state will make it difficult to outline one regulation. How the
distribution of nutrients is finally regulated will be a key factor. Issues such as defining agronomic rate, using a P or N based system, development of a P index, etc. are important considerations in the near future. Another issue to be aware of is that nutrient losses can be deduced from the difference between excretion and manure nutrients, and it is unclear how this will be used. The final consideration is that nutrient excretion and manure nutrient values are outdated, and incorrect for many nutrients. For example, P excretion estimates used by engineers and regulators today for beef finishing cattle are incorrect and need to be updated.

In summary, nutrient management planning will be an important component in new requirements. The key is distribution of manure nutrients and accurate accounting of nutrient flow in feedlots. Land application areas will need to be accessible, managed appropriately, and records kept on nutrient distribution. Existing CAFO operations with NPDES permits are required to file 180 days prior to current permit expiration. Existing CAFOs without NPDES permits have "a duty" to apply immediately. Operations that were below requirements that are now classified as a CAFO must apply prior to April 15, 2006. Finally, all new operations will only be permitted under these new requirements and must apply for the NPDES permit 180 days prior to operation. However, most new CAFO operations have state requirements for construction and operating permits that will incorporate these new rules changes. The Federal Register document supercedes my summary and should be used as the guideline.

**Nutrient Excretion Values**

A committee was formed to evaluate current ASAE (American Society of Agricultural Engineers) standards and update these standards with new information. These standards are the current guidelines that all state regulators use for sizing operations and determining acres for land application. An intake minus retention based model was developed to base nutrient excretion on dietary concentration and intake of nutrients as this method will lead to more accurate excretion values. This approach illustrates the importance of nutrition on nutrient excretion in livestock operations. Our focus is for feedlot cattle and updates excretion of dry matter (DM or total solids), organic matter (OM or volatile solids), N, P, Ca, K, Na, Mg, S, Cu, Fe, Se, Zn, Mn, Co, and I. This approach is being proposed to the ASAE organization in 2003 and will be presented at the 9th International Symposium on Animal, Agricultural, and Food Processing Wastes in October of 2003 in Raleigh, NC. The paper that our committee (Brent Auvermann, Roger Eigenberg, Galen Erickson, Wayne Greene, Terry Klopfenstein, and Rick Koelsch) submitted is briefly outlined.

**Approach for Updating Standards**

Diet formulation and concentration of nutrients such as crude protein, nitrogen, phosphorus, and others are critical factors in determining the amount of nutrient excreted (CAST, 2002). Therefore, nutrition must play a role in accurate determination of nutrient excretion, and accounting for variation from operation to operation. The concentration must be combined with consumption (dry matter intake or DMI is commonly used) to calculate the amount in kg, g, or mg of nutrient intake per animal. The feedlot steer will retain some (usually small amounts relative to intake) of the nutrients in the body, whereas the remainder is excreted in either urine or feces. The difference between amount consumed and amount retained in the body is equivalent to the nutrient excreted. This is the approach that we have utilized to update the nutrient excretion standards for beef cattle.
Average Diet

For accurate determination of intake, both DMI and nutrient concentration must be known. Concentrations of various nutrients used by feedlots were evaluated using a survey of 19 nutritionists (Galyean and Gleghorn, 2001). The average concentrations with minimum and maximum values that are formulated are provided in Table 1. One deviation was assumed for P because of common experience with byproduct feeding common in certain regions of the U.S. The maximum concentration for P was assumed to equal 0.50% of diet DM.

Average Performance

To calculate the amount consumed, these concentrations were multiplied by DMI. Therefore, we must know "average" performance for feedlot cattle today. This becomes very important for calculation of retention as well. Average performance was based on data collected by Professional Cattle Consultants as part of eMerge Interactive. Data were summarized from 1996 to 2002 for cattle fed in the northern, central, and southern plains regions as closeout summaries from member feedlots. The dataset included 13.94 million head of steers with the "average" animal fed in the U.S. weighing 338 kg initially, gaining 1.42 kg per day, consuming 8.84 kg of DM per day, weighing 554 kg at market, and requiring 153 days "on feed" (eMerge/Professional Cattle Consultants, Weatherford, OK). These were the input data used for calculation of DMI, retention of N, P, and Ca, and the days for calculation of total excreted. While performance of feedlot cattle is not constant, the large number of cattle represented in this dataset should accurately represent the performance for the past six years. For individual operations, performance should be used that fits their specific operation.

Retention

Retention of N was based on protein retention equations and retained energy equations using the 1996 National Research Council "Nutrient Requirements of Beef Cattle" (NRC, 1996). The complex equations take into account weights, and gain. As gain increases, retention of N, P, and Ca increase. The retention values used for the standard excretion values are based on performance of the "average" animal described initially. Retention for all other nutrients besides N, P, and Ca were calculated assuming 10% of the nutrient intake was retained when fed at requirements recommended by NRC. This assumption was used because of lack of data on retention values for all other minerals.

Table 1. Dietary assumptions on nutrients (adapted from Galyean and Gleghorn, 2001).

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Average concentration</th>
<th>Minimum concentration</th>
<th>Maximum concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM digestibility</td>
<td>80</td>
<td>70</td>
<td>85</td>
</tr>
<tr>
<td>OM digestibility</td>
<td>83</td>
<td>73</td>
<td>88</td>
</tr>
<tr>
<td>CP, % of DM</td>
<td>13.31</td>
<td>12.50</td>
<td>14.0</td>
</tr>
<tr>
<td>P, % of DM</td>
<td>0.31</td>
<td>0.25</td>
<td>0.50</td>
</tr>
<tr>
<td>Ca, % of DM</td>
<td>0.70</td>
<td>0.60</td>
<td>0.90</td>
</tr>
<tr>
<td>K, % of DM</td>
<td>0.74</td>
<td>0.60</td>
<td>1.00</td>
</tr>
<tr>
<td>Mg, % of DM</td>
<td>0.21</td>
<td>0.15</td>
<td>0.30</td>
</tr>
<tr>
<td>S, % of DM</td>
<td>0.19</td>
<td>0.10</td>
<td>0.34</td>
</tr>
<tr>
<td>Na, % of DM</td>
<td>0.138</td>
<td>0.098</td>
<td>0.197</td>
</tr>
<tr>
<td>Cu, mg/kg</td>
<td>14.8</td>
<td>6.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Zn, mg/kg</td>
<td>74</td>
<td>50</td>
<td>150</td>
</tr>
<tr>
<td>Se, mg/kg</td>
<td>0.21</td>
<td>0.10</td>
<td>0.30</td>
</tr>
</tbody>
</table>
Results and Comparisons

The average consumption of nutrients was based on performance and will be expressed as amount per finished animal. This assumes 153 days fed in the feedlot and will be consistent for presenting retention and excretion values. Assuming 8.84 kg per day for 153 days, total DM, OM, N, and P intakes were 1353, 1300, 28.8, and 4.2 kg, respectively. All excretion values proposed using the intake minus retention model are provided in Table 2. A minimum and maximum excretion was provided to offer insight into variation due to dietary concentration. These values represent the range probable for feedlot cattle today.

Excretion of DM (total solids) was based on DM digestibility of 80% on average. The new value was 270 kg with a range of 210 to 410 depending on diet digestibility ranging from 70 to 85%. Average DM excretion of 270 kg is only 46.6% of the 580 kg as the previous standard. Excretion of OM followed a similar trend as DM, with current recommendation averaging 220 kg over the 153 days, or 45% of the ASAE standard of 491 kg. This assumes OM digestibility is 83%. The observed range in digestibility is 75 to 88%.

Calculating N intake using the average protein content of 13.3% and intake of 8.84 kg per day results in 28.8 kg of N consumed. Using these body weights and gain, retention of N is only 4.2 kg or 14.5% of intake. Nitrogen excretion was similar to previous ASAE standard at 108% the previous value. Phosphorus retention is low as a percent of intake, averaging 24%. P intake averages 4.2 kg, retention is 1.0 kg, and subsequent excretion is 3.2 kg. This assumes NRC (1996) retention equations are accurate. The new recommendation for average P excretion of beef cattle is considerably lower (only 52% of 6.3 kg) than the previous ASAE standard. The lower P excretion standard would markedly decrease the amount of P estimated at feedlots. Considerable variation exists for P excretion due to variation in dietary P. Dietary P varies from no supplemental P (0.25% diet P and 2.1 kg excreted) to diets that contain byproducts high in P (0.50% diet P and 6.4 kg excreted). The previous ASAE standard is similar to the maximum excretion values predicted in diets containing elevated dietary P.

The real advantage of using the intake minus retention model proposed is accounting for changes in dietary concentrations and the subsequent effect on excretion. The most critical factor is accurately measuring nutrient intakes. As a general rule, beef feedlots monitor DMI daily and nutrient composition of diets to ensure optimum performance. This should allow for accurate determinations of nutrient intakes in most beef feedlots.

The remaining minerals in Table 2 were updated using average intakes and assumptions on retention. Similar to P, the retention values may be less precise; however, the impact on excretion is quite small. For all minerals except Zn, the updated excretion values are lower than the previous ASAE standard. However, because the range in dietary concentrations is variable in the feedlot industry, so too is excretion. Except for K and Fe, the previous standard is within the range that might be expected with feedlot diets being fed today.
Table 2. Nutrient excretion standards calculated using an intake minus retention model for beef finishing cattle. Units are expressed as amount per finished animal, either kg or g.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Units</th>
<th>Average excretion</th>
<th>Minimum excretion</th>
<th>Maximum excretion</th>
<th>Previous standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solids, DM</td>
<td>kg</td>
<td>270</td>
<td>210</td>
<td>410</td>
<td>580</td>
</tr>
<tr>
<td>Volatile solids, OM</td>
<td>kg</td>
<td>220</td>
<td>160</td>
<td>330</td>
<td>491</td>
</tr>
<tr>
<td>Nitrogen, N</td>
<td>kg</td>
<td>24.6</td>
<td>21</td>
<td>29</td>
<td>23.2</td>
</tr>
<tr>
<td>Phosphorus, P</td>
<td>kg</td>
<td>3.2</td>
<td>2.1</td>
<td>6.4</td>
<td>6.3</td>
</tr>
<tr>
<td>Calcium, Ca</td>
<td>kg</td>
<td>7.8</td>
<td>5.8</td>
<td>11.0</td>
<td>9.6</td>
</tr>
<tr>
<td>Potassium, K</td>
<td>kg</td>
<td>9.2</td>
<td>7.3</td>
<td>12.7</td>
<td>14.3</td>
</tr>
<tr>
<td>Magnesium, Mg</td>
<td>kg</td>
<td>2.7</td>
<td>1.9</td>
<td>4.0</td>
<td>3.3</td>
</tr>
<tr>
<td>Sodium, Na</td>
<td>kg</td>
<td>1.8</td>
<td>1.2</td>
<td>2.6</td>
<td>2.1</td>
</tr>
<tr>
<td>Sulfur, S</td>
<td>kg</td>
<td>2.4</td>
<td>1.2</td>
<td>4.4</td>
<td>3.1</td>
</tr>
<tr>
<td>Zinc, Zn</td>
<td>g</td>
<td>96.1</td>
<td>63.6</td>
<td>198.9</td>
<td>75.1</td>
</tr>
<tr>
<td>Iron, Fe</td>
<td>g</td>
<td>68.9</td>
<td>60.9</td>
<td>196.2</td>
<td>532.3</td>
</tr>
<tr>
<td>Copper, Cu</td>
<td>g</td>
<td>19.4</td>
<td>7.6</td>
<td>26.5</td>
<td>21.2</td>
</tr>
<tr>
<td>Manganese, Mn</td>
<td>g</td>
<td>49.1</td>
<td>24.3</td>
<td>105.5</td>
<td>81.9</td>
</tr>
<tr>
<td>Selenium, Se</td>
<td>g</td>
<td>0.27</td>
<td>0.12</td>
<td>0.39</td>
<td>--</td>
</tr>
<tr>
<td>Cobalt, Co</td>
<td>g</td>
<td>0.31</td>
<td>0.12</td>
<td>0.78</td>
<td>--</td>
</tr>
<tr>
<td>Iodine, I</td>
<td>g</td>
<td>0.93</td>
<td>0.60</td>
<td>1.95</td>
<td>--</td>
</tr>
</tbody>
</table>

*Steer fed from 338 to 554 kg over 153 days, consuming 8.8 kg per day, and diet assumptions in Table 1

*Calculated from ASAE standard D384.1 DEC99 assuming average body weight of 446 kg and 153 days

References


Example checklist: referenced from the LPES curriculum worksheets (www.lpes.org)

**Producer Checklist:**
**Nutrient Management Plan**
Use the checklist below to identify mandatory issues that must be addressed by a NMP.

**Facility Design and Management:**
- Insure adequate storage of manure, litter, and process wastewater, including adequate operation and maintenance capability.
- Mortalities must be disposed of to prevent discharge of pollutants to surface water, not in liquid manure or process wastewater treatment systems.
- Divert clean water from the production area.
- Prevent direct contact of confined animals with waters of the United States.
- Ensure that chemicals and other contaminants handled on-site are not disposed of in any manure, litter, or process wastewater, or storm water storage or treatment system.

**Land Application:**
- Identify appropriate site specific conservation practices to be implemented, including buffers to control runoff.
- Identify protocols for appropriate testing of manure, litter, process wastewater, and soil.
- Establish protocols to land apply manure, litter, or process wastewater in accordance with site specific nutrient management practices that ensure appropriate agricultural utilization of nutrients.

**Record Keeping:**
Identify specific records that will be maintained to document the implementation and management of the NMP.

**Producer Checklist:**
**Record Keeping Requirements**
Use the checklist below to identify mandatory records that must be kept on-site for five years.
- Expected crop yields.
- The date manure, litter, or process wastewater is applied to each field.
- The weather conditions at the time of application and 24 hours before and after application.
- Test methods used to sample and analyze manure, litter, or process wastewater, and soil.
- Results from manure and soil sampling.
- Explanation of the basis for determining manure application rates.
- The calculations showing the total N and P to be applied to each field, including sources other than manure.
- Total amount of N and P actually applied to each field, including calculations.
- The method used to apply the manure.
- Dates of manure application equipment inspection.
- Maintain for five years.
- Site specific NMP retained on site.
- For transfer of manure or process wastewater to other persons, provide them current nutrient analysis and document recipient information in records.

**Producer Checklist: Annual Report**
- Number and type of animals.
- Total amount of manure produced.
- Amount of manure transferred off site.
- Total acres available for land application.
- Total acres used for land application.
- Summary of discharges from production area and land application area (not including agricultural storm water discharge).
- Whether or not a certified NMP planner was used.
TCFA GUIDELINES FOR CARE AND HANDLING OF FEEDYARD CATTLE

Feedyard Sections from NCBA Guidelines for Care and Handling of Beef Cattle
Prepared by the TCFA Cattle Care Working Group

Introduction
Cattlemen have long recognized the need to properly care for livestock. Sound animal husbandry practices, based on decades of practical experience and research, are known to impact the well-being of cattle, individual animal health and herd productivity. Cattle are produced in very diverse environments and geographic locations in the United States. There is not one specific set of production practices that can be recommended for all cattle producers. These guidelines are just that — suggested guidelines. Personal experience, training and professional judgment can serve as a valuable resource for providing proper animal care. The TCFA Beef Safety and Quality Assurance Program℠ Evaluation Checklist is included in the back of this section. The evaluation includes a “Cattle Handling and Feedyard Audit Checklist.”

Producer Code of Cattle Care
Beef cattle producers take pride in their responsibility to provide proper care to cattle. The Code of Cattle Care below lists general recommendations for care and handling of cattle:

- Provide necessary food, water and care to protect the health and well-being of animals.
- Provide disease prevention practices to protect herd health, including access to veterinary care.
- Provide facilities that allow safe, humane, and efficient movement and/or restraint of cattle.
- Use appropriate methods to euthanize terminally sick or injured livestock and dispose of them properly.
- Provide personnel with training/experience to properly handle and care for cattle.
- Make timely observations of cattle to ensure basic needs are being met.
- Minimize stress when transporting cattle.
- Keep updated on advancements and changes in the industry to make decisions based on sound production practices and consideration to animal well-being.
- Persons who willfully mistreat animals will not be tolerated.

Cattle Care – Training and Education
Many skills are necessary to operate a successful farm, ranch or feedlot. On many farms and ranches, animal care principles have been passed from generation to generation. Most skills come naturally and/or are learned on the job. On farm training and ‘how to’ training is effective. The amount of training varies depending on experience of caretakers, turnover among employees and type of cattle operation. Producers and employees are encouraged to take advantage of educational programs, meetings and interaction with production management specialists. Training for those who have supervisory roles should be prioritized because they become trainers of new employees. All employees who work with livestock should have a basic understanding of livestock handling techniques.

Training of those who handle cattle should include:
- An understanding of the animal’s point of balance and flight-zone.
- Avoiding sudden movement, loud noises or other actions that may frighten cattle.
• Proper handling of aggressive/easily excited cattle to ensure the welfare of the cattle and people.
• Proper use of handling and restraining devices.
• Recognizing early signs of distress and disease.
• How to properly diagnose common illnesses and provide proper care.
• Administration of animal health products and how to perform routine animal health procedures.
• Recognizing signs associated with extreme weather stress and how to respond with appropriate actions.
• Basic feeding/nutritional management of beef cattle.

Feed and Water
Beef cattle can utilize a wide variety of feedstuffs and thrive in a broad range of environments. These environments vary from the arid Southwest ranges, to the lush pastures of the North Central states and large commercial feedyards on the High Plains. Beef cows and bulls typically graze rangelands or pastures throughout their lifetime, and are supplemented as necessary. Beef calves are usually weaned at 7-8 months of age, and a significant portion of weaned calves, called stockers, are grazed on summer pasture, cool season grasses, or small grain forages until they reach feeder cattle weight. Because cattle effectively utilize forages, many beef calves do not enter confinement feedlots until one year of age or more.

General Feeding Guidelines
Nutrition requirements vary according to age, sex, weight, breed or biological type, weather, body condition and stage of production. Diets for all classes of beef cattle, grazing or feeding, should meet the recommendation of the National Research Council (NRC) and/or recommendations of a feed consultant.

Ruminants readily adapt to varying weather conditions. For this reason, they function well in outdoor environments. During periods of decreasing temperature, feeding plans should reflect increased energy needs.

• Incoming cattle should be unloaded and provided feed and water as soon as possible.
• Provide adequate feed. Avoid feed and water interruption longer than 24 hours. When changing rations, avoid abrupt changes in the diet to minimize digestive upsets.
• Feedstuffs and feed ingredients should be of satisfactory quality to meet nutritional needs.
• Under certain circumstances (e.g., droughts, frosts, and floods), test feedstuffs or other dietary components to determine the presence of substances that can be detrimental to cattle well-being, such as nitrate, prussic acid, mycotoxins, etc.
• Producers should become familiar with potential micronutrient deficiencies or excesses in their respective areas and use appropriately formulated supplements.
• The USDA, FDA and EPA approve products for use in cattle. These products must be used in accordance with the approved product use guidelines.

Water
Cattle must have access to an adequate water supply. Estimated water requirements for all classes of beef cattle in various production settings are described in the NRC Nutrient Requirements of Beef Cattle.

Feeding Guidelines for Feeder Cattle
Feedyard cattle eat diverse diets. Regardless of the commodities used, the ration typically contains a high proportion of grain(s) (corn, milo, barley, grain by-products) and a smaller
proportion of roughages (hay, straw, silage, hulls, etc.). The NRC Nutrient Requirements of Beef Cattle lists the dietary requirements of beef cattle (based on weight, weather, frame score, etc.) and the feeding value of various commodities included in the diet.

Because of the variation in feeder cattle such as age, feeding background, ration ingredients, processing methods, etc., it is not appropriate to outline a standard protocol for starting cattle on a feedlot receiving diet and transitioning them to a finishing diet.

General guidelines include:
- Use the NRC Nutrient Requirements of Beef Cattle as the basis of ration formulation.
- Consult a nutritionist (private consultant, university or feed company employee) for advice on ration formulation and feeding programs.
- Avoid sudden changes in ration composition or amount of dry matter ration offered.
- Monitor changes in feces, incidence of digestive upsets (acidosis or bloat) and foot health to evaluate the feeding program.
- A small percentage of cattle in feedyards develop laminitis or founder. Mild cases do not affect animal welfare or performance; however, hooves that are double their normal length may compromise movement. Extreme cases should be provided appropriate care and marketed as soon as possible.

Disease Prevention Practices and Health Care
Like other species, cattle are susceptible to infectious diseases, metabolic disorders, toxins, parasites, neoplasia and injury. Economic losses are reduced by early intervention through health management programs. Healthy herds are more productive.

Many diseases can be prevented or minimized by proper nutrition based on NRC guidelines. Others are controlled by vaccination, parasite control, use of feed additives, biosecurity and other forms of management. Not all diseases can be controlled by vaccination. In some cases, such as cryptosporidiosis, no vaccine exists.
- The producer should work with a veterinarian and/or nutritionist to determine the risk of infectious, metabolic and toxic diseases and to develop effective management programs when designing a herd health plan.
- Producers and their employees should have the ability to recognize common health problems and know how to properly utilize animal health products and other control measures.
- When prevention or control measures are ineffective, the producer should promptly contact a veterinarian for a diagnosis and treatment program to reduce animal suffering and animal losses.
- The use of a diagnostic laboratory to provide a definitive diagnosis is highly recommended for unusual or questionable cases.
- In areas where handling facilities are not readily available, alternative traditional restraining techniques are sometimes necessary. There must be a balance between the stress of handling cattle and the benefits derived from health care procedures.

Stocker and Feeder Cattle
- Weaning, commingling, marketing and transportation predispose calves to disease, primarily Bovine Respiratory Disease (BRD).
- All incoming stocker and feeder cattle should be vaccinated as directed by a veterinarian. The use of vaccines and parasite control should be based on risk assessment and efficacy of available animal health products.
- Procedures such as castration and dehorning are done for the protection of the animal, other cattle in the herd and people who handle the cattle. Early castration improves
animal performance gain and reduces health complications. Castration prior to 120 days of age or when calves weigh less than 500 pounds is strongly recommended. Acceptable reasons to delay castration are if bull calves are being considered as seedstock or to be finished as intact bulls. Producers should vaccinate against tetanus when bands are used for castration.

- Tipping of horns (removing the tip only) can be done with little impact on the well-being of individual animals.
- A local anesthetic should be used when heifers are spayed using the flank approach.
- High risk cattle should be checked at least daily for illness, lameness or other problems during the first 30 days following arrival.
- Pregnancy in immature heifers can result in calving difficulties and subsequent trauma to the birth canal, paralysis or death of the heifer. For these reasons it is often more humane to terminate pregnancy. This should be done under the direction of a veterinarian.
- If heifers in the feedyard or a stocker operation deliver a full-term, healthy calf, it should be allowed to nurse to obtain colostrum. At all times, these calves must be handled humanely and provided proper nutrition. Compromised calves or fetuses should be promptly euthanized and disposed of according to local regulations.
- “Bulling” is a term to describe aggressive riding of a steer by one or more penmates. This occurs both on pasture and in the feedlot, but is more commonly noticed in feedlot cattle. Bullers should be promptly removed from the pen to prevent serious injury.

**Identification**

Permanent identification can be an important management tool. The industry encourages continued development and application of identification methods that can be retained throughout the animals' life cycle, are readily legible and economically feasible.

- When cattle are housed or pastured where they can be readily checked, identification systems such as ear tags are encouraged.
- Hot or freeze branding is necessary under many management conditions. Hot branding in some states is the only legal proof of ownership. In remote locations, when communal grazing is practiced and in many other situations, branding remains the most practical means of permanent identification.
- If cattle are branded, it should be accomplished quickly, expertly and with the proper equipment.
- Feeder cattle should not be re-branded when entering a feedlot unless required by law. Brands should be of appropriate size to achieve clear identification.
- Jaw brands should not be used.
- Ear notching may be used to identify cattle.
- Wattling, ear splitting and other surgical alterations for identification are strongly discouraged.
- Use of emerging cattle identification technology, such as electronic ear tags and retinal scans is encouraged when practical.

**Shelter and Housing**

Cattle reside on pastures and ranges and in various types of feedlots. Genetic variation among cattle species, breeds and individuals makes it possible for them to thrive in a wide range of natural conditions and artificial environments. When behavioral and physiological characteristics of cattle are matched to local conditions, beef cattle thrive in virtually any environment in the United States without artificial shelter. Protection may be beneficial (especially for newborns) during adverse weather conditions. Housing facilities should be designed and constructed to promote the animals' comfort and to enhance their health.
• Cattle on rangelands and pastures are stocked at various rates, depending mostly on forage production.
• Cows, calves, and bulls are held in close confinement for routine processing, veterinary care, weighing or transportation.
• Cattle in backgrounding facilities or feedyards must be offered adequate space for comfort, socialization and environmental management. The allotted space is dependent upon body weight, rainfall, evaporation rate, geographic region, and type of pen surface, pen slope and presence of mounds. Cattle spacing has an influence on manure moisture content and therefore on dust, runoff and mud conditions. Because of this, it is impossible to construct a precise set of recommendations.
• Pen maintenance, including manure harvesting, will help improve pen conditions.
• Mud is more of a problem in the winter with low evaporation rate or improper drainage conditions. Accumulation of mud on cattle should be monitored as a measure of pen condition and cattle care in relation to recent weather conditions.
• Feedyards should use dust reduction measures to improve animal performance. Control measures may include: wetting unpaved roadways; scraping feedlot surfaces; wetting feedlot surfaces if adequate water is available; increasing the stocking rate, therefore increasing the effective "precipitation."
• Floors in housing facilities should be properly drained.
• Floors of barns and handling alleys should provide traction to prevent injuries to animals and handlers.
• Handling alleys and housing pens must be free of sharp edges and protrusions to prevent injury to animals and handlers.
• Mechanical and electrical devices used in housing facilities must be safe.

Cattle Handling
Cattle are gathered to perform routine husbandry procedures, such as veterinary care, weighing, sorting, weaning and transportation to and from pastures, feedlots and livestock markets.

Handling procedures must be safe for the cattle and caretakers, and cause as little stress as possible. Facilities should be designed and constructed to take advantage of cattle's natural instincts.

Facilities
Cattle handling facilities do not have to be elaborate or expensive. Proper design and quick recognition of problems that impede cattle flow are essential for safe, efficient cattle handling.
• Design and operate alleys and gates to avoid impeding cattle movement. When operating gates and catches, reduce excessive noise, which may cause distress to the animals.
• Adjust hydraulic or manual restraining chutes to the appropriate size of cattle to be handled. Regular cleaning and maintenance of working parts is imperative to ensure the system functions properly and is safe for the cattle and handlers.
• Avoid slippery surfaces, especially where cattle enter a single file alley leading to a chute or where they exit the chute. Grooved concrete, metal grating (not sharp), rubber mats or deep sand can be used to minimize slipping and falling. Quiet handling is essential to minimize slipping. Under most conditions, no more than 2% of the animals should fall outside the chute. A level of more than 2% should indicate a review of the process may be of value, including asking questions such as: is this a cattle temperament issue, has something in the handling area changed that is effecting cattle behavior, etc.?
Cattle Handling

- Abuse of cattle is not acceptable under any circumstances.
- Take advantage of cattle’s flight zone and point of balance to move them. For safety and welfare reasons, minimize the use of electric prods. Non-electric driving aids, such as plastic paddles, sorting sticks, flags or streamers (affixed to long handles) should be used to quietly guide and turn animals. When cattle continuously balk, cattle handlers should investigate and correct the reason rather than resort to overuse of electric prods.
- Under desirable conditions, 90% or more of cattle should flow through cattle handling systems without the use of electric prods.
- When cattle prods must be used, avoid contact with the eyes, rectum, genitalia and udder.
- Driving aids powered by AC current should never be used unless manufactured and labeled specifically for that purpose. Voltage must be regulated to less than 50 volts.
- Some cattle are naturally more prone to vocalize, but if more than 5% of cattle vocalize (after being restrained but prior to procedures being performed) it may be an indication that chute operation should be evaluated. Key questions to ask include: is this a cattle temperament issue or effect of prior handling, are chute pressures and catching methods appropriate, or should they be re-evaluated?
- If more than 25% of cattle jump or run out of the chute there should be a review of the situation and questions asked such as: is this a result from cattle temperament or prior handling issue, was the chute operating properly, etc.? Evaluate handling procedures to determine if practices need to be improved or whether the problem is cattle temperament.
- Properly trained dogs can be effective and humane tools for cattle handling. During chute-side cattle processing procedures, dogs that continually bark, impede cattle flow or are unnecessarily rough with cattle should not be used.

Marketing Cattle

The overwhelming majority of cattle are marketed in good health and physical condition. Some compromised cattle should not enter intermediate marketing channels because of animal welfare concerns. Instead, these cattle should be sold directly to a processing plant or euthanized (see Euthanasia section), depending upon the severity of the condition, processing plant policy, and state or USDA regulations.

Sorting Loading and Transporting

Cattle sorting, loading, unloading and transportation is a necessary part of the cattle industry.
- Cattle sorting and holding pens should allow handling without undue stress, be located near the loading/unloading facility and be suitable for herd size.
- Provide properly designed and maintained loading facilities for easy and safe animal movement. Proper design of loading chutes as well as personnel that are knowledgeable of their proper use can assure the safety of both cattle and cattlemen. Ramps and chutes should be strong and solid, provide safe footing, and have sides high enough to keep cattle from falling or jumping off. Studies indicate limiting the ramp angle to 25 degrees or less will improve cattle movement.
- All vehicles used to transport cattle should provide for the safety of personnel and cattle during loading, transporting and unloading.
- All vehicles used to transport cattle should have properly maintained flooring, gates, and latches and adequate ventilation.
- Strictly adhere to safe load levels with regard to animal weight and space allocation.
- Producers hauling cattle in farm and ranch trailers must ensure that adequate space is provided so that cattle have sufficient room to stand with little risk of being forced down because of overcrowding.
Transport crews should have a proper understanding on the basics of transportation and handling cattle. Crews should be aware of basic animal-handling techniques. Cattle that are unable to withstand the rigors of transportation should not be shipped. When the vehicle is not full, safely partition cattle into smaller areas to provide stability for the cattle and the vehicle. Cattle haulers should start, drive and stop their vehicles as smoothly as possible. They should practice defensive driving by ensuring that adequate space is available to stop should an emergency require an unexpected stop. In addition, they should negotiate turns in a smooth manner. Abrupt sharp turns should be avoided. Knowingly inflicting physical injury or unnecessary pain on cattle when loading, unloading or transporting animals is not acceptable. Use internal or external ramps to unload trucks. No gap which would allow injury to an animal should exist between the ramp, its sides, and the vehicle. Vehicle doors and internal gates should be sufficiently wide to permit cattle to pass through easily without bruising or injury. Cattle should be loaded, unloaded, and moved through facilities with patience and as quietly as possible to reduce stress and injury.

Non-Ambulatory (Downer) Cattle
Cattle can become downers for several reasons, including injury, severe disease and chronic emaciation. With proper care, many of these will recover and become productive animals. It is the responsibility of livestock owners and caretakers to make every effort to provide proper care for non-ambulatory livestock. Physical management of downer cattle presents challenges as they may weigh over 1000 pounds.

- A prompt diagnosis should be made to determine whether the animal should be humanely euthanized or receive additional care.
- Provide feed and water to non-ambulatory cattle at least once daily.
- Move downer animals very carefully to avoid compromising animal welfare. Dragging downer animals is unacceptable. Likewise, animals should not be lifted with chains onto transportation conveyances. Acceptable methods of transporting downers include a sled, low-boy trailer or in the bucket of a loader. Animals should not be "scooped" into the bucket, but rather should be humanely rolled into the bucket by caretakers.
- When treatment is attempted, cattle unable to sit up unaided (i.e. lie flat on their side) and refuse to eat or drink should be humanely euthanized within 24-36 hours of initial onset.
- Signs of a more favorable prognosis include the ability to sit up unaided, eating and drinking. It is acceptable to allow more time for recovery for these animals, provided they are offered water, feed and the weather is moderate to good. If weather creates inhumane conditions or the animal’s condition deteriorates, it should be humanely euthanized.
- Cattle that are non-ambulatory must not be sent to a livestock market or to a processing facility. If the prognosis is unfavorable or the animal has not responded to veterinary care, it should be humanely euthanized.

Euthanasia
Euthanasia is humane death occurring without pain and suffering. The decision to euthanize an animal should consider the animal's welfare. The producer will most likely perform on-farm euthanasia because a veterinarian may not be immediately available to perform the service. The person performing the procedure should be knowledgeable of the available methods and have the necessary skill to safely perform humane euthanasia; if not, a veterinarian must be contacted. When euthanasia is necessary an excellent reference is the Practical Euthanasia
of Cattle guidelines developed and published by the American Association of Bovine Practitioners.

Reasons for euthanasia include:
- Severe emaciation, weak cattle that are non-ambulatory or at risk of becoming downers.
- Downer cattle that will not sit up, refuse to eat or drink, have not responded to therapy and have been down for 36 hours or more.
- Rapid deterioration of a medical condition for which therapies have been unsuccessful.
- Severe, debilitating pain.
- Compound (open) fracture.
- Spinal injury.
- Central nervous system disease.
- Multiple joint infections with chronic weight loss.

Emergency Procedures
Develop a plan to ensure the welfare of the animals when unforeseen emergencies occur.
Post names and telephone numbers of the producer or management, veterinarian, equipment suppliers, and the fire and police departments near telephones, along with directions to the cattle operation, including road names and numbers. The person in charge should review possible emergencies that might arise and review these plans with other employees so everyone is familiar with the appropriate emergency response.
- Make advanced plans for dealing with emergencies, such as flooding, blizzards, heat, ice storms or a reportable disease outbreak. If a disease outbreak should occur, notify a veterinarian.
- Arrange animal care to cover weekends, holidays, unexpected absences and other leaves and emergencies. All workers should be qualified to perform assigned duties. Establish a procedure for emergency animal health care after hours, weekends and holidays.
- Almost all operations have some supply of feedstuffs on hand. Make sure adequate feed is available for emergencies, such as winter storms.
- Fire extinguishers should be readily accessible in confinement buildings.

Emergency Transportation Procedures for Haulers under the Control of the Producer
- Provide emergency procedures for cattle haulers in the event of a breakdown, an accident, or other delay during transit.
- Be sure cattle hauler(s):
  1. Know the telephone number of the home or office of the shipper and receiver to immediately report an emergency situation (appropriate numbers should be furnished by shippers).
  2. If necessary, arrange for another vehicle to move the load to a holding facility or final destination.

Feedlot Heat Stress Procedures
- During periods of high heat and humidity and little wind, actions should be taken to minimize the effects of heat stress as cattle are processed.
- Provide adequate water.
- If possible, avoid handling cattle when the risk of heat stress is high. The final decision must consider temperature, humidity, wind speed, phenotype and cattle acclimation. If cattle must be handled, a general rule is to work them before the Temperature Humidity Index (THI) reaches 84 if possible. As an example, when the temperature is 98° F and the humidity is 30%, the THI is 83. At a constant temperature, the THI increases as the relative humidity increases. Each one mile per hour increase in wind
speed decreases the THI by approximately one. More information can be found in NebGuide G00-1409-A (www gpvec.unl.edu).

- Work cattle more prone to heat stress first, earlier in the day or later if conditions moderate. For example, larger cattle should be processed at lower stress times of the day.
- Limit the time cattle spend in handling facilities where heat stress may be more significant.

**Maintaining and Improving Cattle Care and Handling Implementation and Review Programs**

Throughout these guidelines, general “rules of thumb” are provided that can be used as indicators of the performance of cattle handling systems and the employees managing them. Since cattle behavior varies as a result of genetics and previous experiences, there is no one set of performance targets. However, the indicators listed in this document can be helpful in conducting periodic evaluation of cattle care and handling practices. Management practices should be informally assessed every day to ensure that animal welfare is not compromised. Regardless, producers are encouraged to implement a system to verify efforts directed towards animal care and handling.

This can be accomplished by:

- Establishing a network of resources on cattle care.
- Following the Cattle Care and Handling Guidelines.
- Keeping track of training and education activities.
- Conducting self-audits or external audits of animal care and handling procedures.

Informal self-reviews should be periodically conducted by those involved with cattle feeding and care. In other words, managers and employees should continually ask themselves if they are following proper cattle care and handling procedures. Results should be reviewed by those responsible for animal care welfare to assess the effectiveness of the program and to determine training needs.

**Summary**

Cattlemen have, in many cases, passed on animal care principles from generation to generation. More recently, research has provided additional information that can supplement experience and provides the basis for many day-to-day decisions about animal husbandry. Management programs should be science-based and common-sense driven. As such, the cattle industry continues its commitment to proper care and handling of livestock. TCFA has adapted these guidelines for feedyard use by deleting sections pertaining only to cow/calf and stocker cattle producers. The TCFA Beef Safety and Quality Assurance ProgramSM Evaluation Checklist is included in the back of this section. The evaluation includes a “Cattle Handling and Feedyard Audit Checklist.”
For Additional Information:

Training Materials
- National Institute for Animal Agriculture (NIAA):
  - Cattle Handling and Transportation (video)
  - Livestock Handling Guide (pamphlet)
  - Livestock Trucking Guide (pamphlet)
  - Proper Handling Techniques for Non-Ambulatory Animals (pamphlet)
- Flight Zone and Point of Balance
  - www.grandin.com/behavior/principles/flight.zone.html

Transporting Cattle
- Cattle and Swine Trucking Guide for Exporters, USDA Agricultural Marketing Service publication, published May 1997

Euthanasia
- Practical Euthanasia of Cattle, American Association of Bovine Practitioners

Heat Stress
- NebGuide G00-1409-A, www.gpvec.unl.edu

Additional References
- FASS 1999
- Midwest Planning Service (MWPS) Handbooks
# TCFA Beef Safety and Quality Assurance Program℠
## Evaluation Checklist

**Feedyard Name:**

**Date of Evaluation:**

**TCFA Staff:**

**Consultant(s):**

**Quality Control Points**

(Established in 1986)

<table>
<thead>
<tr>
<th>Quality Control Points</th>
<th>Yes</th>
<th>No</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Receiving (Quality)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grain receiving reports</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silage Receiving</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Managerial observations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roughage Receiving</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Managerial observations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed Fat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab results</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab results</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed Supplements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab results</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incoming Cattle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receiving reports</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle Identification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tagging</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Branding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injections (Quality)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processing records/maps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implant/Re-implant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implant/re-implant schedule</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processing records</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Banding/Tipping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment records</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle Handling (Loading, Receiving, Shipping)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weigh-up time vs. pick-up time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purchasing of Pharmaceuticals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Invoices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory records</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receiving and Storage of Pharmaceuticals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory records</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature log</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling of Pharmaceuticals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory records</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disposal records</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Grain Receiving (Mycotoxins)

<table>
<thead>
<tr>
<th>Records Verification</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. On-site analysis (black light or test kits)</td>
<td></td>
</tr>
<tr>
<td>2. Lab analysis</td>
<td></td>
</tr>
<tr>
<td>3. Labeling by Feed &amp; Fert. Control service</td>
<td></td>
</tr>
</tbody>
</table>

## Feed Medications

<table>
<thead>
<tr>
<th>Records Verification</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Assay results</td>
<td></td>
</tr>
<tr>
<td>2. Batching reports</td>
<td></td>
</tr>
<tr>
<td>3. Inventory control logs</td>
<td></td>
</tr>
<tr>
<td>4. Maintenance and calibration logs</td>
<td></td>
</tr>
</tbody>
</table>

## Supplement Receiving

<table>
<thead>
<tr>
<th>Records Verification</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Supplier certification statements</td>
<td></td>
</tr>
<tr>
<td>2. Supplement invoices &amp; analysis</td>
<td></td>
</tr>
<tr>
<td>3. Delivery tickets signed by scale person</td>
<td></td>
</tr>
</tbody>
</table>

## Injections (Broken Needles)

<table>
<thead>
<tr>
<th>Records Verification</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Processing records</td>
<td></td>
</tr>
<tr>
<td>2. Individual records</td>
<td></td>
</tr>
</tbody>
</table>

## Processing & Treatment

<table>
<thead>
<tr>
<th>Records Verification</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lot Withdraw Report/Date Clean</td>
<td></td>
</tr>
<tr>
<td>2. Individual Withdraw Report/Date Clean</td>
<td></td>
</tr>
<tr>
<td>(a,b,c, and d apply to both 1 &amp; 2)</td>
<td></td>
</tr>
<tr>
<td>a. Treatment records with dates</td>
<td></td>
</tr>
<tr>
<td>b. Date of shipment</td>
<td></td>
</tr>
<tr>
<td>c. Number of days post treatment</td>
<td></td>
</tr>
<tr>
<td>d. Extra label withdraw period</td>
<td></td>
</tr>
<tr>
<td>Cattle Arrival and Treatment Programs:</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Cattle arrival and treatment programs are designed by a veterinarian?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cattle Handling:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Use of electric prods -- &quot;E&quot;</td>
</tr>
<tr>
<td>2. Cattle that fall when exiting the chute -- &quot;F&quot;</td>
</tr>
<tr>
<td>3. Cattle that jump or run when exiting the chute -- &quot;J&quot;</td>
</tr>
<tr>
<td>4. Cattle that vocalize after being restrained in the chute, but before procedures are performed -- &quot;V&quot;</td>
</tr>
<tr>
<td>5. Cattle observed being handled without issue -- &quot;(-)&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentage Observed</th>
<th>Maximum Acceptable Percentage</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric prods:</td>
<td>%</td>
<td>10 %</td>
</tr>
<tr>
<td>Cattle falling:</td>
<td>%</td>
<td>2 %</td>
</tr>
<tr>
<td>Cattle jumping or running:</td>
<td>%</td>
<td>25 %</td>
</tr>
<tr>
<td>Cattle vocalizing</td>
<td>%</td>
<td>5 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-Ambulatory (Downer) Cattle:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downer cattle are properly moved (i.e., loader, trailer, etc.)?</td>
</tr>
<tr>
<td>Downer cattle unable to eat or drink are humanely euthanized within 24-36 hours of initial onset?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cattle Unloading, Sorting and Loading Facilities (mark with &quot;(/)&quot;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unloading</td>
</tr>
<tr>
<td>Excellent (well maintained, non-slip floor, no broken gates/fences, etc.)</td>
</tr>
<tr>
<td>Acceptable (non-slip floor, facilities in need of minor repairs, etc.)</td>
</tr>
<tr>
<td>Not Acceptable/Fail (slick floor on ramps or scales, facilities in need of major repairs, etc.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cattle Comfort:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle have free access to feed, water, and space for freedom of movement?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water Troughs:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfactory -- &quot;S&quot;</td>
</tr>
<tr>
<td>Unacceptable -- &quot;U&quot; (algae, manure, or inadequate quantity, etc.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feed Bunks:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfactory -- &quot;S&quot;</td>
</tr>
<tr>
<td>Unacceptable -- &quot;U&quot; (moldy, sour, packed, unpalatable, etc.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cattle Mud Score:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfactory -- &quot;S&quot; (Clean animals or only mud on legs and knees)</td>
</tr>
<tr>
<td>Unsatisfactory -- &quot;U&quot; (Excessive mud caked on belly and sides)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pen</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>P / F</th>
</tr>
</thead>
</table>

3/03
Ecology and Feedlot Epidemiology of *E. coli* O157:H7

G. H. Loneragan*, M. M. Brashears†, D. U. Thomson‡

*Feedlot Research Group, Division of Agriculture, West Texas A&M University, Canyon, TX; †Department of Animal and Food Sciences, Texas Tech University, Lubbock, TX; and ‡Cactus Operating Ltd, Amarillo, TX.

*Escherichia coli* O157 is an important food-borne pathogen within the Enterobacteriaceae family; it is a facultatively anaerobic, Gram-negative, and non-sorbitol fermenting bacterium. O157 refers to a specific somatic antigen and is a specific side chain on the bacterium’s lipopolysaccharide. The majority of *E. coli* O157 possess the H7 flagella and are, therefore, motile. Approximately 10 to 20% of *E. coli* O157 isolates, however, are non-motile and are commonly designated *E. coli* O157:NM. *E. coli* O157 is one of several disease-causing organisms classified as enterohemorrhagic *E. coli* (EHEC). Although other EHEC such as O26:H11, O103, O104, O111, and O128 sporadically cause disease, O157 is the primary EHEC associated with illness in the US.

Outcomes associated with human exposure to *E. coli* O157 include clinically inapparent infection, mild to severe diarrhea, hemorrhagic colitis, and hemolytic uremic syndrome. The latter is life threatening and predominately occurs in children or those with compromised immunity. Virulence factors important in the pathogenesis of *E. coli* O157-induced disease include intimin, other attaching and effacing determinants, hemolysin, and production of shiga-like toxin (*stx1* and/or *stx2* (also referred to as verocytotoxin i.e., *vtx1* and *vtx2*)).

Cattle are the primary reservoir of *E. coli* O157 because this bacterium is uniquely adapted to survival and propagation within the bovine gastrointestinal tract with the likely sites of colonization being the cecum and colon (Grauke et al., 2002). More recent work indicates the rectoanal junction is the site for colonization in experimentally infected animals (Naylor et al., 2003). Although *E. coli* O157 can be life-threatening to humans, naturally acquired infections do not cause overt disease in cattle. *E. coli* O157 is readily recovered from other body surfaces of cattle such as the hide and oral cavity (Keen and Elder, 2002). It is uncertain if recovery from these sites implies site-specific colonization or simply fecal cross-contamination.

As with all enteric bacteria, transmission is via the fecal-oral route and the majority of cattle are initially exposed to *E. coli* O157 prior to weaning (Laegreid et al., 1999b). Transmission may occur via direct exposure from animal to animal or indirectly from the environment. Commingling of animals from multiple sources likely provides for exposure to novel strains of *E. coli* O157 with resultant clonal expansion. Once infected, animals may either clear the infection or become colonized indefinitely. Colonized animals shed fluctuating numbers of the organism with

---

1 A modified version of this paper was originally presented at the Beef Industry *E. coli* Summit Meeting, San Antonio, TX, January 7-8, 2003.
intermittent periods of high-level shedding. Mechanisms associated with intermittent shedding have not been characterized.

*E. coli* O157 can survive in soil, manure, and slurry for extended periods of time (Jiang et al., 2002; Kudva et al., 1998). Survival was greater when manure-amended soil was held at 21°C compared with 5°C (Jiang et al., 2002) but decreased as the temperature of manure approached 37°C or greater (Himathongkham et al., 1999). Others have shown the organism can survive for up to 21 months in manure (Kudva et al., 1998). *E. coli* O157 can be recovered from vegetation (particularly if the crop ground was fertilized with manure), flies (Keen et al., 2002), prepared feedlot diets (Sargeant, 2002), and water (LeJeune et al., 2001). Therefore, feed and water may also be an important vehicle by which cattle populations are exposed to *E. coli* O157 in addition to transmission from animals and the environment (Shere et al., 2002). While multiple environmental sources have been identified, none have been identified as the primary factor involved with transmission or shedding.

Estimates of shedding prevalence vary widely. Ostensibly, it would appear the prevalence of *E. coli* O157 has increased over time. Although this may have occurred, actual increases in prevalence estimates can be primarily attributed to methodological improvements that have increased the sensitivity of culture and isolation of this organism. It is not possible to determine if the prevalence of *E. coli* O157 has increased or decreased using existing data.

Although some data provide an insight into the epidemiology of *E. coli* O157 on cow-calf operations, most research has been performed on cattle confined in either feedlots or dairies. By weaning, 83% of calves from 15 operations had been exposed to *E. coli* O157 (Laegreid et al., 1999a). Others found that initial infection occurs within a couple of weeks of birth indicating that the shedding status of cows may be of importance in subsequent calf exposure (Gannon et al., 2002). Of mature cows sampled three times during October through December, *E. coli* O157 was recovered from 9.1% of animals at least once (Riley et al., 2003). Others have detected shedding in up to 26% of cows one week postpartum. Whereas shedding is thought to decrease in mature animals, cull cows, which are typically older animals, may be at greater risk of shedding.

*E. coli* O157 was detected on all operations and 50 - 70% of pens during two recent studies that included samples from in excess of 70 feedlots (NAHMS, 2001; Sargeant, 2002). *E. coli* O157 was cultured from 10 to 11% of the fecal pats sampled (n>10,000 for both studies). Recent research, however, indicates standard fecal pat sampling substantially underestimates the prevalence of positive fecal pats (Loneragan et al., 2003). In another study in which all cattle from 29 pens of cattle (n=3,162) were sampled, *E. coli* O157 was detected in 23% of cattle and all pens had at least one positive animal (Smith et al., 2001). More recently, *E. coli* O157 was cultured from 66.7% of conventionally fed feedlot cattle on at least one occasion when animals were repeatedly sampled over time (Brashears et al., 2003). Shedding typically increases shortly after arrival and then decreases in a classical epidemic curve. Shedding is also greatest during the warmer months and in one study peaked at 19.9% during September.
compared to approximately 3.5% during February (NAHMS, 2001). Evidence of substantial pen to pen variation in shedding has been observed (NAHMS, 2001; Smith et al., 2001).

*E. coli* O157 shedding is of importance to the safety of edible beef products because pre-harvest status is correlated with carcass contamination (Elder et al., 2000). Hides rather than feces appear to be the primary source for contamination of carcasses. The proportion of carcasses from which *E. coli* O157 is isolated is greater than the proportion of positive animals. In addition, more strains of *E. coli* O157 are isolated from carcasses than from animals pre-harvest (Barkocy-Gallagher et al., 2001). It is postulated that these findings provide evidence for cross-contamination at harvest, presumably during hide removal. Because pre-harvest shedding of *E. coli* O157 is associated with subsequent carcass contamination, it seems likely that the increase in human illnesses caused by *E. coli* O157 during summer and early fall months is in part a consequence of a temporarily associated seasonal increase in shedding by cattle. There is a great need, therefore, to identify factors associated with modulation of shedding pre-harvest.

Several factors have been associated with statistically significant variation in risk of shedding. These included season, the use of barley or soy meal in the diet (Dargatz et al., 1997), muddiness of the pen surface, presence of cats, days since feedlot arrival, arrival weight, antimicrobial usage, and cleanliness of the drinking water (Brashears et al.; Dargatz et al., 1997; NAHMS, 2001; Sargeant, 2002; Smith et al., 2001). Seasonal factors and pen to pen variation appear to account for the greatest proportion of variation in *E. coli* O157 shedding. Other factors are inconsistently identified among the various epidemiological studies. This may indicate certain risk factors may have been identified by chance i.e., a spurious finding, or that subtle differences in study design lead to researchers failing to detect those risk factors described by others. In all epidemiological studies to date, however, most of the variation in shedding of *E. coli* O157 is unexplained. Several factors have been associated with modulation of shedding in experimentally challenged cattle. But because research using artificially challenged cattle often leads to conflicting results from findings using naturally infected cattle, inferences drawn from experimentally infected cattle may be tenuous.

It is unavoidable that multiple sources of cattle will be assembled in feedlots because of the structure of the U.S. cattle industry. Whereas there are approximately 1.05 million cattle herds on which calves are born and raised (NASS; 2002a), in excess of 84.4% of fed cattle are finished in only 1,810 feedlots (NASS, 2002b). Therefore, clonal expansion of various strains of *E. coli* O157 will occur when animals are commingled in feedlots because most animals are infected with *E. coli* O157 prior to weaning and some animals will inevitably carry this bacterium to the feedlot and subsequently expose cattle to novel strains. In essence, all feedlots will have positive animals and essentially all feedlot cattle will be positive at some stage. Even if negative animals were to be identified and segregated, it is probable they too will become infected and shed *E. coli* O157 (Keen, 2002). Even though there are many differences in management of cattle
between feedlots, little variation in feedlot-to-feedlot shedding of *E. coli* O157 exists (NAHMS, 2001; Sargeant, 2002). Therefore, identification and exploitation of management factors used by specific feedlots to reduce the prevalence of *E. coli* O157 is unlikely.

If pre-harvest shedding could be reduced, the pathogen load entering packing plants would be lowered. However, factors associated with shedding of *E. coli* O157 in cattle are complex and uncertain. Shedding displays temporal and spatial variation with the greatest degree of shedding occurring in the warmer months and soon after cattle arrive at feedlots. Beyond the limits of basic husbandry of clean feed and water, and a well drained environment, it is not presently possible or prudent to recommend management strategies to mitigate pre-harvest shedding of *E. coli* O157. It is conceivable that recommendations that are not based on sound scientific evidence may actually be counterintuitive and increase shedding of *E. coli* O157 (Keen, 2002). There are, however, several targeted intervention strategies currently being evaluated that may be of benefit in reducing the prevalence of this important pathogen.

Further research is needed to address pre-harvest mitigation of *E. coli* O157 at all stages of the production continuum and to address uncertainties associated with shedding such as factors leading to the seasonal increase in prevalence during the warmer months of the year. Elimination of risk associated with *E. coli* O157 is improbable; however, pre-harvest risk reduction may be possible. The site of greatest risk reduction will continue to be at our Nation’s packing plants.

**Acknowledgments**

The authors would like to acknowledge the following for help in providing invaluable data and ideas used to formulate this paper:

- Robert O. Elder, PhD. USDA:ARS. College Station, TX.
- Jim E. Keen, DVM, PhD. USDA:ARS: U.S. Meat Animal Research Center, Clay Center, NE.
- Paul S. Morley, DVM, PHD. Department of Environmental Health, Colorado State University, Ft. Collins, CO.
- Jan M. Sargeant, DVM, PhD. Food Animal Health and Management Center, Kansas State University, Manhattan, KS.
- David R. Smith, DVM, PhD. Department of Veterinary and Biomedical Sciences, University of Nebraska, Lincoln, NE.
References


Keen, J. E. 2002. Personal communication, Denver, CO.


Prevalence of O157:H7 and Non-O157 Shiga Toxin-Producing *Escherichia coli* in Commercial Beef Processing Plants\(^1,2\)

Mohammad Koohmaraie*, Terrance M. Arthur, Joseph M. Bosilevac, Genevieve A. Barkocy-Gallagher, Xiangwu Nou, Mildred Rivera-Betancourt, Steven D. Shackelford, and Tommy L. Wheeler

United States Department of Agriculture, Agricultural Research Service, Roman L. Hruska U.S. Meat Animal Research Center, P.O. Box 166, Spur 18D, Clay Center, NE 68933-0166

*For correspondence: Tel: (402) 762-4221; Fax: (402) 762-4149; E-mail: Koohmaraie@email.marc.usda.gov.

\(^1\) Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

\(^2\) The authors wish to acknowledge the secretarial assistance of Carol Grummert.

Introduction

The term *E. coli* is the abbreviation for the bacterium *Escherichia coli*. The bacterium is named after the German scientist, Theodor Escherich, who discovered the bacterium in the human colon, hence the name *Escherichia* (for Escherich) *coli* (for colon). Theodor Escherich demonstrated that certain strains of *E. coli* were responsible for diarrhea in infants and for gastroenteritis.

There probably are thousands of types of bacteria that belong to *E. coli*. *E. coli* is categorized based on the composition of a component (lipopolysaccharide complexes) of its cell wall (O serotypes) and a component (flagellin) of its flagella (H serotype); flagella give *E. coli* its ability to move. If an *E. coli* strain does not have flagella it is classified NM (non-motile) or H-. There are about 170 O antigens and 55 H antigens [http://web.bham.ac.uk/bcm4ght6/path/sero.html](http://web.bham.ac.uk/bcm4ght6/path/sero.html).

Although *E. coli* O157:H7 was isolated for the first time in 1975 by scientists at the U.S. Centers for Disease Control and Prevention (CDC), it was not until 1982 that it was recognized as a foodborne pathogen and a significant public health concern. In 1982, *E. coli* O157:H7 was associated with two outbreaks, one in Oregon and one in Michigan. According to the CDC (1999b), each year foodborne diseases cause about 76 million illnesses, 325,000 hospitalizations, and 5,000 deaths in the United States (Mead et al., 1999). Three pathogens, *Salmonella*, *Listeria*, and *Toxoplasma*, are responsible for 1,500 of the 5,000 deaths. According to the CDC (1999a), between 1982 and 1998 over 4,400 cases of human illness resulted from 203 outbreaks that involved exposure to *E. coli* O157:H7. Of these 4,400 cases, 968 (22%) were hospitalized and 28 (0.6%) died. However, the degree of underreporting for *E. coli* O157:H7 is estimated to be about 20-fold (Hedberg et al., 1997). Hence, *E. coli* O157:H7 is estimated to be responsible for
73,480 total cases annually, of which 62,458 are the result of foodborne illness resulting in 52 deaths, accounting for 2.9% of total deaths attributed to foodborne illnesses (Mead et al., 1999). *E. coli* O157:H7 surveillance data indicate that diagnosis is more common in summer months (June through September) and that the infection varies by age group, with the highest incidence occurring in children (Mead and Griffin, 1998). Food sources implicated in the outbreaks of *E. coli* O157:H7 between 1998 and 1999 in the United States are shown in Table 1.

Reports that attribute 2.9% of deaths to *E. coli* O157:H7 attribute 27.6% and 30.6% of the total of deaths due to foodborne illnesses to *Listeria monocytogenes* and nontyphoidal *Salmonella*, respectively (Mead et al., 1999). Then, why is *E. coli* O157:H7 the focus? The reason for the focus on *E. coli* O157:H7 is that its presence in ground beef is by law an adulteration. Hence, elimination of this pathogen has become a major focus for the industry as well as food safety research establishments.

Shiga toxin-producing *E. coli* O157:H7 is thought to be the most common infectious cause of bloody diarrhea in the United States; one of the consequences of this infection, hemolytic uremic syndrome (HUS; a combination of renal failure, low platelet counts, and hemolytic anemia), is the main cause of acute renal failure in children. The result of consumption of food contaminated with *E. coli* O157:H7 ranges from no response to death. Ingested *E. coli* survives the acidic conditions of the human stomach and travels to the lower intestinal tract, primarily the colon, where it will colonize. Colonized/attached *E. coli* will produce its toxins (Shiga toxins), which in turn will travel via the bloodstream to the kidney and brain where they exert their effects in the forms of kidney failure and neurological impairments. The ultimate mode of action of these toxins is that they inhibit protein synthesis in target tissues. The time from ingestion to first symptom of the disease ranges from 1 to 8 days. Illness usually begins with abdominal cramps and diarrhea (not bloody) that may progress to bloody diarrhea in 2 to 3 days. Severe cases of infection include hemorrhagic colitis (grossly bloody diarrhea) and HUS.

Cattle are considered to be the major reservoir of *E. coli* O157:H7, but the organism has been found in the intestinal tracts of chickens, deer, sheep, and pigs. The majority of the cases of *E. coli* O157:H7 have been due to consumption of undercooked ground beef. A hallmark of *E. coli* O157:H7 is that it does not cause any disease in animals harboring the bacterium; the animal serves as a reservoir for the bacteria. The prevalence of *E. coli* O157:H7 in cattle is highest in summer months. In addition to undercooked ground beef, *E. coli* O157:H7 outbreaks have been associated with a variety of other sources, such as apple cider, raw milk, alfalfa sprouts, drinking or swimming water, and lettuce. The source of *E. coli* O157:H7 in all of these outbreaks is thought to be cattle. For example, in the case of unpasteurized apple cider, apples were picked up from ground that was contaminated with manure (Besser et al., 1993), and in the case of lettuce, it was harvested from a farm adjacent to cattle pasture (Hilborn et al., 1999). In other words, in most if not all cases, the sources of infections can be traced to cattle.

Although *E. coli* O157:H7 has received much of the attention, there is another group of pathogenic *E. coli* that cannot be ignored. *E. coli* O157:H7 is only one of over 200 different serotypes of Shiga toxin-producing *E. coli* (STEC). The non-O157 STEC are present in the food supply and have been associated with several outbreaks of *E. coli* O157:H7 in the United States. Banatvala and coworkers (2001) estimated that less than 20% of HUS cases were due to non-O157 STEC. Mead et al., (1999) estimated that *E. coli* O157:H7 causes at least two-thirds of the human STEC infections in the United States, with the other one-third of cases attributed to the non-O157 STEC population. However, for several reasons these estimates may be biased towards *E. coli* O157:H7, resulting in underestimation of the real role of non-O157 STEC in
foodborne illnesses. First, most clinical laboratories in the United States do not routinely screen for non-O157 STEC. Second, surveillance for non-O157 STEC is not conducted routinely. Third, the non-O157 STEC detection assay is far more complex than the assay for O157 STEC.

Few studies have used unbiased methods to evaluate the relative frequencies at which O157 and non-O157 STEC cause human disease. Fey et al. reported that 14 of 335 diarrheal stools from patients in Nebraska contained Shiga toxins (Fey et al., 2000). Only thirteen of these samples yielded a STEC isolate. Six samples were positive for O157:H7 and seven were positive for non-O157 STEC (Fey et al., 2000). Similarly, Park et al. found that just under half of the eleven human stool samples containing shiga toxins harbored a non-O157 STEC strain, while the rest harbored \textit{E. coli} O157:H7 (Park et al., 1996). Studies have shown the infectious doses to be similar for O157 (<50 organisms) and non-O157 STEC (approximately 10 organisms for O111) (Paton et al., 1996; Tilden et al., 1996).

Unlike \textit{E. coli} O157:H7, all strains of which are considered virulent to humans, it is not clear what proportion of non-O157 STEC detected in cattle feces or on beef carcasses is able to cause disease in humans. Gyles et al. put forward the idea that STEC virulence is likely to be on a continuum, implying that virtually all STEC could be pathogenic under the proper circumstances (Gyles et al., 1998). This would mean that less virulent strains could cause the same types of disease as highly virulent strains, given a sufficiently high dose and a sufficiently low immune status of the infected individual. Although there are most certainly nonpathogenic STEC in this continuum, at the present time there is not enough data to make a distinguishable cutoff to allow for the determination of which STEC in the food supply represent a potential threat to human health.

**Beef Processing Plants Study**

To assess the prevalence of \textit{E. coli} O157 in beef processing plants, during July and August of 1999 we conducted a study in which the feces, hides, and carcasses (carcasses were sampled three times, before evisceration and before and after final inspection) of random lots of cattle were assayed for the presence of \textit{E. coli} O157 in four large Midwestern commercial beef processing plants (Elder et al., 2000). We wanted to: (1) estimate the frequency of \textit{E. coli} O157 in feces and on hides, (2) characterize \textit{E. coli} O157 carcass contamination from feces and/or hides, and (3) determine if there is a relationship between O157 in live animals and on carcasses during processing. For details of the study the reader is referred to Elder et al. (2000). The results indicated that the prevalence of O157 in feces and on hides (27.8% of feces and 10.7% of hides) was far greater than previously reported. This was the first comprehensive study in which the prevalence of O157 on carcasses during the harvest process was determined. We found that 43.4% of the carcasses were positive for O157 at pre-evisceration. (We selected this point in the process because at this stage, in 1999, very little intervention had occurred, hence this was the best step in the harvest process at which to assess carcass contamination by feces and/or hides). At post-evisceration (after final inspection and before final complements of interventions), and post-processing (in the cooler and after full complements of all interventions), 17.8% of carcasses and 1.8% of the carcasses were positive for O157, respectively. These results demonstrate the effectiveness of interventions employed in these processing plants to combat pathogens (the prevalence of O157 was reduced from 43.4% positive at pre-evisceration to 1.8% positive on processed carcasses). The results also demonstrated a positive correlation between fecal and hide prevalence of O157 with carcass contamination of O157, which suggests a role for
the control of O157 on live cattle as a means to reduce the prevalence of O157 in feces/hides and hence on the carcass.

We employed genomic fingerprints for additional useful information and more importantly to track the source of E. coli O157. Results demonstrated that carcass E. coli O157 contamination originates from animals within the same lot and not from cross-contamination between lots and that carcass E. coli O157 contamination occurs early in the harvest process, which argues for intervention at the very early stages in the process (Barkocy-Gallagher et al., 2001). Also significant is that we identified 343 E. coli O157 isolates, which resulted in 77 individual fingerprints. The significance of these genomic differences is not known at this time, but the determination of significance of this observation, if any, is a focus for our program. For example, we want to know if these genomic differences make certain strains of E. coli O157 more resistant to some of the interventions used in the continuum of harvest to table (intervention during harvest, food preparation, etc.). Also we want to know if genomic differences are responsible for variations in pathogenicity. We believe that there is a large variation among O157 strains in their ability to cause disease in humans, but we must provide experimental data to support this notion.

Because of the emergence of the significance of non-O157 STEC, we decided to determine the prevalence of non-O157 STEC in the pre-evisceration and post-processing samples that were described in the above paragraph. Results indicated that at similar stages in the process, non-O157 STEC were just as prevalent, if not more prevalent than O157 strains (Arthur et al., 2002). In that study, 53.9% of the beef carcasses tested in large processing plants in the United States carried at least one type of non-O157 STEC prior to evisceration, but the prevalence was reduced, using various antimicrobial intervention strategies, to 8.3% of the carcasses carrying non-O157 STEC at post-processing (Table 2). Twenty-eight of 30 single-source lots (93%) surveyed included at least one sample containing non-O157 STEC. O serogroups that previously have been associated with human disease accounted for 173 (49%) of 361 isolates. Although forty isolates (11%) carried a combination of virulence factor genes (EHEC-hlyA, eae, and at least one stx gene) frequently associated with STEC strains causing severe human disease, only 12 of these isolates were also of an O serogroup previously associated with human disease (Arthur et al., 2002). We are finding similar observations in an on-going experiment that is designed to determine the prevalence of O157 and non-O157 STEC as well as Salmonella spp. during spring, summer, fall, and winter in commercial beef processing plants.

**Seasonality of pathogens in commercial beef processing plants**

We conducted a second study of E. coli O157:H7 and overall STEC prevalence in fed-beef processing plants in 2001-2002. This second field study was designed to investigate the effects of season on prevalence. The prevalence of E. coli O157:H7 in cattle feces is known to peak in the warmer summer months (Barkocy-Gallagher and Koochmarie, 2002). Human clinical cases also peak in the summer months. However, the relationship between season and E. coli O157:H7 prevalence at the processing plants had never been examined. We sampled hides and feces of the same animal to determine the incidence of these E. coli O157:H7, STEC, and Salmonella entering the processing plants. Carcasses from the same animals then were sampled at two points: (1) prior to evisceration and any washes, and (2) after evisceration, inspection, and antimicrobial treatments. We showed that the prevalence of E. coli O157:H7 and STEC in general was higher on hides than feces (Figure 1). We also showed that the prevalence of E. coli O157 was lowest during the winter months. Although prevalence of STEC overall fluctuated
more by season depending on the type of sample, it was lowest during winter. Finally, this study also demonstrated that the levels and incidence of _E. coli_ O157:H7 drop, sometimes dramatically, during processing and the application of antimicrobial interventions. In total, less than 2% of the processed carcasses were positive for _E. coli_ O157:H7 and less than 20% were positive for cells carrying the genes encoding Shiga toxins. Furthermore, those carcasses that were positive carried very low numbers of these pathogens. Therefore, in general few of these pathogens arrive on beef products, and contamination occurs infrequently.

**Relatedness of pathogen presence**

Recently, it has been determined that many beef carcasses become contaminated with _E. coli_ O157:H7 during the hide removal portion of the harvesting process (Elder et al., 2000; Barkocy-Gallagher et al., 2003). In many cases (68.2%), _E. coli_ O157:H7-positive carcasses have the same PFGE pattern as _E. coli_ O157:H7-positive pre-harvest (fecal or hide) samples from animals from the same lot (Barkocy-Gallagher et al., 2001). Much of the contamination occurs during the hide removal portion of the harvesting process (Elder et al., 2000; Barkocy-Gallagher et al., 2003), suggesting that efforts to decrease the likelihood of _E. coli_ O157:H7 contamination should focus on prevention of hide-to-carcass cross-contamination rather than development of methods to eliminate _E. coli_ O157:H7 from the gastrointestinal tract of cattle. Yet, the extent of the relationship between fecal or hide carriage of _E. coli_ O157:H7 (or other pathogens) and the presence of the pathogen on the corresponding carcass is not known.

The USDA Food Safety and Inspection Service (FSIS) has used presence of _Salmonella_ spp. on carcasses and meat products as a “performance standard” to evaluate the effectiveness of HACCP programs. Implementation of the _Salmonella_ performance standard was predicated on the assumption that the presence of _Salmonella_ was a measure of sanitation. To a certain extent, the presence of _Salmonella_ on a carcass or in a meat product also has been interpreted to imply an increased likelihood of the presence of other pathogens as well. However, in the Steers and Heifers portion of the Nationwide Beef Microbiological Baseline Data Collection Program, the FSIS analyzed 2,089 raw beef carcass surface samples for the presence of six different pathogens (FSIS, 1994). Only 26 of the 304 (8.6%) pathogen-positive samples in their study contained more than one pathogen (FSIS, 1994). Clearly, before the presence of one pathogen should be used as an indicator of the presence of another pathogen, evidence of a relationship should be established.

Thus, we studied (1) the level of relatedness of pathogen presence among beef fecal, hide, pre-evisceration carcass, and post-intervention carcass (after application of all antimicrobial procedures) samples for each of three different pathogens: _E. coli_ O157:H7, _Salmonella_ spp., and cells harboring Shiga toxin-encoding genes (stx), and (2) the level of relatedness among the presence of _E. coli_ O157:H7, _Salmonella_ spp., and stx within each of the four aforementioned beef sampling sites.

We (Shackelford et al., 2003) observed significant relationships between (1) presence of _E. coli_ O157:H7 in an animal’s feces and on its pre-evisceration carcass, (2) presence of _E. coli_ O157:H7 on an animal’s hide and on its pre-evisceration carcass, (3) presence of _Salmonella_ spp. in an animal’s feces and on its pre-evisceration carcass, and (4) presence of _Salmonella_ spp. on an animal’s hide and on its pre-evisceration carcass. Because pre-evisceration sampling occurred before evisceration, it is not likely that spillage of gastro-intestinal contents (which rarely occurs) contributed to the relationship between the detection of these pathogens in the feces and their detection on the pre-evisceration carcasses. The pre-evisceration sampling site
includes and lies adjacent to points where the hide is frequently contaminated with an animal’s own feces during defecation. This area of the hide includes points where the hide is opened (hide pattern line of the crotch and hide pattern lines of each hind limb) at the beginning of the hide removal process. Thus, the pre-evisceration site is a hot spot for hide-to-carcass cross-contamination. It is likely that the relationship between the detection of these pathogens in an animal’s feces and their detection on its pre-evisceration carcass arose via transfer of an animal’s own feces from its colon to its hide during defecation and onto its carcass during hide patterning and/or removal. Therefore, it is likely that an effective hide intervention could dramatically reduce the likelihood that carcasses will become contaminated with *E. coli* O157:H7 or *Salmonella* spp.

We found that pre-evisceration carcasses that were observed to be *Salmonella* spp.-positive were not more likely to be *E. coli* O157:H7-positive than pre-evisceration carcasses that were observed to be *Salmonella* spp.-negative. Similarly, no association was seen between *Salmonella* spp. and *E. coli* O157:H7 for post-intervention carcasses. This suggests that *Salmonella* spp. prevalence should not be used as an indicator organism for *E. coli* O157:H7 prevalence.

**Hide Intervention**

As detailed in the above sections, it is very clear that the hide is the major source of pathogens that are found on beef carcasses (Barkocy-Gallagher et al., 2003; Bell, 1997; Elder et al., 2000; Galland, 1997; Reid, 2002) and that the prevalence of pathogens such as *E. coli* O157:H7 is much higher than previously estimated (Barkocy-Gallagher et al., 2003; Elder et al., 2000). For example, in a recent study, Barkocy-Gallagher et al. (2003), sampling during the summer months, showed that while 13% of cattle were positive for *E. coli* O157:H7 in their feces, 73% of the same cattle were positive for *E. coli* O157:H7 on their hides. Forty-one percent of the carcasses in this study were positive at the pre-evisceration step; this step is examined because it is immediately after hide removal and the carcasses have been subjected to few if any interventions. The fact that carcass contamination by *E. coli* O157:H7 in the processing plants occurs at a much higher rate than that of cattle carrying *E. coli* O157:H7 in their intestinal contents suggests that the viscera play a minor role in carcass contamination by *E. coli* O157:H7.

A number of hide-directed intervention strategies have been evaluated. Simply washing cattle pre-slaughter was not effective in reducing *E. coli* O157:H7 transfer from hide to carcasses (Byrne, 2000), suggesting the need for an antimicrobial intervention strategy. Recently, McEvoy et al. (2001) demonstrated that treatment with steam condensing at subatmospheric pressures significantly reduced *E. coli* O157:H7 on bovine hide material in laboratory tests, but a commercial scale test has not yet been performed. Two antimicrobial hide intervention techniques examined by our group have been chemical dehairing and the spray application of the antiseptic compound cetlypyridinium chloride.

Chemical dehairing was first evaluated by Schnell et al. (1995) for its effectiveness on lowering bacterial load and increasing the visual cleanliness of beef carcasses. They found chemical dehairing produced cleaner carcasses that required less trimming to meet the zero tolerance policy on fecal contamination, but they did not observe a significant reduction in bacterial load present on the carcasses. Later, Castillo et al. (1998) performed laboratory experiments that demonstrated chemical dehairing significantly reduced the counts of aerobic bacteria, coliforms, and *E. coli*, as well as reduced numbers of artificially inoculated pathogens. However, the issue of pathogen transfer from hides to carcasses in the processing environment
was not addressed. Recently Nou et al. (2003) examined the effectiveness of chemical dehairing in a processing plant by sampling conventionally processed and chemically dehaired hides and carcasses directly from the processing line (Table 3). They found aerobic bacterial levels on carcasses were reduced by $2 \log_{10}$, and Enterobacteriaceae (EB; a group of bacteria that includes coliforms and *E. coli*) levels were reduced by nearly $2 \log_{10}$ as well. Most significant was the observation of *E. coli* O157:H7 prevalence. Fifty percent of the conventionally processed pre-evisceration carcasses were positive for *E. coli* O157:H7, whereas following chemical dehairing only 1.25% were positive. Clearly, effective decontamination of the hides will result in great improvement of carcass microbial quality.

Although highly effective, chemical dehairing has not been widely adopted due to a number of implementation problems. An alternative method of hide decontamination that has been examined is the spray application of cetylpyridinium chloride (CPC), a common oral antiseptic. The effectiveness of CPC for reducing microbial counts on beef and poultry has been reported in the past. Cutter et al. (2000) demonstrated the effectiveness of CPC to reduce beef carcass contamination, and in a series of published studies, Slavik and coworkers demonstrated that CPC is efficacious for reducing populations of Salmonella spp. on poultry carcasses (Kim and Slavik, 1996; Wang et al., 1997; Xiong et al., 1998). Also, Pohlman et al., (2002) demonstrated the effectiveness of CPC for reducing *E. coli*, coliforms, and aerobic bacteria in ground beef when applied to beef trimmings before grinding.

In our studies reported by Bosilevac et al. (2003a) it was shown that CPC greatly reduced bacterial counts in laboratory experiments, on beef hide materials, and in controlled studies of CPC application to feed lot cattle. Depending on the application method, 1% CPC reduced aerobic bacterial levels by 2 to 3 $\log_{10}$, and Enterobacteriaceae levels by 1 to 2 $\log_{10}$. This effect was shown to persist for up to 4 hours following the spray treatment. CPC was also demonstrated effective against the pathogen *E. coli* O157:H7. Less than 1% of the *E. coli* O157:H7 used in their experiments survived treatments with CPC concentrations as low as 0.01%. In this series of experiments, it was determined that for CPC treatment to be effective, the hide must be washed practically clean of organic matter. In a subsequent report Bosilevac et al. (2003b) examined the effectiveness of applying CPC to cattle at a commercial processing plant immediately prior to slaughter (Table 3). In that study, thorough washing of cattle followed by CPC treatment resulted in a 1.5 $\log_{10}$ reduction of aerobic bacteria, and just over a 1 $\log_{10}$ reduction of EB on pre-evisceration carcasses. APC and EB levels provided a general measure of improved cleanliness, but did not measure pathogens. As in the dehairing studies, the most compelling results were those of *E. coli* O157:H7 prevalence on hides and carcasses. Fifty-six percent of control cattle presented with *E. coli* O157:H7 on the hide; following CPC treatment this was reduced to 34%. When the pre-evisceration carcasses were examined, 23% of controls were positive whereas only 3% of the CPC treated cattle were positive. These observations are consistent with the conclusion that hides are the major source of carcass contamination.

It appears that procedures such as chemical dehairing and CPC application, which are designed to decontaminate cattle hides before carcass dressing, can be expected to reduce the bacterial loads on carcasses immediately after hide removal by about 2 $\log_{10}$ and dramatically reduce the prevalence of *E. coli* O157:H7. Typically, the various antimicrobial interventions in beef processing plants have a combined effectiveness of 3 to 4 $\log_{10}$ reduction in bacterial load from pre-evisceration carcasses to carcasses chilling in the cooler (Bacon et al., 2000; Barkoczy-Gallagher et al., 2003). Combining an effective hide intervention with subsequent carcass interventions would further improve the safety of beef and beef products by virtually eliminating...
the spikes in pathogen contamination that current carcass interventions alone cannot completely remove.

What Is the Industry Doing to Make Meat Safer?

The results of our field studies have indicated that at certain times of the year the hides of most of the cattle presented for slaughter are positive for *E. coli* O157:H7. Yet less than 2% of the processed carcasses are positive for *E. coli* O157:H7. These results clearly demonstrate the effectiveness of the interventions used by the beef industry to reduce the level of foodborne pathogens. The beef processing industry has changed dramatically during the last decade. The interventions used by the industry include thermal processing (applying moist heat such as steam and hot water [>160°F] to the carcasses to reduce or eliminate pathogens) and organic acid rinses (acetic and lactic acids). Other interventions used include steam vacuuming (areas of visible contamination are steamed and then vacuumed) and trimming (removal of physical contamination by knife trimming). It is important to note that no one single intervention can be fully effective. In a typical commercial beef processing plant multiple interventions are used at multiple steps in the process. In a typical large scale commercial beef processing plant from the time that beef is presented for harvest until the time that the carcass is processed the following interventions are employed: hide washing (water or water including a chemical), steam vacuuming of the pattern areas (areas of hide to be opened for eventual hide removal), steam vacuuming of the exposed surfaces of the carcass after hide removal and throughout the process, pre-evisceration washing (may include any combination of water, hot water, and organic acid rinses), inspection by USDA inspectors, steam treatment, organic acid rinses, hot water washes, and finally, spray chilling with cold water and high air velocity. Although the use of these technologies dramatically reduces the prevalence and levels of pathogens on beef carcasses, the fact that foodborne disease outbreaks continue to occur suggests that more needs to be done. Indeed scientists from many sectors (government, academia and industry) continue to search for additional technologies that can be employed at any step in the continuum of farm to table. Preharvest is a major area of research activity to reduce the level of pathogens in cattle presented for slaughter. Some of the active areas of research include vaccination, probiotics, phage therapy, and general hygienic practices. The fact remains that at the time of the writing of this manuscript, there is no evidence that any preharvest technology is effective in reducing the level of pathogens in cattle presented for slaughter. Despite all the improvements made by the packing industry, it has not been able to eliminate transfer of pathogens from hides to carcasses during the hide removal process. Thus, it is clear that effective hide interventions such as those detailed above should be implemented. The industry is aggressively pursuing feasible options to facilitate hide decontamination.

Food Safety Is Everyone’s Business

To truly reduce and ultimately eliminate the risk of foodborne pathogens to human health, everyone in the continuum of farm to table must play his/her role. Without question, the processing industry has done all that is possible, based on current knowledge and technology, and will continue to identify and implement additional interventions. Likewise the federal government, from the regulatory prospective, has played its role to enhance the safety of our food supply. However, we need to pay a great deal of attention to educating consumers and others who are involved in handling and preparing food. In its September 3, 2002, report on consumers, FSIS reported its key findings in areas of consumer knowledge, behavior, and
confidence since the implementation of the HACCP farm-to-table initiative (USDA-FSIS, 2002). The report concluded that although consumers report that they are more knowledgeable about food safety and have improved their food handling and preparation practices, some consumers still do not practice safe food handling and preparation (Table 4). The report also indicated that most consumers believe that foodborne illness results from food handling at processing plants and food service establishments, rather than in their own homes (Figure 2). Educating consumers and other food handlers is an area that needs great attention and in our assessment will pay great dividends in our collective efforts to put the safest food on our tables.

Conclusions

Pathogenic *E. coli* is far more common than previously thought. At certain times of the year, most of the cattle presented for harvest are positive for STEC (hide and/or feces). The current interventions used by beef processors are very effective in reducing the incidence of STEC, but as evidenced by frequent outbreaks, clearly more needs to be done to manage the problem. The current approaches under investigation include pre-harvest (pre-harvest interventions such as vaccination, probiotics, etc.) and harvest approaches (development of additional interventions at critical steps in the harvest process).

References


Tilden, J., Jr., W. Young, A. M. McNamara, C. Custer, B. Boesel, M. A. Lambert-Fair,


<p>| Table 1. Food sources implicated in outbreaks of <em>E. coli</em> O157:H7, 1998 to 1999 in the United States |</p>
<table>
<thead>
<tr>
<th>Food vehicle</th>
<th>Number of cases</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground beef/hamburger</td>
<td>19</td>
<td>45.2</td>
</tr>
<tr>
<td>Roast beef</td>
<td>2</td>
<td>4.8</td>
</tr>
<tr>
<td>Lettuce</td>
<td>4</td>
<td>9.5</td>
</tr>
<tr>
<td>Coleslaw</td>
<td>3</td>
<td>7.2</td>
</tr>
<tr>
<td>Salad</td>
<td>2</td>
<td>4.8</td>
</tr>
<tr>
<td>Milk</td>
<td>2</td>
<td>4.8</td>
</tr>
<tr>
<td>Tacos</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Apple cider</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Game meat</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Cake</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Cheese curd</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Fruit salad</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Macaroni salad</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Multiple</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Unknown</td>
<td>2</td>
<td>4.8</td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Adapted from CDC, 1999b, 2001.
### TABLE 2. Summary of STEC prevalence

<table>
<thead>
<tr>
<th>Samples</th>
<th>Preevisceration</th>
<th>Postprocessing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>334</td>
<td>326</td>
</tr>
<tr>
<td>total non-O157 STEC positive</td>
<td>180 (53.9)</td>
<td>27 (8.3)</td>
</tr>
<tr>
<td>95% confidence interval</td>
<td>(48.5-59.2)</td>
<td>(5.3-11.3)</td>
</tr>
<tr>
<td>O157:H7 positive b</td>
<td>144</td>
<td>6</td>
</tr>
<tr>
<td>non-O157 STEC positive</td>
<td>84 (58.3)</td>
<td>0</td>
</tr>
<tr>
<td>O157:H7 negative b</td>
<td>190</td>
<td>320</td>
</tr>
<tr>
<td>non-O157 STEC positive</td>
<td>96 (50.5)</td>
<td>27 (8.4)</td>
</tr>
<tr>
<td>Total STEC positive c</td>
<td>240 (71.9)</td>
<td>33 (10.1)</td>
</tr>
</tbody>
</table>

a Values represent number of carcass samples carrying at least one non-O157 STEC isolate. Values in parentheses represent percentages.
b See Elder et al., 2000.
c STEC positive samples (O157 and non-O157) from this work and from Elder et al., 2000. From Arthur et al., 2002.

### TABLE 3. Effectiveness of hide intervention in reducing carcass contamination

<table>
<thead>
<tr>
<th>Intervention</th>
<th>APC a (log CFU/100 cm²)</th>
<th>EBC b (log CFU/100 cm²)</th>
<th>O157:H7 Prevalence (% Positive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical dehairing Control (n = 240)</td>
<td>5.79</td>
<td>3.55</td>
<td>50.0</td>
</tr>
<tr>
<td>Treated (n = 240)</td>
<td>3.78</td>
<td>1.71</td>
<td>1.3</td>
</tr>
<tr>
<td>CPC spray Control (n = 149)</td>
<td>4.87</td>
<td>3.07</td>
<td>22.7</td>
</tr>
<tr>
<td>Treated (n = 139)</td>
<td>3.35</td>
<td>2.00</td>
<td>2.9</td>
</tr>
</tbody>
</table>

a Aerobic plate count.
b Enterobacteriaceae count.
From Nou et al., 2003, and Bosilevac et al., 2003b.
TABLE 4. Changes in consumers’ reported use of specific safe handling practices since the 1996 PR/HACCP final rule

<table>
<thead>
<tr>
<th>Practice</th>
<th>1993 (%)</th>
<th>1998 (%)</th>
<th>2001 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clean: Wash hands and surfaces often</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Usually wash hands with soap after handling raw meat/poultry (main meal raw meat/poultry cooks)</td>
<td>66</td>
<td>76</td>
<td>82</td>
</tr>
<tr>
<td>Always wash hands with soap before preparing food (main meal cooks)</td>
<td>NA</td>
<td>68</td>
<td>72</td>
</tr>
<tr>
<td><strong>Separate: Don’t cross-contaminate</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Properly clean cutting boards or other surfaces after cutting raw meat/poultry before using them to prepare other foods that will be eaten raw at the same meal⁹ (main meal raw meat/poultry cooks)</td>
<td>68</td>
<td>79</td>
<td>85</td>
</tr>
<tr>
<td><strong>Cook: Cook to proper temperatures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Usually serve hamburgers medium⁸ or well-done at home (main meal meat/poultry cooks)</td>
<td>74</td>
<td>83</td>
<td>82</td>
</tr>
<tr>
<td>Own a food thermometer (main meal cooks)</td>
<td>NA</td>
<td>46</td>
<td>60</td>
</tr>
<tr>
<td>Always or often use a food thermometer when cooking roasts or large pieces of meat (main meal raw meat/poultry cooks)</td>
<td>NA</td>
<td>22</td>
<td>32</td>
</tr>
<tr>
<td>Always or often use a food thermometer when cooking chicken parts such as breasts or thighs (main meal raw meat/poultry cooks)</td>
<td>NA</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Always or often use a food thermometer when cooking hamburgers (main meal raw meat/poultry cooks)</td>
<td>NA</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Safely reheat leftovers containing meat/poultry⁶ (main meal meat/poultry cooks)</td>
<td>20</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Chill: Refrigerate promptly</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safely store large amounts of leftovers in the refrigerator⁷ (main meal meat/poultry cooks)</td>
<td>NA</td>
<td>NA</td>
<td>26</td>
</tr>
<tr>
<td>Safely defrost meat/poultry⁸ (main meal meat/poultry cooks)</td>
<td>46</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

⁹Wash cutting boards or other surfaces with soap and/or bleach or use a different cutting board.

⁸Cook hamburgers brown all the way through with no pink in the middle. Although color is not a reliable indicator of doneness, surveys often use color as a measure of doneness to collect information on how consumers cook hamburgers.

⁶Heat leftovers until bubbling or use a thermometer to check for doneness.

⁷Refrigerate leftovers within two hours after cooking and store them in several smaller containers.

⁸Do not let raw meat/poultry defrost at room temperature for any time.

NA = Not available.

Note: Main meal cooks: n = 1,457 (1993), n = 1,816 (1998), and n = 4,175 (2001).
Main meal raw meat/poultry cooks: n = 1,701 (1998) and n = 3,893 (2001). For the 1993 survey, data are not available on the number of meat/poultry cooks who handle raw meat/poultry.


From USDA-FSIS. 2002.
FIGURE 2. Changes in consumers' opinions on sources of foodborne illness since the 1996 PR/HACCP Final Rule

Question: Where do you think food safety problems are most likely to occur? Would you say ...?

Variations in nutritional status prior to entering the feedlot may have as much or more effect on performance and carcass characteristics as the nutritional management of the cattle while in the feedlot. As our marketing programs move toward pricing individual cattle on their carcass merit, identifying the effects of previous nutrition on carcass value will become increasingly important. Producers who retain ownership, or alliances which can influence the nutritional management of the cattle prior to entering the feedlot, can take advantage of enhanced performance and carcass merit.

Myers et al. (1999) early-weaned 24 ¾ Simmental X ¼ Angus steers averaging 117 day of age. Half the steers were immediately adjusted to an 87% concentrate diet while the other half were grazed on a fescue-bromegrass-orchardgrass pasture from day 127 to 208. During this period the pasture calves received .91 kg cracked corn daily. The pasture steers were then gradually adjusted to the finishing diet over a 28-day period. All steers were individually fed using a Pinpointer 4000B (UIS Corp., Cookeville, TN) feeding device. All steers were slaughter at 1.1 cm backfat (which was monitored by ultrasound) when they averaged 413 day of age. At harvest, after 205 days on a common diet, organ and gastrointestinal tract weight were taken for seven steers from both the concentrate and pasture groups (Table 1).
Liver weights were 12.2% smaller (P = .15) and reticulo-rumen weights were 13.5% less (P = .01) as a percent of carcass weight for steers that were weaned directly on concentrates compared to those on pasture. These data show that the high forage diet consumed on pasture resulted in increased reticulo-rumen size even after the steers had been on a high concentrate diet for 205 days. One interpretation of these data is that early forage intake cause changes in rumen size that were not lost during the finishing phase. Another possible explanation is that the pasture fed steers had higher feed intakes (P <.01) during the finishing phase (days 208 to 413 days of age), which resulted in larger reticulo-rumens at slaughter.

From this trial it is impossible to calculate how much effect the heavier livers and reticulo-rumens had on maintenance requirements and feed efficiency. While the steers were on pasture, those consuming the concentrate diet had a feed:gain ratio of 3.48. Also, the total amount of concentrate fed to get the steers to the same backfat endpoint and carcass weight was nearly identical (1,815 kg) whether they were grown on pasture for 82 days or adapted to the concentrate diet immediately.

In order to determine if high-forage diets after early-weaning impacts feed efficiency during the finishing period, 80 Angus X Simmental heifers were early-weaned at an averaged of 71 days of age (Table 2, Wertz et al., 2001). Half the heifers were immediately adjusted to a 90% concentrate diet and the other half were fed a high-fiber diet containing 37.5% alfalfa haylage, 37.5% pelleted soybean hulls and 25% cracked corn (DM basis). All heifers were weighed weekly and the intake of the concentrate-fed heifers was adjusted to achieve the same daily gains as those fed the high-fiber diet. Upon completion of the 119-day growing period, 16 high-concentrate heifers and 16 high-fiber heifers were paired based on their weight and rate of gain throughout the growing period. These heifers, along with 16 early-weaned heifers of the same genetics that had been grown on pasture from the previous year’s calf crop, were individually fed
an 88% concentrate diet using Calan gates. During the finishing period ultrasound measurements were taken at 60-day intervals to monitor backfat and intramuscular fat.

Table 2. Finishing phase performance of yearling heifers grazed on pasture and calve feed a high concentrate or high fiber diet prior to entering the feedlot.

<table>
<thead>
<tr>
<th>Item</th>
<th>Growing period treatment</th>
<th>Contrast Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pasture</td>
<td>Concentrate</td>
</tr>
<tr>
<td>Feedlot-entry Age, d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days on finishing diet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial BW, kg</td>
<td>374.6</td>
<td>176.9</td>
</tr>
<tr>
<td>Final BW, kg</td>
<td>693.4</td>
<td>526.6</td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td>1.48</td>
<td>1.37</td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td>12.17</td>
<td>8.80</td>
</tr>
<tr>
<td>Gain:feed</td>
<td>.121</td>
<td>.156</td>
</tr>
</tbody>
</table>

The yearling heifers were slaughtered after 218 days at 1.6 cm of backfat and the calves were harvested after 258 days with 1.59 and 1.17 cm of backfat for the high-concentrate and high-fiber heifer calves, respectively. Heifer calves fed the high-concentrate diet during the growing phase were more efficient compared to those on the high-fiber diet (.156 v .145, P<.02) even though they were fatter at harvest (1.59 v 1.17 cm, P<.05). Since these differences in feed efficiency are not due to composition of gain, differences in maintenance requirement are a probable explanation. The reduction in maintenance requirement to achieve the superior feed efficiency is at least 15% and may be over 25% depending on how much adjustment is made for fat differences between the two calf treatments.

Similar results have been observed when high-forage diets were fed during the growing phase compared to high concentrate diets in normal weaned calves. Sainz et al. (1995) reported steers fed a high-forage growing diet had 21% (P < 0.01) greater maintenance requirements during the finishing phase compared to those grown on a high-concentrate diet and slaughtered at the same carcass weight. Previous University of Illinois data (Berger, unpublished) showed that steers grown at 2.1 lbs/day from 550 to 825 lbs on a hay based diet required 15.3% more feed per unit of gain during the finishing phase than those grown at 2.9 lbs/day on a corn-corn silage diet, when fed to the same backfat end point.

Most producers don’t recognize how efficient early-weaned calves fed high-energy diets can be during the growing phase weight range. This is illustrated by a cooperative trial conducted by the University of Illinois, Michigan State, Purdue and Ohio State Universities (Arseneau et al., 2001). Across the four universities, calves averaged approximately 100 days of age when weaned and were rapidly adjusted to a high
concentrate diet based on whole corn. Similar diets were fed at each university (1.41 Mcal/kg NE\textsubscript{g} with 16% CP for the first 100 days and 14% CP thereafter). To go from 306 to 950 lbs the calves had a feed:gain of 4.04 (Table 3). If current diets are costing approximately $150 per ton dry matter, then a 4:1 feed conversion is equal to a feed cost of 30 cents/lb of gain (4 X 7.5 cents/lb of feed). Although yardage, interest and other costs have to be added, this is still very competitive with other production systems. Even when the calves were on-feed for 251 days, averaged 1177 lbs and 0.4 inches of back fat, feed:gain were 4.63 on a dry matter basis at slaughter. Although it is impossible to make comparisons with other management systems, we believe at least part of the superior feed efficiency is due to the fact that these calves never received a high-forage diet. This in turn may have reduced their maintenance requirements compared to cattle fed traditional high-forage growing diets.

Table 3. Performance by period of early-weaned steers in a cooperative project conducted at Illinois, Michigan, Purdue, and Ohio State Universities.

<table>
<thead>
<tr>
<th>Period</th>
<th>Int. wt. lbs</th>
<th>End wt. lbs</th>
<th>Days</th>
<th>Feed:Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>306</td>
<td>396</td>
<td>28</td>
<td>2.64</td>
</tr>
<tr>
<td>2</td>
<td>396</td>
<td>671</td>
<td>83</td>
<td>3.93</td>
</tr>
<tr>
<td>3</td>
<td>671</td>
<td>950</td>
<td>71</td>
<td>4.73</td>
</tr>
<tr>
<td>4</td>
<td>950</td>
<td>1177</td>
<td>69</td>
<td>6.18</td>
</tr>
<tr>
<td>1-4</td>
<td>306</td>
<td>1177</td>
<td>251</td>
<td>4.63</td>
</tr>
</tbody>
</table>


Carcass Composition:
Wertz et al. (2002) evaluated the effect of weaning calves and growing then on a high forage diet compared to early-weaning and placing the calves on a high-concentrate diet immediately. Consecutive year’s calf crop from the same herd were used so that differences in genetics were minimized. Twelve ¾ Angus and 12 Wagyu x Angus cross heifers were weaned at 180 days of age and grazed on endophyte infected tall fescue for 16 months before entering the feedlot. The following year’s calves from the same cows and bulls were weaned at 142 day of age and immediately adjusted to an 80% concentrate-20% corn silage diet. Beginning when the early-weaned calves were nine months of age and the previous year’s calves were 22 months of age, all heifers were adjusted to Calan gate-equipped bunks and individually fed. Real-time ultrasound was used to monitor intramuscular and subcutaneous fat at approximately 60-day intervals. Each age group was slaughtered when it was estimated that 50% of the heifers would grade USDA Prime. When marbling score was regressed against cumulative gain:feed, early-weaned calves were approximately 20% more efficient at any marbling endpoint compared to the two-year-old heifers (Figure 1). In addition, at any given backfat level,
the early-weaned calves had higher quality grades. At the same marbling endpoint, the two-year-old heifers average 0.2 inches more backfat than the early-weaned calves.

Figure 1. Regression of gain:feed on ultrasound determined marbling score for early-weaned heifers finished as 2-year-olds or finished as calves (Wertz et al., 2002).

Marbling score

Similar results were observed with Angus x Simmental heifers as reported above (Wertz et al. 2001). In that study, when marbling was regressed against backfat (both determined by ultrasound) the slope of the line differed (P < 0.01) due to age (Figure 2). Calves that were fed-high energy diets at 208 day of age or earlier, deposited more marbling relative to backfat than heifers of the same genetics that were finished as long yearlings.

Figure 2. Regression of marbling score on 12th-rib fat thickness (both determined by ultrasound) for early-weaned heifers finished as long yearlings or finished as calves (Wertz et al., 2001)
An obvious question one could pose is whether feeding high-concentrate diets early in life only improves carcass quality in cattle that have the genetics to achieve high levels of marbling (i.e., Angus and Wagyu), or does it also benefit cattle that are predominately Continental breeding? To answer this question, 144 Simmental steers (mostly 7/8 or greater) from sires with known marbling EPD’s were weaned at approximately 90 days of age and immediately adjusted to an 80% concentrate diet based on whole corn. This trial was conducted for three years with 48 individually-fed steers per year. Steers were implanted at weaning with Synovex C, approximately 100 days later with Synovex S, and Revalor S 120 days before the predicted slaughter date. Marbling EPD’s of the sires ranged from −0.24 to 0.51 and averaged 0.057. Steers were harvested at 14.5 months of age and averaged nearly 1400 lbs after a 4% shrink. All steers were slaughtered at the IBP plants in Iowa or Illinois and quality and yield grades determined by USDA graders. Quality grades were: 18.4% select, 44.7% low choice, 34.0% average or high choice and 2.8% prime. Yield grades were: 23.4% YG 1, 55.3% YG 2, 19.9% YG 3 and 1.4% YG 4. Because we wanted to measure the changes in gains, feed efficiency, and carcass value over time, these cattle were fed to heavier weights than would be typical. Approximately 20% of the cattle had carcasses that weighed more than 950 lbs. Although one could argue that the quality grades would be reduced if the cattle were marketed at an optimum carcass weight, very few of the heavy cattle were near the break in select-low choice marbling. Although it is impossible to make direct comparisons with traditionally managed cattle, steers from the same sires and percent Simmental in the Simmental Association database average less than 55% choice.

Feeding high-starch diets early in life can also improve the quality grades of other classes of cattle. Angus x Simmental calves were allotted to a bull or steer group based on sire, birth date and birth weight (Schoonmaker et al., 2002). At 75 day of age calves in the steer group were castrated. All calves were weaned at 115 days of age with no exposure to creep feeding. Beginning at weaning, and continuing until the calves averaged 200 days of age, they were fed a 70% concentrate and 30% corn silage diet. For the first two weeks after weaning the diet contained 17.3% crude protein and was then reduced to 15%. From day 201 to slaughter all calves were fed a 14% crude protein diet that was 85% concentrate and 15% corn silage on a dry matter basis. Ultrasound was used to monitor backfat thickness and individual cattle were slaughtered when backfat was estimated to be 0.45 inches.

Although there are no comparisons with more traditional management systems, most researchers who have fed young bulls would admit that over 80% grading choice, and over 50% in the average choice or greater quality grade at less than a year of age, is a result of early-weaning on high energy diets (Table 4). With this system there was no difference in the quality grades of bulls and implanted steers.
Table 4. Carcass characteristics of Early-weaned Angus-Simmental bulls and steers.

<table>
<thead>
<tr>
<th>Item</th>
<th>Bulls</th>
<th>Steers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot wt. lbs</td>
<td>744</td>
<td>719</td>
</tr>
<tr>
<td>Fat Thickness, in.</td>
<td>0.48</td>
<td>0.50</td>
</tr>
<tr>
<td>Yield Grade</td>
<td>3.2</td>
<td>3.4</td>
</tr>
<tr>
<td>Quality Grade:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Select, %</td>
<td>15.8</td>
<td>15.0</td>
</tr>
<tr>
<td>Low Choice, %</td>
<td>26.3</td>
<td>50.0</td>
</tr>
<tr>
<td>Ave. Choice, %</td>
<td>36.8</td>
<td>30.0</td>
</tr>
<tr>
<td>High Choice, %</td>
<td>21.1</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Schoonmaker et al., 2002.

**Early-weaning on Finishing Diets vs. Creep Feeding:**
Previous research by Faulkner et al. (1994) showed that creep feed energy source could affect carcass quality even when gains were similar while the calves were on the creep feed. In that study calves receiving a corn-based creep had higher marbling scores (P <0.05) compared to those receiving soy hulls even though they were fed identical diets from weaning to slaughter. To compare the effects of early-weaning on a high-concentrate diet with creep feeding on carcass quality, 168 Angus x Simmental steers from the University of Illinois beef herd were weighed on two consecutive days to calculate initial weight and randomly allotted to 24 pens (Shike et al., 2003). The four treatments compared were: 1) Early-weaned with a programmed intake of a whole corn diet; 2) Normal-weaned after being fed a 25% corn creep feed; 3) Normal-weaned after being fed a high-fiber creep feed; and 4) Normal-weaned with no creep feed. The early-weaned steers were weaned at an average of 65 days of age. Creep feeders were placed in pastures when steers were early-weaned. Steers were vaccinated against IBR, BVD, PI3, BRSV and clostridia (7-way) 3-4 weeks prior to weaning and again at weaning. Upon arrival at the feedlot, steers were treated for internal and external parasites. Steers were implanted at early-weaning and again at normal weaning.

The experimental growing period was from 63 to 189 days of age. The normal-weaned calves were weaned at 189 days of age. All calves were weighed and placed on common diet for 23 days to allow for an adaptation period. Steer weights were then taken on two consecutive days to calculate starting weights for the finishing period. All steers were then placed on a common finishing diet for the remainder of the trial. Final weights were calculated from carcass weights using a standard dressing percent of 62%.

Feed intake of the early-weaned steers was restricted from day 63 to 189(normal weaning age) to achieve the same rate of gain as the average of the creep fed steers. Consequently, there were no differences in gain or days to slaughter between early-weaned and creep-fed steers, or among creep-fed steers. The normal-weaned steers without creep feed gained 0.12 kg/day less (P <0.01) and were 12 days older (P < 0.01) at slaughter compared to the other treatments.
When comparing carcass traits, the normal-weaned steers without creep had lighter carcasses ($P < 0.01$) than the average of the other treatments (Table 5). There was trend ($P = 0.09$) for the early-weaned steers to have more backfat than the average of the creep-fed steers. The marbling score was greater ($P < 0.01$) for the early-weaned steers compared to those receiving creep feed. By industry standards all treatments graded very well with between 73 and 90% choice. However, early-weaned steers had a greater ($P < 0.01$) percentage of average choice or higher carcasses compared to the average of the creep-fed steers.

Table 5. Carcass characteristics of early-weaned, normal-weaned creep-fed, and normal-weaned steers without creep.

<table>
<thead>
<tr>
<th>Carcass Characteristics</th>
<th>Early Wean (1)</th>
<th>Corn Creep (2)</th>
<th>Fiber Creep (3)</th>
<th>No Creep (4)</th>
<th>1 vs 2&amp;3</th>
<th>2 vs 3</th>
<th>1&amp;2&amp;3 vs 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H CW, lb.</td>
<td>757</td>
<td>774</td>
<td>757</td>
<td>724</td>
<td>.53</td>
<td>.23</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Backfat, in.</td>
<td>0.50</td>
<td>0.44</td>
<td>0.47</td>
<td>0.47</td>
<td>.09</td>
<td>.40</td>
<td>.77</td>
</tr>
<tr>
<td>K PH</td>
<td>2.24</td>
<td>2.45</td>
<td>2.23</td>
<td>2.62</td>
<td>.40</td>
<td>.13</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>REA, cm²</td>
<td>83.05</td>
<td>83.82</td>
<td>85.33</td>
<td>81.18</td>
<td>.31</td>
<td>.39</td>
<td>.04</td>
</tr>
<tr>
<td>Yield Grade</td>
<td>2.98</td>
<td>2.90</td>
<td>2.77</td>
<td>2.92</td>
<td>.17</td>
<td>.28</td>
<td>.74</td>
</tr>
<tr>
<td>Quality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marbling Score*</td>
<td>663</td>
<td>588</td>
<td>608</td>
<td>615</td>
<td>&lt;.01</td>
<td>.43</td>
<td>.79</td>
</tr>
<tr>
<td>% ≥ Choice</td>
<td>90</td>
<td>79</td>
<td>80</td>
<td>73</td>
<td>.19</td>
<td>.91</td>
<td>.16</td>
</tr>
<tr>
<td>% ≥ Choice*</td>
<td>73</td>
<td>33</td>
<td>44</td>
<td>46</td>
<td>&lt;.001</td>
<td>.33</td>
<td>.68</td>
</tr>
</tbody>
</table>

* Marbling Score 500 = Small 600 = Modest 700 = Moderate 800 = Slightly Abundant

Shike et al., 2003

Mode of Action:

After reviewing these data, a logical question to ask is whether there is a metabolic or hormonal explanation for an apparent increase in marbling deposition in early-weaned cattle fed high-concentrate diets? Obviously, intramuscular fat and hence carcass quality can be influenced by numerous factors including nutritional management and breed. Myers et al. (1999b) reported that calves that were early-weaned and placed on a grain diet immediately, had higher marbling scores at lower backfat endpoints than normally weaned calves. Additionally, Myers et al. (1999) reported an increased percent of early-weaned, grain-fed steers to grade USDA choice relative to early-weaned steers grown on pasture and then fed grain. These data suggested that marbling deposition may be affected early in development and furthermore that diet composition during this growing period may have influenced marbling deposition.

The literature indicates several mechanisms by which nutrition can affect composition of gain in ruminants. Diet composition influences volatile fatty acid profile which has been attributed to differences in composition of gain. Prior (1983) indicated that nutritional factors in hay-fed cattle yielded adipocyte hypertrophy without increased adipose tissue mass. In contrast, increased adipocyte hyperplasia and increased adipose tissue mass occurred as a result of nutritional factors from grain diets (Prior, 1983). These data
suggested that grain-fed cattle had smaller adipocytes but that there were more of them. Furthermore, Cianzio et al. (1985) reported that the number of adipocytes was more closely related to marbling score than was cell diameter. Additionally, Hood and Allen (1978) reported the *longissimus dorsi* to contain a greater proportion of these small adipocytes. The combination of these reported findings might suggest that adipocytes in the *longissimus dorsi* prefer available substrates resulting from the fermentation of grains compared to forages. Additionally, Cianzio et al. (1985) reported an increased hyperplasia between 11 - 15 months of age in steers which have been creep fed and immediately placed on high concentrate diets. Exactly which nutritional factors caused differences in lipogenesis were not delineated. However, the interaction of volatile fatty acids and hormones have been implicated as the mechanism. Etherton et al. (1986) reported lipogenesis to be stimulated by the presence of insulin and to a lesser extent by insulin-like growth factor-I *in vitro*.

The research of Sainz et al. (1995) further supported the premise that dietary treatment during the growing phase affects backfat and marbling at finish. These researchers slaughtered cattle in two groups, one after the growing phase and one after the combined growing-finishing phase. Data reported for cattle slaughtered after the growing phase demonstrated that cattle fed *ad libitum* concentrate during this period had greater backfat and marbling than the restricted concentrate and *ad libitum* forage groups when fed to the same live weight (Sainz et al., 1995).

Several researchers have attempted to address the question of whether it was simply caloric density or dietary substrates that gave rise to differences in lipogenesis. Smith et al. (1984) demonstrated no difference in the marbling scores of steers weaned at eight months and fed to 16 to 18 months of age on *ad libitum* corn silage or *ad libitum* corn. Nor was a difference in enzyme activity, adipocyte diameter or cells per gram as a result of diet or age (16 Vs. 18 mo.) reported (Smith et al., 1984). However Smith et al. (1984) did report that while acetate provided 70-80% of the acetyl units for lipogenesis in subcutaneous adipocytes, it only supplied 10-25% in intramuscular adipocytes. The majority (50-60%) of the acetyl units for lipogenesis in intramuscular adipocytes came from glucose (Smith et al., 1984). High-grain diets yield a greater proportion of propionate than forage-based diets. Propionate, a gluconeogenic precursor, may lead to greater glucose and hence greater marbling deposition. The negative correlation between the number of adipocytes per gram of *longissimus dorsi* tissue and the incorporation of acetate into that tissue reported by Hood and Allen (1978) supported the hypothesis that acetate was not the preferred carbon source for intramuscular fat deposition. Research conducted by Okine et al. (1997) supported the theory that glucose was the preferred substrate. They reported a 52% increase in the enzyme acetyl-CoA carboxylase and a 38% increase in the fatty acid synthase enzyme when isoenergetic diets of barley relative to alfalfa hay were fed to sheep (Okine et al., 1997). Two explanations were proposed for the differences in lipogenesis which resulted from dietary energy source. First, glucose or glucose precursors, insulin, and NADPH-linked dehydrogenases were increased by the grain diet relative to a roughage diet (Okine et al., 1997). Trenkel (1970) also reported a 50-60% increase in insulin level concomitant to the propionate increase that resulted from grain versus a hay diet. Secondly, it is possible that when grain-based
diets are fed the methylmalonyl-CoA produced from propionate may replaced malonyl-CoA as a primer for lipogenesis (Okine et al., 1997). It appears that if the proper substrates are present, marbling deposition may occur early in the growing period with little subcutaneous fat deposition. Feeding early-weaned calves so that they never have a high-acetate fermentation, may allow us to increase marbling deposition while limiting back fat development.

**Effect of Season on Carcass Merit:**
The effects of season of the year when cattle are slaughtered on percentage grading choice is well documented (Anderson, 2001). In general, the percentages of the carcasses that grade low choice or better increases in the Spring and peaks around April. It then gradually decreases to a low point in October. In November and December it starts to improve and the cycle is repeated. Based on supply and demand, the choice-select spread is usually lowest in the spring ($3-$4), and highest in the late fall ($8-$10). As more cattle are marketed on the basis of their individual carcass merit, quality grade can make a large difference in average price.

At first glance it may not seem like season of the year would have much effect on the nutrition of the cattle. Most feedlot diets have a relatively constant nutrient profile across season. However, when one considers that the nutrient profile consumed by the cattle six to eight months before slaughter may have a strong influence on quality grade, then the effects of the season of the year may make sense.

In the past 10 years we have begun to understand the factors that regulates the conversion of preadipocytes to adipocytes that can fill and be detected as marbling (Kawada et al. 1990). These researchers showed that in vitro the fat soluble vitamins inhibited the conversion of preadipocytes to adipocytes, while vitamin B₆ and vitamin C stimulated differentiation. Although this work was done in vitro using the 3T3-L1 preadipocytes as a model, it appears to apply to cattle. Oka et al., (1992) was the first to show a relationship between serum vitamin A concentrations and marbling deposition (Figure 3). The regression line was $Y = 104.9 -5.3x$, with and $R^2 = -0.37$ (P< 0.05). A similar relationship was detected between liver vitamin A levels and marbling index (data not shown). The Japanese marbling score described here has a much higher scale than the USDA quality grades. For example, a marbling index of 10 is equal to 15% intramuscular fat. By comparison, USDA average prime is in the range of 13-14% fat. More recently, Adachi et al. (1999) reported that the serum vitamin A levels 4-6 months prior to slaughter were significantly (P< 0.05) lower in high marbling steers compared to low marbling steers. The high marbling steers (9.0 marbling index) averaged 30 and the low marbling steers (4.8 marbling index) 49 IU of vitamin A/dl.
Kawada et al. (1996) reviewed how vitamin A can influence preadipocyte differentiation. Adipose tissue plays an important role in the storage and metabolism of retinoids through lipoprotein lipase. The effects of vitamin A appears to be mediated by retinoic acid. The effects of retinoic acid are then controlled by three nuclear receptor proteins (retinoic acid receptor (RAR); subtypes alpha, beta and gamma). These proteins are members of the steroid and thyroid receptor superfamily of ligand-dependent transcriptional regulators. Distinct nuclear receptors that participate in retinoid signal transduction in response to 9-cis retinoic acid, referred to as retinoid X receptor (RXR) have also been identified. In addition, the active form of vitamin D, 1,25-OH2D3 also plays an important role in adipocyte differentiation. The effects of vitamin D3 are mediated by a specific nuclear receptor protein (vitamin D receptor; VDR) which is also a member of the steroid and thyroid/retinoid receptor superfamily of ligand-dependent transcriptional regulators.

Our current understanding is that RXR functions as an auxiliary protein to form heterodimers with RAR, VDR, or peroxisome proliferator-activated receptor gamma (PPAR) and thereby activates target genes (Figure 4, Kawada et al., 1996). High levels of PPAR gamma favors gene transcription and leads to adipocyte differentiation. The addition of physiological levels of either vitamins A or D reduces RXR messenger RNA in 3T3-L1 cells thus inhibiting differentiation. The presence of vitamins A and D causes and increase in RAR and VDR, respectively and a concomitant decrease in RXR
resulting in competition between heterodimers that stimulates transcription leading to differentiation.

Figure 4. Role of Vitamins A and D in Adipocyte Differentiation (Kawada et al., 1996)

---

**Positive state**

- Vitamin A
- Vitamin D
- Gene transcription

**Negative state**

- VDR
- RAR
- RXR

Positive factors: FAAR, PPAR, TR, etc.

Postulated control mechanism of adipocyte development by vitamins A and D through the same family of ligand-dependent transcriptional factor. FAAR, fatty acid activated receptor; PPAR, peroxisome proliferator-activated receptor; TR, thyroid receptor; PPARY2/RXRα complex, ARF6.

The logical question to ask is if vitamin A and D levels in the diet don’t change with season of the year, why should we suspect that they influence seasonal quality grade changes? The answer lies in the fact that the lowest point on the seasonal quality grade pattern is usually in the fall. If you count back 4-5 months, those cattle will often enter the feedlot in late spring or early summer. The majority of those cattle will have been on lush growing grasses or wheat pasture that can have 100,000-300,000 IU/kg vitamin A activity (Dairy NRC, 1989). Kohlmeier and Burroughs (1970) looked at the rate of plasma vitamin A depletion in the feedlot of steers coming off wheat pasture or grass-legume hay diets. The feedlot diets were low in vitamin A activity (2.4 mg carotene/kg).
These data show that it takes over 84 days for the cattle grazing wheat pasture to get to the blood levels of those entering the feedlot having been fed grass-legume hay. Only at 140 days did plasma vitamin A levels approach those observed as increasing marbling in the Adachi (1999) trial. Galyean and Gleghorn (2001) summarized vitamin A data from 13 consulting nutritionist that indicated their receiving diets averaged 3,660 IU/lb (range 1,600 to 7,000) and typical finishing diets averaged 2,070 IU/lb (range 1,500 to 3,300). These concentrations of supplemental vitamin A may be slowing adipocyte differentiation, especially in cattle entering the feedlot in spring or summer coming off lush grass that has high levels of vitamin A activity. The 1996 Beef NRC recommends 1,000 IU/lb of vitamin A activity for feedlot cattle.

Vitamin D may be just as important as vitamin A in preventing adipocyte differentiation. Unfortunately, most of the circulating vitamin D in feedlot cattle comes from endogenous synthesis and not the diet. Hidiroglou et al., (1979) reported how blood vitamin D$_3$ levels changed with the season of the year in heifers fed grass-legume silage (Figure 6). Half the heifers were housed indoors and half were outdoors exposed to UV light.
This trial was conducted in Canada where the variation in sunlight between the shortest photoperiod (December) and the longest (June) is greater than for much of the U.S. However, cattle that were outside showed a dramatic increase in plasma vitamin D as the exposure to light increased. Cattle housed indoors should reflect the baseline level of vitamin D provided by the diet. Cattle that grade poorly in the fall will have been exposed to maximum sunlight in the late spring and summer. This will increase circulating vitamin D which can inhibit adipocyte differentiation at a time which could then contribute to the poor grading in the fall. This explanation seems reasonable until one looks at the interaction with sex described by Anderson (2001). In these data the drop in quality grade is much more dramatic in steers than heifers (Figure 7).

Figure 7. Percentage USDA Choice Cattle by Month (Anderson, 2001)

The next logical question is whether there is any biological explanation why heifers should be less susceptible to the effects of vitamin A and D than steers? To my knowledge there aren't any studies addressing this issue directly in cattle. However, there is human data which may give us some insights. First, it is known that estrogens in humans modulates VDR gene expression. This may make heifers less susceptible to the marbling depressing effect of high vitamin D levels resulting from long days. Secondly, progestins have been shown to down regulate RAR gene expression. This could make heifers more tolerant to high vitamin A levels without inhibiting adipocyte differentiation. Obviously, one has to be cautious in extrapolating human data to cattle, but it may provide some background for more research with cattle.
In summary, the lifetime nutrition of cattle entering the feedlot can have a dramatic effect on feedlot performance and carcass characteristics. Feeding high-forage diets during the growing periods appears to increase maintenance requirements in the feedlot. Cattle fed high-concentrate diets early in life may have higher marbling scores at the same backfat compared to those fed high-forage growing diets. Feeding diets high in vitamin A activity prior to entering the feedlot may have delayed adipocyte differentiation. Cattle exposed to long day lengths 3-5 months prior to slaughter may produce enough endogenous vitamin D to inhibit adipocyte differentiation. The combined effects of high vitamin A levels from previous diets and/or high vitamin D concentrations due to day length may explain the seasonal variation in quality grade.

**Literature Cited**


Net Feed Efficiency and its Commercial Applicability
John A. Basarab¹, Mick A. Price² and Erasmus K. Okine²

¹Alberta Agriculture, Food and Rural Development, Western Forage Beef Group, Lacombe Research Centre, 6000 C & E Trail, Lacombe, Alberta, Canada T4L 1W1; ²Dept. Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, Alberta, Canada T6G 2P5

Introduction

The cost of feed is second only to fixed costs in importance to the profitability of commercial beef operations (Basarab, 1999) and 70-75% of the total dietary energy cost in beef production is used for maintenance, including maintenance of the dam (Ferrell and Jenkins 1985; NRC 1996). In addition, a 5% improvement in feed efficiency could have an economic impact four times greater than a 5% improvement in average daily gain (Gibb and McAllister 1999). Thus improvements in feed efficiency will have a tremendous influence on the unit costs of production and value of breeding stock, embryos and semen since measures of feed efficiency are moderately heritable (Koch et al. 1963).

Feed efficiency can be defined in many different ways. However, there are two ways of defining feed efficiency that are useful in genetic improvement. The first is feed conversion ratio (FCR), which is the amount of feed consumed by an animal divided by its live weight gain. Feed Conversion Ratio is also referred to as Gross Feed Efficiency because it does not attempt to break down feed requirements into sub-components of maintenance and gain. For this reason, FCR is not very useful for measuring feed efficiency in the breeding herd, where females are not growing. In addition, many studies suggested that the measurement of individual animal feed intake was unnecessary due to the strong, negative genetic correlation (r[g] = -0.46 to -0.67) between FCR and growth rate (Arthur et al. 2001). Thus, if one selected for average daily gain, improvements in feed efficiency would also occur. This dogma was held within the beef industry for at least five decades, with little if any improvement in feed efficiency due to genetic selection. The problem is that FCR is more related to growth, body size, composition of gain and appetite than to the energy required for maintenance. What appears to have happened was that we selected for a faster growing, larger animal with an increased appetite, but with no improvements in feed efficiency.

The second useful measure of feed efficiency is residual feed intake (RFI) or net feed efficiency. Researcher from the University of Nebraska and Oklahoma State University (Koch et al. 1963) were the first to identify RFI as a feed efficiency trait that was independent of body weight and weight gain. RFI is defined as the difference between an animal’s actual feed intake and its expected feed requirements for maintenance and growth. Thus, it is the variation in feed intake that remains after the requirements for maintenance and growth have been removed. Take for example a British cross steer on a finishing diet consisting of 22% barley silage, 73.3% steam rolled barley, 1.6% molasses and 3.1% feedlot supplement. If this steer averaged 453.6 kg (1000 lb) in body weight over the last 120 days on feed and its ADG was 1.76 kg/day, the "Nutrient Requirements of Beef Cattle" (NRC 1996) would predict an average feed intake of 14.5 kg/day over this same period. If the actual feed intake for this steer was 12.2 kg/day, this would be 2.3 kg/day less feed than expected, and its RFI would be minus 2.3 kg/day. Like a golf score, a negative value is better and indicates a more efficient animal.

Measuring residual feed intake

Residual feed intake can be measured on young bulls and replacement heifers (seedstock test) or can be measured on steer progeny in the feedlot (commercial test). In each test, animals that have been tagged with radio frequency transponders are placed in front of a machine that automatically and non-invasively records the feed intake of each animal in the pen. The machine used by the present authors is called the GrowSafe® System (GrowSafe Systems Ltd., Airdrie, Alberta) and consists of rubberized sensing mats (1-3 antenna /tub), 10-16 feed tubs with two load bars per tub, a PC computer and GrowSafe data acquisition and analysis software. Each feed tub or “node” can hold approximately 0.5 days feed for 6-7 young bulls on a growing diet. Presently, the GrowSafe System can be constructed for approximately $10,000 CAN/node. A facility with 10 feed tub nodes could test 120-140 animals per year for residual feed intake as long as there were two tests/year. If the cost of the facility plus 10%/year for maintenance and upgrade were spread over five years then the cost per animal would be estimated at $215 to $250 CAN. The labour requirements for monitoring the system are estimated at 0.25 person years. Presently, changes in tub design are being tested that could allow for each tub to hold 0.5 days feed for 9-10 young bulls on a growing diet.

Accuracy

The GrowSafe® System has been found to be a robust and accurate system for monitoring individual animal behaviours at the feed bunk (Schwartzkopf et al. 1999; Sowell et al. 1998). Studies at the Lacombe Research Centre (Basarab et al. 2002) have shown that the GrowSafe hardware and acquisition software in combination with independently developed software (Feed Intake from Raw GrowSafe Data, version 6.1 for SAS) had accuracies of 98.7% and 98.4% for the determination of feeding event and daily feed intake, respectively. In addition, this system of hardware and software accounted for 98.6% of the feed delivered to the tubs by the feed truck. The GrowSafe Compile Intake III software (Version 1.818), which comes as a stock item with the GrowSafe hardware, had accuracies of 93.7% and 89.5% for the determination of feeding event and daily feed intake, respectively (Basarab et al 2002).

Procedure

Animals, 6-8 months of age, are accustomed to the diet and the GrowSafe® System during a 28 day pre-test adjustment period. The pre-test period is followed by a 112-day test where daily feed intake is recorded for each animal and the animals are allowed ad libitum access to feed. The animals are weighed every two weeks using traditional weigh scales or can be weighed several times daily using an in-pen automatic, non-invasive weigh scale. The use of an in-pen automatic weigh scale may reduce the test period to 45 to 70 days, thus allowing for three tests per year. The growth of each animal over the test period is modeled by linear regression of weight on time. Initial weight, average daily gain (ADG), and mid-point weight (MIDWT) are calculated from the regression coefficients of each animal’s growth curve. Mean daily feed intake (as fed basis) of each animal during the test period is standardized (SFI) to 10 MJ/kg DM and then regressed against ADG and metabolic MIDWT to give the equation $SFI = a_0 + b_1ADG + b_2MIDWT^{0.75}$ (Archer et al. 1997; Arthur et al. 2001). The residuals (actual minus expected feed intake) are used as residual feed intake. Thus, animals with low or negative residual feed intake values are more efficient than their pen mates with high or positive residual feed intake values.
Benefits of selecting for residual feed intake

Improved competitiveness and value of genetic seedstock

In 2000 and 2001, researchers at the Lacombe Research Centre in Alberta, Canada, measured feed intake, growth rate and RFI on 148 steers from five genetic strains (Basarab et al. 2003). Steers grew at 1.52 kg/day and had dry matter intakes of 8.5 kg/day. Individual animals varied in RFI from an efficient -1.95 kg/day to an inefficient +1.82 kg/day (Figure 1). This represented a difference in actual feed intake of 3.77 kg/day between the most and least efficient steers. This variation in RFI represented a difference of $45.69 CAN in feed costs (assuming feed costs of $0.101 CAN/kg as fed) during a 120-day test period or approximately $109 million annually when extrapolated to Alberta’s 2.4 million feeder cattle. The benefit to cow-calf and seedstock producers is unknown but is estimated to be at least as high. Similar results have been reported by Australian researchers at the Trangie Agricultural Research Centre in Australia where 1166 calves and 116 sires from different breeds were evaluated for post-weaning RFI (http://www.augusaustralia.com.au/Breedplan/NFI; Archer et al. 1998). Thus, considerable variation exists among individual animals within breeds or genetic strains in RFI. This infers that substantial progress can be made in RFI or feed efficiency since the heritability of the trait is approximately 40% (Archer et al. 1998; Arthur et al. 2001).

In March of 2003, Alberta completed its first commercial bull test for RFI using the GrowSafe System. Thirty British and 46 Continental bulls were placed in two adjacent pens each fitted with the GrowSafe System for measuring individual animal feed intake. The bulls were allowed 28 days to adjust to the feeding facility and diet. The adjustment period was followed by a 112-day test period. The test period diet consisted of 77.0% barley silage, 20.0% steam rolled barley and 3.0% beef supplement (32% crude protein). The British bulls were 263 days of age (SD=18) and weighed 356 kg (SD=45) at the start of the test. Ultrasound backfat averaged 2.9 mm (SD=1.2) at start of test and 6.3 mm (SD=2.0) at the end of test. The bulls grew at 1.56 kg/day, consumed 8.17 kg DM/day, had a feed:gain ratio of 5.3:1, and a RFI of 0.0 kg/day (SD=0.73). The 30 British bulls varied in RFI from an efficient -1.78 kg as fed/day to an inefficient +1.42 kg as fed/day (Figure 2). The Continental bulls were 271 days of age (SD=16) and weighed 391 kg (SD=41) at the start of the test. Ultrasound backfat averaged 2.0 mm at start of test and 4.1 mm at the end of test. The bulls grew at 1.42 kg/day, consumed 8.51 kg DM/day, had a feed to gain ratio of 6.05:1, and a RFI of 0.0 kg/day (SD=1.21). The 46 Continental bulls varied in RFI from an efficient -2.03 kg as fed/day to an inefficient +3.34 kg as fed/day (Figure 3). These results show that feed intake can be accurately measured using the GrowSafe System under commercial bull test conditions, considerable variation exists in RFI among breeds of beef cattle and RFI is independent of ADG, thus allowing seedstock producers to select for animals that are feed efficient and fast growing.

Estimated Breeding Values (EBV) for RFI

The Breedplan program for the Angus Society of Australia has generated EBVs for RFI that ranged from -1.32 to +1.23 kg/day, with accuracies ranging as high as 87%. Their website can be visited at: (http://www.angusaustralia.com.au/Breedplan/NFI). A useful quote from their website clearly explains the benefits of EBVs for RFI.

"If bull A has a RFI EBV of -0.6 and bull B has a RFI EBV of +0.4, after adjusting for weight and gain of the progeny, we predict that the progeny of bull A will eat 0.5 kg/day less feed (half the difference between the EBV's) than the progeny of bull B. Thus animals with lower (more negative) EBVs will have a lower feed intake at the same weight and growth rate than those with a positive
EBV. "Little if any change will occur in ADG or weight since RFI is not correlated with either growth rate or body size. In practice, seedstock producers could select for RFI and growth, thus improving both traits simultaneously. The advantage of RFI over FCR is that RFI allows breeders to place different emphasis on growth and feed efficiency.

**Reduction of methane, manure, N, P and K**

Methane emissions from cattle range from 2 to 12% of gross energy intake. This represents not only a substantial loss in efficiency of production, but the methane emitted contributes to greenhouse gases. Cattle with negative RFI values may produce less methane and manure than cattle with positive RFI values. Okine and co-workers (Okine et al. 2001) recently calculated the methane emission and manure production from feeder steers with low, medium and high RFI. They found no difference in methane emission as a percent of gross energy among RFI groups. However, yearly methane emissions from low RFI steers were 21% lower than for high RFI steers (56.6 vs. 68.5 kg/year). These results have been confirmed by Herd et al. (2002) who showed that cattle selected for low RFI produced 15% less (P<0.001) enteric methane per day than cattle selected for high RFI. Methane and nitrous oxide production from faeces were also lower by 15% and 17%, respectively, for low RFI cattle. Okine et al. (2001) also reported that low RFI steers had lower (P < 0.05) yearly manure (14.5%), N (16.9%), P (17.0%) and K (17.1%) production than high RFI steers.

There appears to be a cumulative benefit from genetic selection for both growth rate and RFI. For example, steers with low RFI and above average daily gain (1.46 kg/day) are estimated to produce 45.9% less methane than steers with high RFI and below average daily gain (52.5 vs 76.6 kg/year; Okine et al. 2001). Assuming that a carbon credit is worth $7.50 CAN/tonne of carbon dioxide equivalence, the methane credit for the low RFI steers with above average daily growth rate would be worth $3.80 CAN/head/yr relative to a high RFI steers with below average daily gain.

**Consequences of selecting for residual feed intake**

**Growth, body size and feed intake**

In 1993, Australian researchers began mating the top 5% of efficient bulls (negative residual feed intake) to the top 50% of efficient heifers, while the bottom 5% of inefficient bulls (positive residual feed intake) were mated to the bottom 50% of inefficient heifers (Arthur et al. 2001). The results revealed that after two generations of selection for RFI, the progeny from efficient parents had lower RFI, actual feed intake and FCR than the progeny of inefficient parents (Table I). There was no correlated response in either yearling weight or average daily gain. Canadian researchers (Basarab et al. 2002) have also shown that steers with low RFI consumed 6.4% and 10.4% less dry matter than medium and high RFI steers, respectively (8.00 vs. 8.55 vs. 8.93 ± 0.05 kg DM/day; P < 0.01). FCR was improved in low and medium RFI steers by 9.4% and 4.2% as compared to high RFI steers (5.39 vs. 5.70 vs. 5.95 ± 0.06 kg DM/kg gain; P < 0.01). Growth rate and body size were similar (P > 0.10) among the RFI groups.

**Carcass characteristics**

In a study conducted by Basarab et al. (2003), RFI was slightly and positively related to carcass marbling (r = 0.15, P = 0.07), dissectible carcass fat (r = 0.14, P = 0.09), gain in ultrasound backfat thickness (r = 0.22, P < 0.01), gain in ultrasound marbling (r = 0.22, P < 0.01) and
negatively related to dissectible carcass lean (r = -0.21, P = 0.01). Thus, steers with high RFI (inefficient) had slightly more subcutaneous and marbling fat than steers with low RFI. These results suggest that selection for animals with negative RFI will result in a slightly leaner animal. Similar results were obtained by Richardson et al. (2001), who reported that the progeny from cattle selected for low RFI had 12.4% less carcass fat than the progeny from cattle selected for high RFI (Table 2). The efficient progeny also tended (P < 0.10) to have 7.9% less total dissectible fat than the inefficient progeny. This lower carcass fat content in the efficient progeny raises several concerns, such as the potential genetic antagonisms of RFI with marbling and reproductive fitness and the effect that composition of gain has on the true energetic efficiency of the animal. Thus it is possible that differences in RFI were partially due to differences in fattening and not due to inherent differences in the energy required for maintenance and growth of specific animal types.

Body composition and composition of gain

A study just completed at the Lacombe Research Centre has provided new insight into the relationship between composition of gain and RFI. Basarab and coworkers (Basarab et al. 2003), in cooperation with BeefBooster Cattle Alberta Ltd., measured the individual feed intake of 148 steer calves (333 kg; 7-8 months of age). Steers from each of the five BeefBooster strains (M1, M2, M3, M4 and TX) were equally represented and all animals were adjusted to a high-barley diet. The steers were processed at the Lacombe Research Centre abattoir and carcass, organ and tissue weights were obtained and body composition evaluated. Multiple regression analysis revealed that metabolic midpoint weight, ADG, gain in empty body fat and gain in empty body water accounted for 67.9%, 8.6%, 3.9% and 1.1%, respectively, of the variation in actual feed intake. Simple correlation analysis across years showed that the relationship between RFI and gain in empty body fat, either expressed in grams per day (r = 0.26, P = 0.0015) or grams per kilogram of metabolic weight per day (r = 0.30, P = 0.0002), was positive (Figure 4), and gain in empty body fat accounted for 6.8% to 9.0% of the variation in RFI. The relationship between RFI and gain in empty body protein, either expressed in grams per day (r = -0.11, P = 0.1637) or grams per kilogram of metabolic weight per day (r = -0.13, P = 0.1170), was numerical negative, but not statistically significant (Figure 5). These results suggest that steers with low RFI had a slightly slower rate of empty body fat deposition than steers with high RFI (Table 3). Richardson et al (2001) reported that less than 5% of the variation in parental RFI was explained by variation in body composition evaluated. In their study, this small relationship in RFI to body composition manifested itself as a trend (P < 0.1) toward a 2.2% increase in protein gain by low RFI steers as compared to high RFI steers. Adjustment for this bias in body composition may be achieved by measuring animals for ultrasound backfat thickness and marbling score at the beginning and end of the test period.

Heat production (net energy for maintenance plus heat increment of feeding)

The Canadian study also revealed that high RFI steers consumed 4.6% more metabolizable energy (MEI) and produced 5.3% more heat than medium RFI steers and consumed 11.3% more MEI and produced 10.3% more heat than low RFI steers (Table 3). High RFI steers also partitioned more of the increase in MEI towards heat production and less toward retained energy than either medium or low RFI steers. This result may be partially explained by the finding that low and medium RFI steers had lower weights of liver (P <0.01), small and large intestine (P = 0.09), and stomach and intestine (P < 0.01) than high RFI steers. Other researchers (NRC 1996; Ferrell and Jenkins 1998) have reported that the efficiency of ME use for retained energy is not constant, but decreases as MEI increases. Ferrell and Jenkins (1998) suggested that a portion of non-linearity in the relationship of retained energy on MEI was due to a depression in metabolizability of the diet at high levels of
intake, higher maintenance cost or heat increment of feeding at higher levels of feed intake and heavier organ weights of stomach complex, intestines, heart, lung, kidney and spleen.

Cow reproduction and lifetime productivity

Several studies are presently underway in Canada and Australia on the longer-term consequences of selecting for post-weaning RFI on cow reproduction and efficiency. Preliminary results suggest that there is a high genetic correlation between post-weaning RFI and mature cow efficiency, and cow reproduction is unaffected (P. F. Arthur, 2002, pers. communication).

Implications

There is strong scientific evidence to support residual feed intake (net feed efficiency) as an indicator of the maintenance energy requirements of an animal. This trait is moderately heritable, indicating that genetic progress could be made in residual feed intake by incorporating it into already existing genetic improvement programs. In addition, residual feed intake can be used to select animals for lower maintenance requirements and feed consumption, without adversely affecting growth rate. Some effort may be required to adjust residual feed intake for differences in the chemical composition of gain so as not to adversely affect carcass characteristics and fat deposition in breeding females. Improving feed efficiency by measuring residual feed intake also has the potential to reduce methane emissions from cattle and, possibly, result in new agriculture investment due to methane credits being sold to the energy sector.


Figure 1. The relationship between feed conversion ratio (feed to gain ratio) and residual feed intake.
Average ADG=1.558 kg/day; Feed to Gain Ratio vs. RFI, R=0.45, P=0.013; ADG vs. Feed to Gain Ratio, r=-0.63, P<0.0001

Figure 2. Relationship between feed to gain ratio and residual feed intake in British beef bulls (n=30).
Average ADG = 1.429 kg/day; Feed to Gain Ratio vs. RFI, R=0.54, P<0.0001; ADG vs. Feed to Gain Ratio, r=-0.66, P<0.0001

Figure 3. Relationship between feed to gain ratio and residual feed intake in Continental beef bulls (n=46).
Table 1. Performance of progeny from low (efficient) or high (inefficient) residual feed intake bulls and heifers after five years of selection

<table>
<thead>
<tr>
<th>Traits</th>
<th>Number of animals</th>
<th>Net feed intake, kg/day</th>
<th>365 day live weight, kg</th>
<th>Average daily gain, kg/day</th>
<th>Actual feed intake, kg/day</th>
<th>Feed conversion ratio, kg/kg</th>
<th>Yearly Correlated response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low residual feed intake parents</td>
<td>62</td>
<td>-0.54a</td>
<td>384.3</td>
<td>1.44</td>
<td>9.4a</td>
<td>6.6a</td>
<td>0.25</td>
</tr>
<tr>
<td>High residual feed intake parents</td>
<td>73</td>
<td>0.71b</td>
<td>380.7</td>
<td>1.40</td>
<td>10.6b</td>
<td>7.8b</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Adapted from Arthur et al. (2001a)
b,c means in the same row differ, P<0.05

Table 2. Weight of carcass fat for yearling Angus steer progeny of parents selected for low (efficient) or high (inefficient) residual feed intake

<table>
<thead>
<tr>
<th>Traits</th>
<th>Number of animals</th>
<th>Cold carcass weight, kg</th>
<th>Carcass fat (IM and SQ)\textsuperscript{2}, kg</th>
<th>Carcass fat/final weight, %</th>
<th>Total dissectible fat/final weight, %</th>
<th>Sign.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low residual feed intake parents</td>
<td>16</td>
<td>240</td>
<td>42.1</td>
<td>9.9</td>
<td>19.8</td>
<td>NS</td>
</tr>
<tr>
<td>High residual feed intake parents</td>
<td>17</td>
<td>245</td>
<td>48.5</td>
<td>11.3</td>
<td>21.5</td>
<td>P &lt; 0.05</td>
</tr>
</tbody>
</table>

Adapted from Richardson et al. (2001)
\textsuperscript{2} IM = Intermuscular fat; SQ = Subcutaneous fat.
Figure 4. Relationship between residual feed intake and gain in empty body fat in steers, expressed either in grams per day ($r = 0.26$, $P = 0.0015$, $n=148$) or grams per kilogram of metabolic weight per day ($r = 0.30$, $P = 0.0002$, $n=148$).

Figure 5. Relationship between residual feed intake and gain in empty body protein, expressed either in grams per day ($r = -0.11$, $P = 0.1637$, $n=148$) or grams per kilogram of metabolic weight per day ($r = -0.13$, $P = 0.1170$, $n=148$).
Table 3. Body composition, daily accretion rates of protein, fat and energy, retained energy and heat production from steers with high, medium and low residual feed intake.

<table>
<thead>
<tr>
<th>Traits</th>
<th>Residual feed intake group²</th>
<th></th>
<th></th>
<th>SEM</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of steers</td>
<td>43</td>
<td>61</td>
<td>44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Empty body composition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water, g/kg</td>
<td>510b</td>
<td>513b</td>
<td>526a</td>
<td>3.0</td>
<td>0.0148</td>
</tr>
<tr>
<td>Fat, g/kg</td>
<td>282a</td>
<td>281a</td>
<td>265b</td>
<td>3.8</td>
<td>0.0211</td>
</tr>
<tr>
<td>Protein, g/kg</td>
<td>167</td>
<td>165</td>
<td>167</td>
<td>1.5</td>
<td>0.7331</td>
</tr>
<tr>
<td>Ash, g/kg</td>
<td>41</td>
<td>40</td>
<td>42</td>
<td>0.6</td>
<td>0.1518</td>
</tr>
<tr>
<td>Energy, MJ/kg</td>
<td>15.0a</td>
<td>14.9a</td>
<td>14.3b</td>
<td>0.1</td>
<td>0.0106</td>
</tr>
<tr>
<td>Empty body component gain, g/(kg⁷⁵. day)⁻¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>5.32b</td>
<td>5.46b</td>
<td>6.11a</td>
<td>0.17</td>
<td>0.0364</td>
</tr>
<tr>
<td>Fat</td>
<td>7.18a</td>
<td>6.98a</td>
<td>6.19b</td>
<td>0.07</td>
<td>0.0050</td>
</tr>
<tr>
<td>Protein</td>
<td>2.15</td>
<td>2.03</td>
<td>2.08</td>
<td>0.07</td>
<td>0.6057</td>
</tr>
<tr>
<td>Ash</td>
<td>0.41</td>
<td>0.36</td>
<td>0.44</td>
<td>0.02</td>
<td>0.1637</td>
</tr>
<tr>
<td>ME intake, KJ/(kg⁷⁵. day)⁻¹</td>
<td>1083a</td>
<td>1035b</td>
<td>973c</td>
<td>4.4</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Retained energy, KJ/(kg⁷⁵. day)⁻¹</td>
<td>332a</td>
<td>322a</td>
<td>292b</td>
<td>6.1</td>
<td>0.0018</td>
</tr>
<tr>
<td>Heat Production, KJ/(kg⁷⁵. day)⁻¹</td>
<td>751a</td>
<td>713b</td>
<td>681c</td>
<td>7.3</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>
a division of the Lesaffre Group, provides innovative products to livestock feed producers and pet food manufacturers.

- Live yeast for pelleted and non-pelleted feeds
- Inactive Feed Yeast
- Mineral Yeast (Selenium, Chromium, Manganese and Zinc)
- Enzymes (Xylanase, Glucanase, Cellulase and Hemi-Cellulase)
- Mannanoligosaccharides (Yeast Glucans)
"Where biotechnology, quality and service meet."
Feedlot Research at Texas Tech University: Effects of Nutrition on Nutrient Excretion, Health, and Performance by Cattle


Introduction

Over the last year, research conducted at Texas Tech University has focused on nutrient excretion, health, bacterial contamination, performance, and carcass merit of feedlot cattle. Ever tightening environmental regulations demand that producers be aware of and design programs to manage excess nutrient excretion, especially nitrogen and phosphorus. In addition, cattle health remains a concern and the development of new methods to prevent illness is a priority. Public concern and retail losses stemming from bacterial contamination of beef from E. coli has resulted in continued research into methods of reducing this harmful pathogen in the feedlots in hopes that this will reduce possible contamination at packing facilities. Finally, methods to continue to improve feedlot performance and carcass merit of cattle are consistently evaluated.

The effects of dietary crude protein concentration and source on nitrogen absorption and retention by feedlot steers

Twenty-seven crossbred steers (average BW = 353.2 ± 8.4 kg) were used in a metabolism trial with three collection periods (approximately 35, 95, and 155 d on feed) to evaluate the effects of dietary CP source and concentration on nitrogen balance by steers. Treatments were arranged in a factorial arrangement and consisted of three dietary CP concentrations (11.5, 13.0, and 14.5%) and three supplemental urea:cottonseed meal (CSM) ratios (100:0, 50:50, and 0:100 of supplemental N). During each nutrient collection period, steers were housed in individual metabolism stalls and urine and feces excreted were collected and frozen. In the first collection period, total N excretion increased linearly (P = 0.002) with increasing CP concentration. Nitrogen absorbed (g/d) and N retained (g/d) increased linearly (P < 0.0001 and P = 0.01, respectively) with increasing CP concentration. In the second collection period, total N excretion linearly increased (P < 0.0001) with increasing CP concentration. Nitrogen absorbed (g/d) and N retained linearly increased (P < 0.0001 and P = 0.001, respectively) when CP increased from 11.5 to 14.5%. In the third collection period, fecal N excretion increased linearly (P < 0.0001) with increasing CP. Nitrogen retained (% of absorbed) decreased linearly (P = 0.009) as CP in the diet increased from 11.5 to 13.0%. Nitrogen absorbed (g/d) decreased linearly (P = 0.03) with decreasing urea:CSM ratio. Nitrogen absorbed (% of intake) increased quadratically (P = 0.05) with decreasing urea:CSM ratio. Based on our observations, feeding growing steers diets containing 11.5 to 13.0% CP and supplemented with higher proportions of degradable protein may potentially optimize N utilization and potentially reduces N losses to the environment.
Effect of water and mineral source on performance of growing heifers

Ninety-six beef heifers (British x Continental; average initial BW = 335.54 kg) were used in a randomized complete block design to determine the effects of water sulfate concentration and supplemental mineral source on animal performance. Two water and three mineral sources were applied in a 2 x 3 factorial arrangement. Water treatments contained either 39.5 mg/kg sulfate (no added sulfate; NS) or 1,810 mg/kg sulfate (added sulfate; WS). Mineral treatments were: no supplemental Zn, Cu, Mn, and Co (NTM); inorganic sources of Zn, Cu, Mn, and Co (ITM); and organically complexed sources of Zn, Cu, Mn, and Co (CTM). Mineral treatments were supplied via three separate supplements included in a 90% concentrate finishing diet. Heifers were fed for 56 d and weights were recorded on d 0, 28, and 56. Average daily gain of heifers consuming NS water was greater (P = 0.04) than WS heifers (1.83 and 1.61 kg/d, respectively) for the first 28 d, however, water source had no effect (P = 0.07) on ADG for the 29-56 d period or for the entire 56-d trial (P = 0.77). Mineral source had no effect (P = 0.31) on ADG for the length of the study. Dry matter intake was not affected by either water (P = 0.70) or mineral source (P = 0.18) for any period of the trial. Heifers consuming NS water were more efficient (P = 0.01) than heifers consuming WS water (4.41 and 5.01, respectively) for d 0-28. However, water source had no effect on feed to gain for d 29-56 (P = 0.06) or 0-56 (P = 0.44). Mineral source had no effect (P = 0.39) on feed to gain for the length of the study. Results from this trial indicate that heifers introduced to high sulfate drinking water (~1,800 mg/kg) require an adjustment period, but soon perform at levels similar to animals consuming water with very low sulfate levels. Moreover, neither level nor source of supplemental trace minerals affected heifer performance, however, this may be a result of the relatively short duration of the trial.

Effects of live cultures of Lactobacillus acidophilus (Strains 45 and 747) and Propionibacterium freudenreichii on performance, carcass and intestinal characteristics, and Escherichia coli 0157:H7 shedding in finishing beef steers

British and Continental steers (240; initial BW = 332.8 ± 23.1 kg) were used to determine the effects of live cultures of Lactobacillus acidophilus (LA) and Propionibacterium freudenreichii (PF) on performance, carcass and intestinal characteristics, and prevalence of Escherichia coli O157:H7 (EC) shedding during the finishing phase. Cattle were fed a steam-flaked corn-based, 92% concentrate diet for an average of 170 d. The four treatments included: 1) control (CON) lactose carrier only; 2) 1 x 10^9 cfu of LA Strain 747 plus 1 x 10^6 cfu of LA Strain 45 plus 1 x 10^9 cfu of PF-24 per animal daily (G); 3) 1 x 10^9 cfu of LA Strain 747 plus 1 x 10^9 cfu of PF-24 per animal daily (Y); and 4) 1 x 10^6 cfu of LA Strain 747 plus 1 x 10^6 cfu LA Strain 45 plus 1 x 10^9 cfu of PF-24 per animal daily (B). A randomized complete block design was used with pen as the experimental unit (12 pens/treatment). No differences (P > 0.10) among treatments were detected for final BW, DMI, ADG, gain:feed, and hot carcass weight. In addition, dressing percent, longissimus muscle area, fat thickness at the 12th rib, percentage of internal fat, and yield grade did not differ (P > 0.10) among treatments. A trend (P = 0.08) was detected for treatment differences in ileal lamina propria (LP) thickness. The average LP thickness for Y and G steers was less (P < 0.05) than the
average for CON and B steers (0.38 vs 0.45 mm). Moreover, Y and G steers had a lower
\( P < 0.10 \) incidence of EC shedding than CON and B steers. Overall, these data indicate
that under the conditions of this study live cultures of LA plus PF did not greatly affect
feedlot performance and carcass characteristics. Some of the cultures used in this study
decreased fecal EC shedding, which might be related to the results for ileal LP thickness.

**Effects of dietary crude protein level and source on performance and carcass
characteristics of growing-finishing beef steers**

Two experiments were conducted at two locations (Clayton Livestock Research
Center and Texas Tech University Burnett Center) to determine the effects of dietary CP
level and source on performance and carcass characteristics of beef steers. British x
Continental steers were blocked by BW (357 ± 28 and 305 ± 25 kg initial BW; \( n = 360 \)
and 225; four and five pens/treatment in Exp. 1 (Clayton) and 2 (Burnett Center),
respectively). Steam-flaked corn-based diets were arranged in a 3 x 3 factorial with three
CP levels (11.5, 13, 14.5% of DM) and three sources of supplemental CP (N basis):
100% urea (U), 50:50 blend of urea and cottonseed meal (B), or 100% cottonseed meal
(C). Steers in both experiments were initially implanted with Ralgro and reimplemented
with Revalor-S on d 56. Performance and carcass data were pooled over location and
analyzed with mixed model procedures using pen as the experimental unit. Crude protein
level quadratically affected ADG \( P < 0.05 \) and carcass-adjusted (to a common dress)
ADG \( P < 0.10 \). Increasing the level of supplemental urea linearly increased carcass-
adjusted ADG and gain:feed \( P < 0.05 \) and carcass-adjusted gain:feed \( P < 0.001 \). Dry
matter intake was not affected by CP level or source \( P > 0.10 \). Hot carcass weight
(HCW), longissimus muscle area (LMA), and dressing percent tended to increase linearly
with increasing urea level \( P < 0.06 \), whereas increasing CP level quadratically affected
HCW \( P < 0.05 \), with a maximum value at 13% CP. Differences in back fat thickness
and yield grade were negligible across treatments. Neither marbling score nor percentage
of carcasses grading Choice was affected by CP level or source. Results indicate that
increasing CP levels from 11.5 to 13% slightly increased ADG and carcass-adjusted
ADG, whereas increasing the proportion of supplemental urea increased carcass-adjusted
ADG, gain:feed, carcass-adjusted gain:feed, HCW, LMA, and dressing percent. A CP
level above 13% seemed to be detrimental to ADG and HCW.

**Effects of supplemental amylase and roughage source on performance and carcass
characteristics of finishing beef cattle**

One hundred twenty steers (average BW = 370 ± 33.2 kg) were used in
randomized complete block design with a 2 x 2 factorial arrangement of treatments to
evaluate the effects of an experimental enzyme preparation with amylase activity
(Alltech, Inc., Nicholasville, KY) and source of roughage NDF on performance and
carcass characteristics of finishing beef cattle. Treatments were: 1) ALF-, 88%
concentrate diet with alfalfa as the roughage source and no added amylase preparation;
2) CSH-, 93.5% concentrate diet with cottonseed hulls as the roughage source and no
added amylase; 3) ALF+, 88% concentrate diet with alfalfa as the roughage source plus
amylase; and 4) CSH+, 93.5% concentrate diet with cottonseed hulls as the roughage
source plus amylase. Roughage level between the two sources was formulated to supply the same percentage of NDF from each source. Cattle were sorted into six weight blocks with one pen (five steers per pen) for each treatment within a weight block and were fed for an average of 152 d, after which they were harvested at a commercial slaughter facility. An amylase x roughage source interaction was detected for d 0 to 28 average daily gain (ADG; \( P = 0.02 \)); cattle fed CSH+ had greater ADG than those fed ALF+, ALF- or CSH-. Similarly, for ADG from d 0 to 112, an amylase x roughage source interaction was observed (\( P = 0.04 \)); cattle fed CSH+ had greater ADG than those fed CSH-. An amylase x roughage source interaction (\( P < 0.10 \)) was observed for dry matter intake (DMI) for d 0 to 56 and for d 0 to 112. Cattle fed the CSH+ had greater DMI than those in the other three treatments. Roughage source did not affect DMI, ADG, or feed efficiency at any point in the feeding period. Neither roughage source, amylase addition, nor the interaction affected (\( P > 0.10 \)) carcass weight, dressing percent, fat thickness, percentage of kidney, pelvic, and heart fat, marbling score, yield grade, or percentage of cattle grading USDA Choice or better. The addition of amylase increased longissimus muscle area (\( P = 0.05 \)). Based on these data, adding amylase to a steam-flaked corn-based finishing diet increased ADG and DMI at various periods during the finishing phase, but performance was not affected by roughage source when the percentage of NDF supplied by the roughage sources was similar.
Implant and programmed feeding of steers

Two experiments were conducted to determine the effect of implanting and programmed feeding strategies on performance and carcass characteristics in growing calves (Experiment 1) and yearlings (Experiment 2).

During experiment 1, 96 growing steers (average body weight, 270 ± 16.2 kg) were assigned to 12 pens in a completely randomized block design. Implant (Synovex-S) or no implant, and programmed fed to gain at a slow or fast rate (non implanted cattle were fed to gain 0.9 and 1.3 kg/d, respectively) were randomly assigned to a pen of steers in a 2 x 2 factorial arrangement. Steers were fed a diet consisting of 65% corn, 25% alfalfa pellets, and 10% supplement (as fed). After 88 and 60 days for steers fed to gain slow or fast, respectively, steers were transitioned to ad libitum consumption of a high concentrate finishing diet (10% roughage). At the beginning of the finishing period, all steers were implanted with Synovex-S and reimplanted with Revalor-S on day 63 and 72 for steers fed to gain fast or slow, respectively. Steers were harvested when the average fat thickness of the steers in the pen was predicted to be 12 mm as measured by ultrasound. There was an interaction between implant and rate of gain for ADG \((P = 0.053)\) and gain efficiency \((P = 0.075)\) during the growing period. The interaction occurred due to a higher ADG and gain efficiency in implanted steers fed to gain fast but not those fed to gain slow during the growing period. Implant treatments did not affect subsequent ADG or gain efficiency during the finishing period. From reimplant to harvest, steers fed to gain at a fast rate during the growing period gained more \((P = 0.066)\) than those fed to gain at a slow rate. Implant or rate of gain treatments did not affect marbling score, quality grade, fat thickness, or yield grade \((P > 0.10)\). In steers fed to gain at a slow rate in the growing period, implanting increased *Longissimus dorsi* area compared to those not implanted, but not when steers were fed to gain fast during the growing period. Feeding steers for a slow rate of gain during the growing period improved \((P = 0.013)\) gain efficiency in the finishing period (200 vs 155 g gain/kg feed).
When harvesting at a constant external fat, a greater percentage of the implanted steers fed to gain at a slow rate graded USDA Choice compared to those implanted and fed to gain fast. The non-implanted steers were intermediate in USDA Choice quality grade regardless of rate of gain during the growing period. Correlation coefficients of regression analysis between fat thickness and marbling score obtained via ultrasound and fat thickness and marbling score measured at harvest, was higher the closer the ultrasound measurements were made to the final harvest date. These data show that feeding level prior to the start of the finishing period affects performance during the finishing period.

During experiment 2, 96 steers (average body weight = 335 kg) were allotted to 12 pens in a completely randomized design with a 2 x 2 factorial arrangement of treatments. Factors were: a) implant on day 1 or no implant, and b) ad libitum access to feed (fast rate of gain) or programmed-fed for a target gain of 1.4 kg/d (slow rate of gain) during the first 62 day of the feeding period. On day 63 all steers were implanted with Revalor-S and provided ad libitum access to feed. External fat was estimated by ultrasound on day 1, 62 and 117. Steers were harvested when external fat was predicted to be 12 mm. Post harvest, carcass characteristics were determined. The 9th to 11th rib section was dissected to determine proportion of bone, fat and lean. By experimental design, ADG was greater ($P < 0.05$) for steers fed to gain fast (1.96 kg) compared to those fed to gain slow (1.27 kg) from day 1 to 62. During day 63 to 116, ADG and gain efficiency for steers programmed-fed to gain slow (2.24 kg and 194 g gain/kg feed, respectively) were greater ($P < 0.05$) than for steers fed to gain fast (1.67 kg and 140 g gain/kg feed, respectively). Restricting feed intake to reduce ADG during the first 62 day of the finishing period increased ($P = 0.005$) ADG during the remaining portion of the finishing period. Gain efficiency was improved ($P = 0.097$) throughout the entire finishing period by reducing ADG during the first 62 days of the experiment. An interaction ($P = 0.024$) occurred for fat weight from the 9th to 11th rib section. Implanted steers fed to gain fast had the least fat and non-implanted steers programmed-fed to gain slow had the most fat. Marbling score, yield grade, fat thickness, and longissimus dorsi area was not affected by experimental treatment. However, delaying the first implant during the finishing period reduced ($P = 0.039$) kidney, pelvic and heart fat percentage compared to steers implanted on day 1. Correlation coefficients between ultrasound measurements of external fat and marbling score were higher the closer the measurement was taken to the harvest date. Reducing ADG during the first 62 days of the finishing period, increased ($P = 0.097$) gain efficiency throughout the experiment. In the present study, this increased efficiency resulted in less N and P (2,650 and 461 g/ steer, respectively) being transported to the feedyard when ADG was restricted during the first part of the finishing period.

Effects of cation anion intake on acid base balance and performance of heifers before and during transition to a high concentrate finishing diet

Cattle grazing forages in areas where high sulfate water sources exist may have lower urinary pH and be more susceptible to metabolic acidosis during transition to high concentrate diets. Twenty seven British cross heifers, 255 kg, were blocked by weight and randomly assigned to three DCAD diets to determine the effect on urine and blood pH and performance during the growing period. The DCAD diets consisted of $-100$, $+75$
and +250 mEq/kg of diet DM. Heifers were housed in 3 pens and individually fed using Calan electronic gate feeders. During day 1 to 70, heifers were fed to gain .91 kg/d. During day 71-80 heifers were transitioned to full feed. On day 81, heifers where started on a feedlot finishing step up program for 16 d. Urine pH was determined on day 14, 28, 42, 56, 70, 80, 96 and 110. Blood pH, pCO₂ and plasma HCO₃⁻ was determined on day 28, 56, 70, 80, 96 and 110. By day 14, urine pH was lower for the heifers fed -100 mEq/kg compared to the heifers fed +75 and +250 mEq/kg (6.79 vs. 7.94 and 8.13) and remained lower until day 85. When heifers were fed their respective diets ad libitum, urine pH decreased 15% for those fed -100 mEq/kg from day 70 to 80 but not for those fed +75 and +250 mEq/kg. There was no difference in blood pH due to DCAD treatment. Blood pCO₂ and HCO₃⁻ were lower on day 80 for heifers fed the -100 mEq/kg diet compared to those fed +75 and +250 mEq/kg diets. Feed intake and ADG were lower for -100 mEq/kg than for +75 and +250 mEq/kg for day 70-110. Results indicate that consumption of a diet containing -100 mEq/kg DCAD prior to entering the feedlot may decrease feed intake and hinder ADG during the transition period.

Performance of Feedlot Heifers Fed Corn Silage or Brown Midrib Forage Sorghum Silage as the Roughage Portion of a Finishing Diet

One hundred twenty-six cross bred heifers (average body weight = 315 kg) were used to determine the performance of heifers fed brown midrib forage sorghum silage vs. corn silage as the roughage source in a high concentrate finishing diet. Silage was stored in 4.5 meter diameter silage bags. Heifers were blocked by weight and previous grazing program, and randomly assigned to one of three diets; 10% (DM basis) corn silage, 10% (DM basis) brown midrib sorghum silage, 7.5% (DM basis) brown midrib sorghum silage. Other diet ingredients consisted of steam flaked corn, white tallow grease, and supplement. Diets were formulated to include corn silage and brown midrib sorghum silage at equal levels of DM inclusion, and equal NDF concentrations. Heifers were housed in 18 pens (n = 7/pen), and fed in fence-line bunks. Heifers were weighed at 28-d intervals, and carcass characteristics determined post harvest. Heifers fed either the 10 or 7.5% brown midrib sorghum silage gained 11.3% faster (P < 0.03) than those fed corn silage (1.38 and 1.38 vs. 1.24 kg/d, respectively). Feed intake was not different (P = 0.43). Feed efficiency was improved (P < 0.01) for heifers fed the 10 and 7.5% brown midrib sorghum silage diets than those fed the corn silage diet (2.88 and 2.87 vs. 3.08 respectively). Feedlot performance was not different between the 10 and 7.5% brown midrib sorghum silage diets. No differences in carcass measurements were detected. Results indicate that BMRS as a roughage source will not affect performance of heifers fed a high concentrate finishing diet when compared to those fed CS. This experiment is currently being repeated using steers.

Performance of crossbred steers grazing photoperiod sensitive and non photoperiod sensitive Sorghum Sudangrass hybrids.

Twelve 2.23 ha pastures were seeded with 28 kg/ha of two non photoperiod sensitive sorghum sudan hybrid, SS 200 BMR or SS 201 BMR, or two photoperiod sensitive sorghum sudan, Mega Green or non photoperiod sensitive 210 BMR (n=3 pastures/hybrid). Sorghum sudan 200 BMR, 201 BMR and photoperiod sensitive 210
BMR contained the brown midrib gene. Pastures were irrigated with 49.4 cm/ha and fertilized with 336 kg/ha of 20-10-0 before planting. Crossbred steers (n=132; avg BW=251 kg) were allotted to the pastures using a ‘put-and-take’ pasture management. On day 0 and the last day of the grazing period, forage availability was determined by hand clipping six predetermined areas in each pasture. For the forage samples collected on day 0, leaf and stem percentages were determined. Grazing was terminated when forage growth and availability did not support steer growth. Amount of available forage at the initiation of grazing was greater (P=0.0464) for 201 BMR (3,002 kg/ha) than MG (2,163 kg/ha) or 200 BMR (2,206 kg/ha) with 210 BMR being intermediate (2,500 kg/ha). No differences (P=0.3869) occurred in the initial percentage of leaf or stem. Grazing head days/ha were greater (P=0.0234) for mega green than for 210 BMR, 201, BMR and 200 BMR (447 vs 382, 373, and 373 d/ha). Amount of available forage at the conclusion of grazing was similar (P=0.2414) for the hybrids (1,763, 1,253, 1,186, and 868 kg/ha for mega green, 210 BMR, 201 BMR and 200 BMR, respectively). Steers grazing 200 BMR had a greater (P=0.0086) ADG than those grazing mega green, 210 BMR or 201 BMR (1.38 vs. 1.02, 1.05, and 1.16 kg/d, respectively). Gain per ha was greater (P=0.1010) for steers grazing 200 BMR (515 kg/ha) than 210 BMR (404 kg/ha) with MG (456 kg/ha) and 201 BMR (436 kg/ha) being intermediate. These data show that grazing 200 BMR resulted in greater ADG and gain/ha than 210 BMR.

Precision feeding of protein to steers using calan electronic feeders.

Forty five crossbred steers (average initial weight = 423 kg) were previously trained to consume their daily feed from calan electronic gate feeders. Steers were blocked by weight and fed ad libitum a finishing diet containing 10% roughage (DM basis) formulated to contain 13% crude protein (DM basis) for 62 days. Data was analyzed as a randomized block design. On day 62, the dietary crude protein was maintained at 13% crude protein or reduced to 11.5% crude protein or no supplemental protein. At the time of the diet change, the average body weight of steers was 536 kg. Steers were harvested when they had 25 mm of external fat. At harvest (day 109) the average body weight was 585 kg. From day 62 to 109, reducing the crude protein content of the diet to 11.5% or no supplemental crude protein did not affect (P=.51) ADG of steers (1.12, 1.06 and .99 kg/d for no supplemental protein, 11.5% CP and 13% CP, respectively). The ADG of steers were similar throughout the feeding period regardless of crude protein treatment (1.49, 1.50 and 1.45 kg/d for no supplemental protein, 11.5% CP and 13% CP, respectively). These data suggest that crude protein levels can be reduced during the final stages of finishing without any reduction in ADG.

Nitrogen and phosphorus utilization by beef cattle fed three dietary crude protein levels with three levels of supplemental urea

Three dietary CP levels (11.5, 13.0, and 14.5% of DM) and three supplemental urea levels (100, 50, and 0% of supplemental CP from urea) were used in a 3 x 3 factorial arrangement of treatments to determine performance, blood urea N (BUN), and N and P balance. Crossbred steers (n = 27; average BW = 315 kg) were blocked by BW and individually fed the dietary treatments in a completely randomized block design. A steam-flaked corn-based diet was fed, with supplemental CP supplied by either urea, a 50:50 blend (N basis) of urea and cottonseed meal (CSM), or CSM (100, 50, and 0% of
supplemental CP from urea, respectively). Steers were used in three nutrient balance collection periods (NBCP) at the beginning, middle, and end, of the feeding period. Venous jugular blood was obtained at the start and end of each NBCP. No dietary CP level x supplemental CP source interactions (P > 0.10) were observed for any variables. Steer DMI, ADG, and gain efficiency did not differ (P > 0.10) among treatments. For each NBCP, urinary total N (g/d), urinary urea N (UUN), and BUN increased linearly (P < 0.10) as dietary CP level increased. For NBCP 1 and 3, fecal N output increased linearly (P < 0.10) as supplemental CP from CSM increased. For NBCP 2 and 3, UUN decreased linearly (P < 0.10) as supplemental urea level decreased. For NBCP 1, fecal and urinary P excretion (g/d) increased linearly (P < 0.10), and P retained (% of intake) decreased linearly (P < 0.10), as dietary CP level increased. Phosphorus intake increased linearly (P < 0.10) as supplemental CP supplied by CSM increased for each NBCP. Fecal P output increased linearly (P < 0.10) in all NBCP, and urinary P excretion in NBCP 1 and 2 increased linearly (P < 0.10) as supplemental urea level decreased. Phosphorus retained (% of intake) decreased linearly (P < 0.10) as supplemental CP from urea decreased for NBCP 3. Results suggest that as dietary CP level increased, N retention (% of intake) decreased, and as supplemental CP supplied by urea decreased, P balance decreased in feedlot steers. As days on feed increased, less (P < 0.10) N and P were retained, suggesting the potential to decrease N and P excretion by feeding less N and P as the feeding period progresses.
Research Update-University of Nebraska

Galen Erickson¹

Introduction
In the feedlot nutrition area, we have been working in a few areas over the past couple of years, which are an extension of long-term research areas at the University of Nebraska. These areas include: nutrient management, protein nutrition, corn milling byproduct utilization, starch utilization and acidosis management, and growth promotion. A new area that we have been involved in relates to pre-harvest intervention strategies for E. coli O157:H7. The research update will relate primarily to my research program. I have included recent abstracts as a guide, but a more complete description is available in our annual beef report publication. For access to our annual beef report publication, please visit: http://www.ianr.unl.edu/pubs/beef/beefrpt.htm or contact me for copies. There are other research abstracts being presented and published in the abstract section of the proceedings that were purposely omitted to avoid redundancy.

Effects of starch endosperm type and corn processing method on feedlot performance and nutrient digestibility of high-grain diets.
C.N. Macken*¹, G.E. Erickson¹, C.T. Milton¹, T.J. Klopfenstein¹, H.C. Block¹, and J.F. Beck²,
¹University of Nebraska, Lincoln, NE, and ²Sygenta Seed, Golden Valley, MN.

Finishing and metabolism experiments were conducted concurrently to evaluate two starch types and two corn processing methods. For both experiments, two dent type corn hybrids were grown under similar conditions with one hybrid containing primarily vitreous endosperm (FLINT) and the other hybrid containing primarily floury endosperm (FLOUR). Corn was harvested at two different times, as high-moisture (HMC; > 28% moisture) or dry corn (DRC) and processed through a roller. Treatment design was a 2x2 factorial with factors being corn hybrid (FLINT or FLOUR) and processing method (HMC or DRC). Diets contained 81% of the respective corn, 8% alfalfa hay, 3% molasses, and 8% supplement. In the finishing experiment, 160 crossbred steer calves (291 kg) were used in a completely randomized design with 4 pens per treatment. Steers were implanted with Synovex C on d 0, reimplanted with Revalor-S on d 72, and fed a total of 191 d. The FLOUR endosperm improved (P < 0.05) ADG and feed efficiency compared to FLINT endosperm when fed as DRC. However, ADG and feed efficiency were similar between endosperm types when fed as HMC. Feeding FLINT as HMC improved feed efficiency by 9.5% compared to DRC and feeding FLOUR as HMC improved feed efficiency by only 3.5%. In the metabolism experiment, four ruminally fistulated steers (542 kg) were used in a 4x4 Latin Square experiment with periods consisting of 14 d adaptation and 7 d of continuous rumen pH measurement. Chromic oxide was used as a digestibility marker. The FLOUR endosperm had higher (P = 0.06) starch digestibility than the FLINT endosperm, while processing method had no effect.

¹ Correspondence: C220 Animal Science, P. O. Box 830908; Lincoln, NE 68583-0908; ph: 402 472-6402; email: geericks@unlnotes.unl.edu
Ruminal pH change and variance were increased (P < 0.10) for HMC compared to DRC with no significant difference between endosperm types. These data suggest an important interaction between starch type and processing method, with less intensive processing required for corn containing less vitreous endosperm.

**Corn processing method and crude protein level in finishing diets containing wet corn gluten feed.**

C.N. Macken*, G.E. Erickson#, T.J. Klopfenstein†, and R.A. Stock‡,

*University of Nebraska, Lincoln, ‡Cargill Inc., Blair, NE.

Three hundred twenty crossbred steer calves (307 kg) were used in a completely randomized design finishing experiment to determine the effect of corn processing and additional urea on performance of steers fed diets containing Sweet Bran® wet corn gluten feed (WCGF). Steers were stratified by initial weight and allotted to 1 of 40 pens (8 steers/pen). Pens were assigned randomly to 1 of 10 dietary treatments (4 pens/treatment). The treatment design was a 5x2 factorial with factors being corn processing method (dry-rolled, DRC; fine-ground, FGC; rolled high-moisture, RHMC; ground high-moisture, GHMC; or steam-flaked corn, SFC) and CP level (13 or 14%).

Observed protein levels fed were 14 and 15%. The final diet contained 60% of the respective corn, 25% WCGF, 10% corn silage, and 5% supplement. Steers were adapted to final diets in 21 d. Steers were implanted with Synovex S on d 1, reimplemented with Revalor-S on d 51, and fed for 152 d. No significant protein x grain processing interactions occurred for any feedlot performance or carcass variables. Protein level had no effect on any of the variables measured, suggesting protein requirements were met. Grain processing method did affect cattle performance. Dry-rolled corn and FGC had similar intakes but had higher (P < 0.01) intakes than RHMC, GHMC, or SFC. Intakes were similar among RHMC, GHMC, and SFC. Therefore, more intense processing decreased DMI. Daily gain was similar across all treatments (average = 1.94 kg/d). Feed efficiency was improved (P < 0.01) by 3.8, 7.0, 8.7, or 11.8% for FGC (0.189), RHMC (0.195), GHMC (0.198), or SFC (0.204), respectively, compared with DRC (0.182). Feed efficiency was significantly different among the processing treatments, except for RHMC and GHMC. While the grains were not fed without WCGF, the large response to intensive processing suggests WCGF alleviated problems with acidosis and sorting which allowed expression of differences in energy value associated with processing.

**Evaluation of initial implants on performance and carcass quality in feedlot heifers**

T. B. Farran*, G. E. Erickson†, T. J. Klopfenstein†, G. Sides‡, B. Dicke‡, J. S. Drouillard‡

*University of Nebraska-Lincoln; ‡Intervet, Inc.

A commercial feedyard experiment was conducted to compare a new low-dose implant to a more traditional high-dose product as the initial implant for feedlot heifers. Heifers (n = 1,124; initial BW = 278 kg) were implanted with either Revalor-IH® (Rev-IH; 8 mg estradiol, 80 mg TBA) or Synovex-H² (Syn-H; 20 mg estradiol benzoate, 200 mg testosterone propionate) at initial processing. Each group of incoming cattle constituted a treatment replication, providing a total of six replications per treatment (12 pens total).
Heifers were kept separate by arrival date and assigned to treatment by every other animal during initial processing. After processing, pens were immediately group weighed to establish initial weight of the pen prior to experiment initiation. Replicates of heifers were reimplanted with Revalor-200® (20 mg estradiol, 200 mg TBA) as the common terminal implant 81 d (range 69 to 85 d) prior to slaughter. Cattle were fed for an average of 177 d (range 147 to 202 d). DMI was similar between treatments. Implanting heifers initially with Rev-IH improved feed efficiency (0.190 vs. 0.186; \( P = 0.03 \)) and tended to increase ADG (\( P = 0.10 \)) with a 4-kg difference (\( P = 0.15 \)) in hot carcass weight compared to heifers implanted with Syn-H. Furthermore, Rev-IH implanted heifers had higher marbling scores (\( P < 0.07 \)), with 8.7% more carcasses (\( P = 0.02 \)) achieving the upper two-thirds Choice category compared to heifers initially implanted with Syn-H. Fat depth and longissimus area were not different (\( p > 0.25 \)), but calculated yield grades were higher for heifers administered Rev-IH (2.60 vs. 2.71; \( P = 0.09 \)). Syn-H heifers contained 29.0% empty body fat compared to 29.4% for Rev-IH implanted heifers (\( P = 0.12 \)). Results indicate that in commercial feedlot size pens, Rev-IH can improve feed conversion, marbling scores, and carcass quality with no negative impact on growth performance.

**Impact of cleaning frequency of pens and carbon to nitrogen (C:N) ratio as influenced by the diet or pen management on N losses from outdoor beef feedlots**

G. E. Erickson, J. R. Adams, T. B. Farran, C. B. Wilson, C. N. Macken, and T. J. Klopfenstein

Nitrogen losses from outdoor feedlots is an important environmental issue facing beef producers. Two methods that may lower N losses are cleaning pens more frequently to prevent exposure of manure N during collection on pen surfaces or increasing the C:N ratio of manure by increasing organic matter (OM) on the pen surface. Feeding diets lower in OM digestibility or directly adding OM to pen surfaces may increase the C:N ratio and decrease N losses.

In Exp. 1, calves in the winter/spring or yearlings in the summer were fed diets lower in digestibility (BRAN) or fed in pens with sawdust additions (SAWDUST) to increase the C:N ratio and OM on the pen surface. These two treatments were compared to conventional feeding and pen management systems (CONTROL). While decreasing digestibility did depress performance as measured by feed efficiency, feeding BRAN did increase OM on the pen surface and decreased N losses compared to CONTROL in the winter/spring but did not affect N losses or increase manure N during the summer. Adding SAWDUST directly to pens yielded similar results to BRAN, with decreased losses in the winter/spring and little effect during the summer compared to CONTROL. However, when manure was composted, N recovery during composting was increased for both the BRAN and SAWDUST treatments compared to CONTROL suggesting that OM may decrease N losses when manure is composted.

In Exp. 2, diets similar to CONTROL and BRAN were evaluated as a 2 X 2 factorial treatment design experiment. The other factor evaluated was cleaning frequency. Pens were either cleaned monthly or cleaned once at the end of the winter/spring feeding period. Performance of steers was similar to results in Exp. 1, with lower feed efficiency for cattle fed BRAN compared to the CONTROL treatment. Dietary treatment and
cleaning frequency treatments interacted for N balance in the feedlot. Nitrogen losses were decreased and manure N increased for cattle fed BRAN compared to CONTROL if pens were clean monthly. If pens were not cleaned until the end of the feeding period, diet had little effect on N losses. Interestingly, N losses were similar between both cleaning frequency treatments for cattle fed CONTROL.

In Exp. 3, 54 pens were used to evaluate the impact of monthly cleaning on N removal in manure during the summer months. The same diet was fed in all pens, resulting in similar performance across treatments. Cleaning pens monthly increased the amount of manure N removed per steer by 3.74 kg or 66.2% compared to pens cleaned once at the end of the feeding period. These data suggest that cleaning pens more frequently and adding OM to pen surfaces or compost may decrease N losses from outdoor feedlot pens. Treatment responses appear to be dependent on ambient temperature or season, suggesting that future research needs to address both summer and winter/spring feeding periods typical of beef cattle operations.

**Work in Progress**

Hybrids are currently being characterized using laboratory assays for kernel traits, in vitro digestion, in situ digestion, and feedlot performance. Seven hybrids varying in kernel size, starch type, and vitreousness were grown, stored, and are currently being fed and characterized.

We are currently conducting one commercial trial comparing Revalor-IS to Synovex-S followed by Revalor-S terminal implant. We are also evaluating numerous combinations of implant regimens for both initial and terminal implants in our research feedlot. This study will utilize serial slaughter techniques to evaluate optimum days on feed for carcass composition.

Managing N and P are still major focus areas. We are currently working in the P nutrition and excretion area with some exciting preliminary data from this spring. The N management area is primarily focused on one last question relative to the lower OM digestibility trials that we have been conducting. The question remains, can we get the performance back and still capture N in manure with OM? Once that question is addressed, this research focus will take a different direction next year. The other method to manipulate N losses is to continue work in the protein area. We are working on protein metabolism in finishing diets to "fine-tune" requirements for the future. Our goal is to optimize performance while minimizing excess. In a related area, one improvement may relate to the escape fraction of protein in corn. Therefore, we are currently evaluating methods to manipulate corn protein.
Servi-Tech Laboratories
Dodge City, KS
800-557-7509
www.servitechlabs.com

Hastings, NE
800-468-5411

Cargill
Animal Nutrition
High moisture tempering of corn before flaking: Effects on bacterial contamination from house flies and fecal shedding in finishing cattle.

Kansas State University, Manhattan

Adding high levels of moisture to corn prior to flaking was used to increase gelatinization of starch in steam-flaked corn. The resulting product contained more moisture than conventional flaked grain (36% vs. 18%, respectively), greater starch availability (72 vs. 56.8%, respectively), and was very attractive to house flies. Tempered, high moisture (TEMP) and non-tempered (NT) steam-flaked corn samples and total mixed rations containing 73% (dry matter basis) of either TEMP or NT steam-flaked corn were exposed to flies and the environment for 21 hours. Exposure of both TEMP and NT corn to flies and environment increased generic E. coli (P<0.05), other coliforms (which includes E. coli O157:H7; P<0.05), total coliforms (P<0.05), and total aerobic plate counts (P<0.05). E. coli and coliforms were numerically, but not significantly greater (P>0.05) for TEMP corn compared to NT corn. Tempering corn before steam-flaking increased (P<0.05) total plate counts before (3.86 log10 CFU/g vs. 5.78 log10 CFU/g, for NT and TEMP, respectively) and after exposure (5.49 log10 CFU/g vs. 8.19 log10 CFU/g, for NT and TEMP, respectively). Exposure of rations containing TEMP and NT steam-flaked corn to environment and flies did not alter generic E. coli, other coliforms, total coliforms, or total aerobic plate counts. Generic E. coli were greater (P<0.05) in total mixed rations containing TEMP corn compared to NT corn, both before (1.88 log10 CFU/g vs. 3.46 log10 CFU/g, for NT and TEMP, respectively) to flies and environment. Total aerobic plate counts differed (P<0.05) for total mixed rations after exposure (6.44 log10 CFU/g vs. 8.60 log10 CFU/g, for NT and TEMP, respectively). Following the initial experiment, ninety-six finishing beef heifers were used to evaluate effects of tempering steam-flaked corn on acid-resistant generic E. coli, other coliforms (which includes E. coli O157:H7), and total fecal coliforms. On day 56 of the feeding period, fecal grab samples were taken to enumerate E. coli and other coliforms. No significant differences (P>0.05) due to tempering treatment were observed for generic E. coli, other coliforms, and total fecal coliforms when cultured at a neutral pH. However, cattle fed rations containing TEMP steam-flaked corn as compared to NT steam-flaked corn shed fewer acid resistant other coliforms (0.85 log10 CFU/g vs. 1.33 log10 CFU/g, for TEMP and NT, respectively; P<0.01) and total acid resistant fecal coliforms (0.85 log10 CFU/g vs. 2.49 log10 CFU/g, for TEMP and NT, respectively; P<0.01). Tempering steam-flaked corn prior to flaking did not significantly increase (P>0.05) generic E. coli, other coliforms, and total coliforms in steam-flaked corn, but fecal shedding of acid resistant other coliforms (including E. coli O157:H7) and total coliforms were actually lower (P<0.01) for cattle receiving the ration containing NT steam-flaked corn. Total aerobic plate counts may include organisms that competitively inhibit acid resistant E. coli. It is possible that differences in starch availability between TEMP and NT steam-flaked corn (72% and 56.8%, respectively) resulted in greater ruminal digestion of tempered grain, thereby resulting in less substrate to support hind-gut proliferation of acid resistant E. coli.

Effect of purchasing bull vs steer calves on receiving performance and wheat pasture gain.

H. A. DePra, R. E. Peterson, D. R. Gill, and C. R. Krehibe
Oklahoma State University

Beef production historically has existed as a highly segmented industry with various segments being owned and operated independently of one another. Often, profitability of one segment has occurred at the expense of another, with little or no attention afforded to overall profitability of the entire production system. Understanding interactions among various phases of beef production are key to identifying the means of fully capitalizing on their relationships. The objective of our study was to determine the difference in performance of sale barn calves bought as bulls and castrated at processing vs comparable steer calves during a 42-day receiving trial and subsequent wheat pasture grazing period. A total of 104 steer (avg initial BW = 236 ± 24 kg) and 103 bull (avg initial BW = 240 ± 23 kg) calves of sale-barn origin (Oklahoma City) were received in two loads, one week apart, at the Willard Sparks Beef Research Center during September 2002. At processing (d 1), bull calves were castrated using a Newberry knife and a single crimp emasculator. Calves were sorted by sex and blocked by initial BW, then randomly assigned to pens. Within each pen, one-half of the calves were randomly assigned to implant treatments of: 1) Component E-C w/Tylan® (10 mg of estradiol benzoate, 100 mg progesterone), or 2) no implant. All calves were fed a diet consisting of 49.7% whole shelled corn, 12% cottonseed hulls, 25% ground alfalfa, 3% molasses, and 10.3% pelleted...
supplement (DM basis). Overall ADG was greater (P < 0.01) for steers (0.84 kg) compared with bulls (0.65 kg), and for implanted (0.82 kg) vs non-implanted (0.68 kg) calves. In addition, implanted bulls had lower (P < 0.01) gain compared with non-implanted steers (0.71 vs 0.76 kg, respectively). Dry matter intake was not influenced (P = 0.68) by sex throughout the feeding period (5.72 vs 5.63 kg/d for steers vs bulls, respectively). Overall, steers were more (P = 0.03) efficient during the receiving period than bulls. Following the receiving period, all calves were implanted with Component E-S (20 mg estradiol benzoate, 200 mg progesterone) and distributed by original load to wheat pasture in Piedmont (Load A) or Thomas (Load B), OK. Despite differences (P < 0.01) in body weight between bulls and steers entering wheat pasture (264 vs 275 kg, respectively), there was no difference (P = 0.11) between the weights at which bulls and steers came off of wheat pasture (361 vs 367 kg, respectively). Days on wheat were not different (P = 0.42) for bulls (113 d) compared with steers (111 d). Similarly, ADG on wheat was not different (P = 0.22) between bulls (0.85 kg/d) and steers (0.82 kg/d). There was a main effect interaction (P < 0.05) due to implanting during the initial receiving period on the final wheat weight of bulls (367 vs 355 kg implanted vs non-implanted, respectively) and steers (366 vs 367 kg implanted vs non-implanted, respectively). We conclude that purchased bull calves, castrated at processing, will be approximately 9.5 kg lighter than comparable steer calves after a 42-day receiving period. However, purchased bulls will regain approximately 5.9 kg of that difference in body weight after grazing wheat pasture for 112 days.

Key Words: Castration, Implants, Receiving Cattle, Wheat Pasture

Effects of Flax Supplementation and a Combined Trenbolone Acetate and Estradiol Implant on Circulating Insulin-Like Growth Factor-1 (IGF-1) and Muscle IGF-1 mRNA Levels and Satellite Cell Activity in Beef Cattle.

Kansas State University

Objectives of this study were to evaluate the effects of a 5% ground flaxseed supplement (FLAX) and a combined trenbolone acetate (TBA) and estradiol (E2) growth promotant, Revalor-S, (IMP) on circulating IGF-1 and muscle IGF-1 mRNA concentrations as well as muscle satellite cell activity. Sixteen yearling crossbred steers (initial BW = 874 lb) were randomly assigned to one of four treatments: 1) FLAX/IMP, 2) No FLAX/IMP, 3) FLAX/No IMP, 4) No FLAX/No IMP. Steers were allowed ad libitum access to a 93% concentrate diet for the entire study. Serum was harvested from blood collected via jugular venipuncture on d 0 (before implantation or FLAX addition), 14 and 28, and stored for subsequent use in analysis of circulating IGF-1 levels. Biopsy samples (3.5 g) were obtained from the longissimus muscle on d 0, 14, and 28. Total RNA was isolated from the muscle samples and real-time quantitative-PCR was used to evaluate relative differences in gene expression. Satellite cells were isolated from the biopsy samples and cultured. FLAX supplementation had no effect (P > 0.10) on circulating IGF-1 levels. Following implantation, sera from IMP steers had 52 and 84% greater (P < 0.05) IGF-1 levels as compared to sera from No IMP steers on d 14 and 28, respectively. On d 28, local muscle IGF-1 mRNA levels were increased 2.4-fold (P < 0.01) in biopsy samples obtained from IMP as compared to No IMP steers. No FLAX cattle had increased levels of muscle IGF-1 mRNA as compared to FLAX cattle on d 28 (4.4-fold, P < 0.01). FLAX or IMP had no effect on satellite cell activity. However, number of nuclei at 24 h post-plating increased (P < 0.001) from d 0 to 28 whereas total nuclei number 192 h post-plating was unchanged (P > 0.10). Myotube nuclei increased (P < 0.05) from d 0 to 28 and thus fusion percentage also increased (P < 0.03) from d 0 to 28. Number of times cells doubled in culture decreased (P < 0.001) from d 0 to 28. Administration of a Revalor-S implant increased circulating IGF-1 and local muscle IGF-1 mRNA concentrations in finishing cattle. However, the increase in muscle IGF-1 mRNA appears to be attenuated by the addition of a FLAX supplement. These data suggest satellite cells were activated in vivo over the 28 d period and that the cells lost some of their proliferative capacity when placed in culture, as indicated by the reduction in doubling on d 28 as compared to d 0 and 14. Also, the increases in myotube nuclei and fusion percentage over time indicate that isolated satellite cells became more inclined to differentiate into muscle over the feeding period regardless of FLAX or IMP. This inclination toward differentiation into muscle could ultimately impact the rate and efficiency of lean tissue deposition in finishing cattle.
In Exp. 1, 240 beef steers (British and Continental; initial BW = 332.8 kg) were used to determine the effects of live cultures of *Lactobacillus acidophilus* (LA) and *Propionibacterium freudenreichii* (PF) on performance, carcass and intestinal characteristics, and *Escherichia coli* 0157:H7 shedding of finishing beef steers.

**Effects of live cultures of Lactobacillus acidophilus (Strains NP45 and NP51) and Propionibacterium freudenreichii NP24 on performance, carcass and intestinal characteristics, and Escherichia coli 0157:H7 shedding of finishing beef steers**

N. A. Elam¹, J. F. Gleghorn², J. D. Rivera³, M. L. Galveya, P. J. Defoor², M. M. Brashers¹, and S. M. Younts-Dahl³

¹Texas Tech University, Lubbock; ²Clayton Livestock Research Center

In Exp. 1, 240 beef steers (British and Continental; initial BW = 332.8 kg) were used to determine the effects of live cultures of *Lactobacillus acidophilus* (LA) and *Propionibacterium freudenreichii* (PF) on performance, carcass and intestinal characteristics, serum IgA concentrations, and prevalence of *E. coli* O157:H7 (EC). Cattle were fed a steam-flaked corn-based, 92% concentrate diet, and the four direct-fed microbial (DFM) treatments (12 pens/treatment) included in a randomized complete block design were: 1) control, lactose carrier only (R); 2) 1 x 10⁹ cfu of LA NP51 plus 1 x 10⁶ cfu of LA NP45 plus 1 x 10⁶ cfu of NP24 per animal daily (Y); and 3) 1 x 10⁹ cfu of LA NP45 plus 5 x 10⁶ cfu of PF NP24 per animal daily (G); 4) 1 x 10⁹ cfu of LA NP51 plus 1 x 10⁶ cfu LA NP45 plus 1 x 10⁶ cfu of NP24 per animal daily (Y); and 4) 1 x 10⁹ cfu of LA NP51 plus 1 x 10⁶ cfu LA NP45 plus 1 x 10⁹ cfu of NP24 per animal daily (B). Pen-based performance, serum IgA concentration, and carcass characteristics did not differ (P > 0.10) among treatments. The average lamina propria (LP) thickness for Y and G steers was less (P = 0.02) than the average for R and B steers (0.38 vs 0.45 mm). Moreover, Y and G steers had a lower (P = 0.06) incidence of EC shedding than R and B steers. In Exp. 2, 712 steers fed a 91% concentrate, steam-flaked corn-based diet were used to determine the effects of the following DFM treatments on performance, carcass, and intestinal characteristics of finishing steers: 1) control, lactose carrier only (R); 2) 5 x 10⁶ cfu of LA NP51 plus 5 x 10⁶ cfu of LA NP45 plus 1 x 10⁶ cfu of PF NP24 per animal daily (G); and 3) 1 x 10⁶ cfu of LA NP51 plus 5 x 10⁶ cfu LA NP45 plus 1 x 10⁶ cfu of PF NP24 per animal daily (Y). Steers were from two backgrounds (BG): BG1, BW at arrival = 351.5 kg, had grazed before arrival, and BG2, BW at arrival = 314 kg, had been in a grower yard before arrival. A split plot was used with BG as the whole-plot factor and DFM treatment in the split-plot. The BG affected (P ≤ 0.03) both final BW and DMI; however, relative to DFM treatment, no differences (P ≥ 0.67) were detected for DMI or BW data. There was an interaction of BG and DFM treatment for ADG (P = 0.05) and for carcass-adjusted ADG (P = 0.08). The simple-effect ADG and carcass-adjusted ADG means for DFM treatments differed (P ≤ 0.01) between BG classifications. In addition, within BG1, ADG for R and B did not differ (P = 0.70) from each other, but both differed (P < 0.08) from Y. Carcass-adjusted ADG did not differ (P ≥ 0.23) for any DFM treatment within BG. There was a BG x DFM interaction (P ≤ 0.08) for both F:G and carcass-adjusted F:G; however, the simple-effect feed:gain (F:G) means and carcass-adjusted F:G means for DFM treatments did not differ (P ≥ 0.12) across or within BG. There was a BG x DFM interaction (P ≤ 0.04) for marbling score and ranked quality grade data, which resulted from differences in the percentage of Choice vs Select for the B treatment between BG. The DFM treatments did not affect LP thickness in cecal samples taken adjacent to the ileocecal junction. Overall, these data indicate that under the conditions of these studies live cultures of LA plus PF did not greatly affect feedlot performance and carcass characteristics. Some of the DFM used decreased fecal EC shedding, which might be related to the results for ileal LP thickness.

---

**Steroid hormone profiles and brain monoamine oxidase type A (MAO-A) activity of buller steers.**

M.P. Epp, D.A. Blasi, B.J. Johnson, and J.P. Kayser

Kansas State University, Manhattan

One grazing/feedlot field study was conducted to evaluate the steroid hormone profile and brain monoamine oxidase type A (MAO-A) activity of steers exhibiting characteristics attributed to the Buller Steer Syndrome (BSS) in a feedlot environment. Sera were harvested from 600 crossbred steers of eastern Missouri origin 7 to 14 days before placement on five different intensive early stocked pastures (pre-grass or PG) in south central Kansas. In mid to late July of 2002, all steers were sent directly to a commercial feedlot in western Kansas (BW = 403 kg) where serum was again harvested from all steers (feedlot arrival or FA). Each pasture group was maintained as a separate pen. When removed from its home pen for exhibiting classical buller steer characteristics, blood was collected from that buller steers from FA to BL (0.0042 ng/ml vs. 0.016 ng/ml). In the MAO-A analysis, brains were harvested from 12...
BL and 12 control steers at the packing plant. Brain MAO-A mRNA levels measured by the real-time quantitative polymerase chain reaction method (RTQ-PCR) was 74.5% higher ($P = .03$) in BL as compared to control steers. Previous studies have shown that progesterone, estrogen, and androgens influence the activity of MAO-A. This study suggests that MAO-A activity under potential influence of steroidal hormones in the steer brain may be a plausible mechanism that induces BSS.

**Key Words:** Buller steer syndrome, Steroid hormones, Monoamine oxidase type A

Combinations of wet corn gluten feed and alfalfa hay in finishing diets:
Effects on performance, feeding economics, and nitrogen balance.

T. B. Farran$^1$, G. E. Erickson$^1$, T. J. Klopfenstein$^1$, C. N. Macken$^1$, R. U. Lindquist$^2$

$^1$University of Nebraska-Lincoln; $^2$Archer Daniels Midland Company

One hundred ninety-two crossbred steers were used to determine the effects of removing alfalfa hay (AH) from dry-rolled corn (DRC) based diets containing wet corn gluten feed (WCGF) on animal performance, feeding economics, and nitrogen mass balance in open feedlot pens. Steers (initial BW = 774 ± 24 lb) were stratified by weight and assigned randomly to 1 of 24 pens (2 x 3 factorial; 4 pens/treatment) and fed for 132-d from June to October. Finishing diets contained either 0 or 35% WCGF and 0, 3.75, or 7.5% AH. Experimental diets were formulated to be iso-nitrogenous based upon the 35% WCGF and 7.5% AH treatment. Daily Intake, ADG, and HCW increased linearly ($P < 0.05$) as AH increased. Feeding WCGF also resulted in higher DMI, ADG, and HCW compared to steers fed no WCGF. Interactions for AH and WCGF were observed for feed conversion, fat depth, and ribeye area. Feed conversions of cattle fed WCGF were improved 4.5% ($P = 0.10$) compared to conversions of cattle fed no WCGF at 0% AH, suggesting a reduction in acidosis when WCGF was included. Within 35% WCGF diets, efficiency decreased as AH inclusion increased ($P = 0.06$). Efficiency was equal across AH levels when 0% WCGF was fed; however, ADG was depressed when AH was removed. With WCGF priced at 90% the value of DRC, WCGF fed cattle returned higher profits and had a reduced cost of gain compared to those fed no WCGF ($P < 0.05$). Cost of gain decreased and profit increased ($P < 0.05$) with AH inclusion in diets containing 0% WCGF, suggesting AH should be included. However, profit and cost of gain were not different across AH levels in diets containing 35% WCGF, suggesting that AH had less value in diets containing WCGF. Interactions between AH and WCGF were not observed for feedlot N mass balance; therefore, only main effects of AH and WCGF are presented. As level of AH increased across diets, N intake, N retention and N excretion increased ($P < 0.05$). Cattle fed WCGF consumed and excreted more N than those fed no WCGF. More manure DM ($P = 0.11$) and OM ($P < 0.01$) was removed from pens with cattle consuming WCGF; however, only a numeric increase was observed in the amount of N in manure, suggesting that the extra manure excretion from WCGF fed steers was unsuccessful in retaining more N. When expressed as a percentage of N excretion, loss of N from cattle fed 0 and 35% WCGF was not different, averaging nearly 80%. These data suggest that AH has less value when diets contained WCGF, and can be decreased from conventional levels. Furthermore, loss of N from open feedlots is high during the summer months and feeding WCGF may not reduce this loss.

**Keywords:** Feedlot cattle, Roughage, Wet corn gluten feed

Vaccination and Feeding a Competitive Exclusion Product as Intervention Strategies to Reduce the Prevalence of *Escherichia coli* O157:H7 in Feedlot Cattle.

J.D. Folmer$^1$, C.N. Macken$^1$, G.E. Erickson$^1$, S. Hinkle$^1$, R.A. Moxley$^1$, D.R. Smith$^1$, and T.J. Klopfenstein$^1$

*University of Nebraska, Lincoln; $^1$Animal Science; $^1$Veterinary Science

A clinical trial was conducted to test the effect of vaccination (VAC) and feeding a competitive exclusion (CE) product on the proportion of feedlot steers shedding *Escherichia coli* O157:H7 (O157:H7) in feces. Three hundred eighty-four steers were blocked by weight, stratified by weight within block and assigned randomly to 48 pens. The finishing diet of 54.5% high moisture corn, 35% wet corn gluten feed, 5% corn silage, 2.5% alfalfa hay, 2% supplement, and 1% water was identical for all treatments and contained a minimum of 12.5% CP, 0.7% Ca, 0.65% K, and 0.3% P. CE and VAC treatments were allocated to pens in a 2 x 2 factorial design with three weight blocks and twelve replications per treatment. The VAC, designed to immunize against secreted proteins of O157:H7, was administered 3 times at 3-week intervals to cattle within assigned pens beginning d-0 of each block. A *Lactobacillus acidophilus* CE product was fed with the ration continuously from d-24 of the trial. Samples of rectal feces were collected for bacterial culture. Each block was sampled every three weeks for the entire 121d (May-September).
feeding period resulting in 1 pre-treatment and 5 test-period samplings. Outcome measures were pen-level performance and the proportion of animals per pen culture-positive for O157:H7. Feedlot performance and O157:H7 outcomes were analyzed using MIXED procedures of SAS accounting for repeated sampling for O157:H7. Treatment groups did not differ in performance (ADG, DMI, gain to feed, marbling score, fat thickness, or yield grade). The pre-treatment prevalence of O157:H7 averaged 31%, and did not differ significantly between treatments (P=0.19). The average proportion of cattle shedding O157:H7 differed (P=0.01) over the 5 test-periods (18.5%, 10.2%, 11.7%, 4.4%, and 18.8%, respectively); however, no interaction was observed between treatments or between treatment and time. The average proportion of cattle shedding O157:H7 for treatments of control, CE alone, VAC alone, and CE with VAC were 21.3%, 13.3%, 8.8%, and 7.7%, respectively. Adjusting for the effect of CE and block, the proportion of cattle shedding O157:H7 in VAC treated pens was significantly less than non-VAC pens (P=0.03). VAC alone, or possibly in combination with CE feeding, may be useful to reduce prevalence of O157:H7 in feedlot cattle.

Effects of dietary crude protein level and degradability on serum urea nitrogen and efficacy of the metabolizable protein system.

J. F. Gleghorn, N. A. Elam, M. L. Galyean¹, G. C. Duff², and N. A. Cole³

¹Texas Tech University, Lubbock, ²University of Arizona, Tucson, ³USDA-ARS, Bushland

Two experiments were conducted at two locations to determine the effects of dietary CP level and source on serum urea nitrogen (SUN) of beef steers, as well as to evaluate the metabolizable protein (MP) system (NRC, 1996). British x Continental steers were blocked by BW (357 ± 28 and 305 ± 25 kg initial BW; n = 360 and 225; four and five pens/treatment in Exp. 1 and 2, respectively). Steam-flaked corn-based diets (10% alfalfa) were arranged in a 3 x 3 factorial with three CP levels (11.5, 13, 14.5% of DM) and three sources of supplemental CP (N basis): 100% urea (V), 50:50 blend of urea and cottonseed meal (B), or 100% cottonseed meal (C). Steers in both experiments were initially implanted with Ralgro and reimplanted with Revalor-S on d 56. Blood was collected from randomly selected steers (n = 3 in Exp. 1 and n = 2 in Exp. 2) in each pen at 28 d intervals through 112 d on feed. Pen averages were calculated from individual concentrations and pooled across experiments. Repeated measures analysis using the MIXED procedure (SAS Institute, Cary, NC) was utilized to quantify changes in SUN during the growing and finishing phases of both experiments. Feedlot performance and actual diet composition data was used to evaluate the MP system. Equations from the MP system were used to determine relationships between animal and microbial requirements and actual performance. A time x CP level (P < 0.01) interaction was observed for SUN concentrations. At d 0, no CP level effect was observed (P = 0.964); however, subsequent collection dates revealed CP level effects. At d 28, cattle fed 11.5 and 13% CP had lower SUN than those fed 14.5% CP (P < 0.03). At d 56, 11.5% SUN was lower (P < 0.02) than both 13% and 14.5% CP, and SUN with 13% tended to be lower than 14.5% CP (P = 0.054). At d 84, cattle fed 11.5 and 13% CP had lower SUN than those fed 14.5% CP (P < 0.05). On d 112, SUN was less (P < 0.01) for cattle fed 11.5 vs 14.5% CP, with SUN of cattle fed 13% CP not different from that of cattle fed the other two CP levels. Shrunken weight gain (SWG) from d 0 to end, undegraded intake protein (UIP), and MP allowable gain differed among treatments. Shrunken weight gain quadratically increased with increasing CP level (P < 0.03). A CP level x CP source interaction affected UIP intake (P < 0.01); UIP intake was least for the 14.5U treatment, reflecting the combined effects of no supplemental UIP and slightly lowered DMI. The MP allowable gain increased with increasing UIP intake (P < 0.05); however, regression of actual SWG on MP allowable gain revealed no relationship (H₀: β₀ = 0; P = 0.344). Although excess MP linearly increased with increasing dietary UIP (P < 0.001), the difference in MP available for gain and the MP requirement for gain revealed that diets were in excess of MP requirements for gain with all sources. Results indicate that SUN increased with increasing CP level, but was not consistently affected by CP source. Evaluation of the MP system indicated that although DIP/UIP intakes differed among supplemental CP sources, these differences did not affect SWG. In contrast, SWG quadratically responded to increasing CP level, and MP was not limiting for SWG during the growing and finishing phase of beef cattle fed steam-flaked corn-based finishing diets.
Ground Flaxseed as a Component of Finishing Cattle Diets


In previous research, ground flaxseed fed to feeder cattle at approximately 10% of the diet significantly increased plasma concentrations of alpha linolenic acid and eicosapentanoic acid. Additionally, feeding ground flaxseed at approximately 10% of the diet increased quality grades, while decreasing retail display life of the product. An experiment was conducted to determine the effects of combinations of ground flaxseed and vitamin E on feedlot performance, carcass quality, retail display life, fatty acid composition, and growth performance. Steers (n=79; 743 lb BW) were individually fed diets containing ground flaxseed at 0, 5, 10, or 15% of the diet, with and without the addition of 220 IU vitamin E/kg DM. All diets were fed throughout a 120-d finishing period. After completion of the finishing period, carcass data, including hot carcass weight, yield grade, marbling score, subcutaneous fat thickness, ribeye area, and percentage of kidney, pelvic and heart fat, were determined for each animal. Also, retail display life, 2-Thiobarbituric Acid Reactive Substances (TBARS), fatty acid composition and sensory attributes of longissimus dorsi muscles were evaluated. Cattle fed flax had a tendency for increased average daily gain (linear, P=0.08; quadratic, P=0.12), increased DMI (linear, P<0.01; quadratic, P=0.06), but gain:feed was not affected. There was a quadratic increase (P<0.05) of flax level on KPH, and the amount of fat over the 12th rib (P<0.05); KPH and 12th rib fat thickness were greatest for cattle fed the intermediate levels of flaxseed. Additionally, there was a linear increase in dressing percent as the level of flax was increased (P<0.05). Feeding flaxseed tended (P=0.08) to increase the percentage of carcasses grading USDA choice, with 5% flax as the optimum level. There were no differences in TBARS among any of the treatments. A trained taste panel evaluated myofibrillar tenderness, juiciness, flavor intensity, connective tissue amount, overall tenderness and off-flavor intensity on the steaks, but observed no differences in these sensory attributes among treatments. Furthermore, there were no differences among dietary treatments for Warner Bratzler shear force. Retail shelf life display was improved (P<0.05) by feeding any level of flax with vitamin E. Vitamin E did not improve retail shelf life in the absence of flax. Dietary treatments combining vitamin E and ground flaxseed produced no negative effects on meat quality aspects. Flax is an acceptable source energy and may enhance growth and carcass quality attributes of cattle.

Key Words: Flaxseed, vitamin E, carcass quality

Night Feeding to Reduce Bird Predation: Effects on Feedlot Performance

M. A. Greenquist, J. J. Sindt, J. S. Drouillard, T. J. Kessen, E. R. Loe, and M. J. Sulpizio
Kansas State University, Manhattan, KS

Feedlots can experience 25 to 30% increases in feed intakes during times of heavy bird infestation. We hypothesized that feeding at night would minimize feed contamination and feed loss due to birds. Crossbred beef heifers (n=96; 770 lb) were used to evaluate the effects of feeding at night on performance and carcass characteristics. Heifers were randomly assigned to one of two treatments consisting of either continuous access (CA) to feed or night access (NA). Heifers were fed (8 head/pen, 6 pens/treatment) for 107 days during the winter months of November to March when large bird populations were observed. Feed was delivered once a day at approximately 10:00 a.m. for CA heifers and 30 minutes prior to dusk for NA heifers. Feed calls for NA heifers were managed so that no feed remained in the bunk at dawn (12 hours of feed access), whereas CA heifers were allowed ad libitum access to feed. Individual carcass data were collected and analyzed with performance data using pen as the experimental unit. Carcass adjusted weights and ADG were calculated using a common dressing percentage of 64.0%. Dry matter intake (21.51 vs. 18.15 lb for CA and NA, respectively) was decreased by 16% (P<0.01) for NA heifers while ADG was not different. Feed efficiency improved 14% (8.33 vs. 7.14 for CA and NA, respectively; P=0.05) for NA heifers. Carcass weights and dressing percentage were similar. Night access heifers tended (P=0.08) to be leaner (0.39 vs. 0.34 in²) than CA heifers, while marbling and USDA quality grade were not different. Taking into account a 3.36 lb difference in feed intake at $0.05/lb for 107 days the feed cost were $19.77 greater for CA heifers. This cost can be attributed to the combination of bird predation, lower feed efficiencies and reduced feed intake. Further research is necessary to isolate bird predation and changes in digestive patterns making up the superfluous feed cost observed.

Key words: Bird predation, Restricted feed access, Feedlot cattle
The effects of dietary crude protein concentration and source on nitrogen absorption and retention by feedlot steers

A. Gueye*, C. R. Richardson¹, J. H. Mikus¹, G. A. Nunnery¹, N. A. Cole², and L. W. Greene³

¹Texas Tech University, Lubbock; ²USDA-ARS-CPRL, Bushland, TX; ³Texas Agricultural Experimental Station, Amarillo

Twenty-seven crossbred steers (average BW = 353.2 ± 8.4 kg) were used in a metabolism trial with three collection periods (approximately 35, 95, and 155 d on feed) to evaluate the effects of dietary CP source and concentration on nitrogen balance by steers. Treatments were arranged in a factorial arrangement and consisted of three dietary CP concentrations (11.5, 13.0, and 14.5%) and three supplemental urea:cottonseed meal (CSM) ratios (100:0, 50:50, and 0:100 of supplemental N). During each nutrient collection period, steers were housed in individual metabolism stalls and urine and feces excreted were collected and frozen. In the first collection period, total N excretion increased linearly (P = 0.002) with increasing CP concentration. Nitrogen absorbed (g/d) and N retained increased linearly (P < 0.0001 and P = 0.01, respectively) with increasing CP concentration. In the second collection period, total N excretion increased linearly (P < 0.0001) with increasing CP concentration. Nitrogen absorbed (g/d) and N retained linearly increased (P < 0.0001 and P = 0.001, respectively) when CP increased from 11.5 to 14.5%. In the third collection period, fecal N excretion increased linearly (P < 0.0001) with increasing CP. Nitrogen retained (% of absorbed) decreased linearly (P = 0.009) as CP in the diet increased from 11.5 to 13.0%. Nitrogen absorbed (g/d) decreased linearly (P = 0.03) with decreasing urea:CSM ratio. Nitrogen absorbed (% of intake) increased quadratically (P = 0.05) with decreasing urea:CSM ratio. Based on our observations, feeding growing steers diets containing 11.5 to 13.0% CP and supplemented with higher proportions of degradable protein may potentially optimize N utilization and potentially reduces N losses to the environment.

Key Words: Absorption, Retention, Dietary Protein, Steers

Effects of Roughage Level and Min-Ad® on Ruminal Metabolism and Site and Extent of Digestion in Beef Steers Fed a High-Grain Diet

C. D. Keeler¹, C. R. Krehbiel¹, and J. J. Wagner²

¹Oklahoma State University and ²ContiBeef, LLC Lamar, CO

Five crossbred steers (initial BW= 263 ± 9 kg) fitted with ruminal and duodenal cannulas were used in a 5 x 5 Latin square design to evaluate the effects of roughage level and calcium magnesium carbonate (Min-Ad®; Inter-Rock, Greeley, CO) on ruminal metabolism and site and extent of digestion in beef steers. Steers were allowed ad libitum access to a 90% concentrate feedlot diet consisting of steam-flaked corn and corn silage. Steers were randomly allotted to one of five treatments: 1) 3.8% roughage and 0% Min-Ad; 2) 7.5% roughage and 0% Min-Ad; 3) 11.3% roughage and 0% Min-Ad; 4) 3.8% roughage and 1.5% Min-Ad; and 5) 7.5% roughage and 1.5% Min-Ad. Each period included 16 d for adaptation and 5 d for sampling. Water consumption was lower (P < 0.05) when 7.5% roughage and 1.5% Min-Ad were fed compared with the other treatments. Dry matter intake was not different (P = 0.21) among treatments, although DMI numerically increased as roughage level increased (6.2, 6.9, and 7.5 ± 0.6 kg/d for 3.8, 7.5, and 11.3% roughage, respectively). Duodenal flow of OM followed a similar trend as intake, numerically increasing with increasing roughage. Neutral detergent fiber (P = 0.09), ADF (P = 0.01) and N (P = 0.06) intake increased as dietary roughage increased, although ruminal and total tract digestibility of these response variables was not different (P > 0.10) among treatments. Ruminal fluid volume and turnover time was not influenced (P > 0.10) by roughage level or Min-Ad. Feeding Min-Ad decreased (P = 0.07) fluid flow rate out of the rumen. Ruminal fluid pH was not (P > 0.10) affected by roughage level or Min-Ad. In our experiment, replacing 100% of MgO and 67% of limestone with Min-Ad did not appear to influence site and extent of digestion. However, DMI by steers was greater when 1.5% Min-Ad was added to the 3.8% roughage diet compared with 3.8% roughage and no Min-Ad.

Key Words: Steers, Buffer, Roughage Level, Calcium, Magnesium
Effect of calcium source and concentration on blood acid-base status, circulating mineral concentrations, and apparent nutrient digestion and retention

E. A. Lauterbach, M. S. Brown, C. D. Drager, E. M. Cochran, and R. Brown

Division of Agriculture, West Texas A&M University, Canyon, TX

Decreased particle size of limestone has been implicated with increased in vitro acid reactivity below pH 5.5. However, few data are available that describe the influence of limestone particle size on Ca bioavailability and nutrient digestion and retention by cattle fed high-concentrate diets. Five crossbred beef steer calves were used in a 5 X 5 Latin Square design to determine the effect of limestone source and concentration on acid-base balance, nutrient digestion and retention, and circulating metabolite concentrations. Steers were fed a common basal 90% concentrate diet based on steam-flaked corn and containing 0.3% Ca (DM basis), and supplemented with reagent-grade limestone (R) to provide an additional 0.11, 0.22, 0.33, and 0.44% dietary Ca or supplemented with feed-grade limestone (F) to provide an additional 0.44% dietary Ca only. Experimental periods were 14 days in length; 11 days for adaptation, 2 days of total excreta collection, and 1 day for blood collection. Arterial and venous blood samples were collected before feeding, and at 2 and 4 hours after feeding day 14. Arterial whole blood total CO₂, HCO₃⁻, and base excess concentrations were lower (P < 0.09) for 0.44% R than for 0.44% F. Serum total Ca (10.76, 10.80, 10.82, and 11.03 ± 0.11 mg/dL) and whole blood ionized Ca (4.86, 5.00, 4.99, and 5.10 ± 0.06 mg/dL) concentrations increased linearly (P < 0.07) as level of supplemental Ca from R increased. Apparent absorption of Ca (55.2, 51.4, 41.0, and 42.0 ± 3.8%), P, and S as a percentage of intake decreased linearly (P < 0.03) as level of supplemental Ca from R increased. Apparent absorption of Ca was similar (P > 0.14) between 0.44% R and 0.44% F for Ca (42.0 vs 47.3), P, K, Mg, and S. Calcium retention as a percentage of absorbed (98.4, 98.7, 98.2, 98.6, and 98.4 ± 0.4%) did not differ (P > 0.72) among treatments. Sulfur and Mg retention as a percentage of absorbed were lower (P < 0.10) for 0.44% R than for 0.44% F. Decreased organic matter digestibility as supplemental Ca from R increased, and for 0.44% R compared to 0.44% F (P < 0.05) seemed to be due to decreased starch (P < 0.08) and acid detergent fiber (P < 0.10) digestibility. Fecal pH increased (P = 0.02) as supplemental Ca from R increased (6.55, 6.79, 6.90, and 7.01 ± 0.19). Reagent-grade limestone was associated with decreased blood buffering capacity, decreased Mg and S retention, and decreased organic matter digestibility compared to feed-grade limestone at a similar concentration of dietary Ca.

Effect of level of wet corn gluten feed on feedlot performance and economics

in steam-flaked corn based finishing diets.

C.N. Macken¹*, G.E. Erickson¹, T.J. Klopfenstein¹, and R.A. Stock²,

¹University of Nebraska, Lincoln, ²Cargill Inc., Blair, NE.

A finishing experiment was conducted to determine the effect of level of wet corn gluten feed (WCGF) in steam-flaked corn (SFC) based diets on feedlot steer performance and economics. One hundred ninety-two crossbred steer calves (298 kg) were stratified by initial weight and assigned randomly to 1 of 24 pens (8 steers/pen). Pens were assigned to 1 of 6 treatments (4 pens/treatment). Treatments were six levels of Sweet Bran® WCGF, with 0, 10, 20, 25, 30, and 35% WCGF replacing SFC (DM basis). All diets contained 10% corn silage, 5% supplement, and 3.5% tallow. Diets were formulated to contain at least 9.2% dietary DIP. The diets of 0, 10, 20, 25, 30, and 35% WCGF contained 1.8, 1.4, 1.0, 0.8, 0.5, and 0.3% urea, respectively. Steers were implanted with Synovex C on d 0, reimplanted with Revalor-S on d 53, and fed for 151 d. Feed efficiency and ADG were similar among treatments. A linear increase was observed for dry matter intake as level of WCGF increased. In the economic analysis, ration prices were determined using a Nebraska ten-year average corn price ($2.31/bu.). The flaking cost used was $8.55/ton of DM flaked ($6.07 variable and $2.48 fixed cost). These costs were based on assumptions of $5.12/mcf and 0.38 mcf/ton of DM flaked. WCGF was priced into the ration at 100% of dry corn price. Supplemental protein cost (urea) was lower with increasing level of WCGF. Ration price was greatest for the 0% level and differed by $4.96/ton of DM with the 35% level of WCGF. Economic analysis was conducted based on two scenarios: same prices were determined using a Nebraska ten-year average corn price ($2.31/bu.). The flaking cost used was
affecting finishing performance. There were no statistical differences in economic data, however, there appeared to be important economic differences.

Key Words: Finishing cattle, Byproducts, Steam-flaked corn

Effect of cottonseed byproduct feeds on feedlot performance and carcass traits of finishing heifers
C.E. Markham, C.R. Krehbiel, D.R. Gill, R.E. Peterson, and H.A. DePra,
Oklahoma State University

One hundred fifty crossbred yearling heifers (initial BW = 318 ± 12 kg) were fed to compare the effect of source and level of cottonseed byproducts on feedlot performance and carcass characteristics. A control treatment was established consisting of 78.5% dry-rolled corn, 7.5% cottonseed hulls (CSH), 3.0% fat and 8.7% cottonseed meal (CSM). Delinted whole cottonseed (DWC) or pelleted delinted whole cottonseed (PWC) was included in the diet to replace CSH and supplemental fat (15% of diet DM), or to replace CSH, fat, and cottonseed meal (25% of diet DM).

In the initial 28-d period heifers fed the control diet tended (P = 0.06) to have greater ADG compared with heifers fed 25% PWC, 15% DWC or 25% DWC diets. From d 56 to 84, heifers fed 15% PWC had the greatest (P < 0.001) ADG, while heifers fed the control, 15 or 25% DWC diets had the lowest ADG; 25% PWC was intermediate. From d 112 to 140, heifers fed 15 or 25% PWC or the 25% DWC diet had greater ADG (P = 0.03) than heifers fed 15% DWC with control cattle being intermediate. Over the entire feeding period (d 0 to 150), heifers fed the 15% PWC diet had greater (P = 0.002) ADG and heavier (P = 0.001) final live weights (560 vs 540 kg) compared with heifers fed the DWC or control diets. Heifers fed 25% PWC also tended (P = 0.10) to have greater ADG and final live weights than DWC and control treatments. No treatment differences (P > 0.10) were observed for overall DMI or feed efficiency. Heifers fed 15 and 25% PWC had greater (P = 0.001) HCW (avg = 349 vs 337 kg, respectively) compared with heifers fed DWC and control diets. No other differences (P > 0.10) were observed for carcass traits.

We conclude that including PWC in finishing rations resulted in greater live weight gain and heavier hot carcass weights compared with DWC or a combination of com, CSH, CSM and fat.

Key Words: Feedlot Cattle, Cottonseed, Byproduct Feeds

Effect of copper level and zinc level and source on finishing cattle performance and carcass traits
Oklahoma State University

One hundred sixty heifers (BW = 317 ± 22 kg; Trial 1) and 160 steers (BW = 341 ± 18 kg; Trial 2) were fed for an average of 140 d to determine to effect of Cu level and Zn level and source on feedlot performance and carcass merit. Treatments were: 1) 80 ppm ZnS04 and 12 ppm amino acid complexed Cu (AACu); 2) 80 ppm ZnS04, 12 ppm AACu and 12 ppm CUS04; 3) 40 ppm ZnS04, 40 ppm amino acid complexed Zn (AAZn) and 12 ppm AACu; 4) 40 ppm ZnS04, 40 ppm AAZn, 12 ppm AACu and 12 ppm CUS04; 5) 320 ppm ZnS04 and 12 ppm AACu; 6) 320 ppm ZnS04, 12 ppm AACu and 12 ppm CuS04; 7) 160 ppm ZnS04, 160 ppm AAZn, 12 ppm AACu and 12 ppm CUS04; 8) 160 ppm ZnS04, 160 ppm AAZn, 12 ppm AACu and 12 ppm CuS04. Heifers and steers were blocked by initial weight and assigned to 32 pens each (5 head/pen; 16 pens/block). Data were analyzed using PROC MIXED of SAS with treatment, pen and block as class variables and 28-d periods as repeated measures. The model included Cu level, Zn level, and Zn source and subsequent interactions. In Trial 1, no significant differences (P > 0.10) were observed for overall gain. From d 0 to 27, DMI was greater (P < 0.05) for heifers consuming 320 vs 80 ppm Zn and 12 vs 24 ppm Cu. From d 0 to 27 DMI and gain feed were greater for heifers consuming 12 vs 24 ppm Cu but this result was reversed (P < 0.05) from d 28 to 56. No differences (P > 0.05) were observed for hot carcass weight, ribeye area, kidney, pelvic and heart fat, marbling, or quality grade. Twelfth-rib fat depth was greater (P < 0.05) for heifers fed 320 vs 80 ppm Zn and yield grade was greater (P < 0.05) for heifers consuming AAZn. In Trial 2, no significant differences (P < 0.10) were observed for overall gain, DMI, or feed efficiency. At 12 ppm Cu, ADG was significantly greater (Cu level x Zn source, P < 0.05) for steers consuming AAZn vs ZnS04 from d 0 to 27 but at 24 ppm Cu ADG was numerically greater for AAZn vs ZnS04 from d 0 to 27. Similarly, ADG was greater (Zn level x Zn source, P < 0.05) at 80 ppm Zn for steers consuming ZnS04 vs AAZn, but at 320 ppm Zn, ADG was greater for steers consuming AAZn vs ZnS04. Twelfth-rib fat depth was greater (P < 0.05) at 320 vs 80 ppm Zn, and for steers consuming AAZn at 320 ppm Zn vs those consuming AAZn at 80 ppm Zn. In our experiments, there appeared to be
no advantage to feeding 24 vs 12 ppm Cu and inconsistent with previous research, source of Zn had little influence on animal performance or carcass merit.

Key Words: Copper, Zinc, Steers, Feedlot

Nitrogen and phosphorus utilization by beef cattle fed three dietary crude protein levels with three levels of supplemental urea.

Texas A&M University System, Amarillo, USDA-ARS, Bushland, TX, and Texas Tech University, Lubbock

Three dietary CP levels (11.5, 13.0, and 14.5% of DM) and three supplemental urea levels (100, 50, and 0 % of supplemental CP from urea) were fed to determine performance, serum urea N (SUN), and N and P balance. Crossbred steers (n = 27; average BW = 315 kg) were blocked by weight and individually fed the nine treatments in a completely randomized block design. A steam flaked corn-based diet was fed, with supplemental CP supplied by either all urea, a 50:50 blend of urea and cottonseed meal (CSM), or all CSM. Steers were used in three nutrient balance collection periods (NBCP) at the beginning, middle, and end, of the feeding period. Venous jugular blood was obtained at the start and end of each NBCP. No CP level x CP source interactions (P < 0.10) were observed. Steer DMI, ADG, and feed efficiency did not differ (P < 0.05) among treatments. For each NBCP, urinary total N, urinary urea N (UUN), and SUN increased linearly (P < 0.10) as CP level increased. For NBCP 1 and 3, fecal N output increased linearly (P < 0.10) as supplemental CP from urea decreased. For NBCP 2 and 3, UUN decreased linearly (P < 0.10) as urea level decreased. For NBCP 1, fecal and urine P excretion increased linearly (P < 0.10), and P retained (% of intake) decreased linearly (P < 0.10), as CP level increased. Phosphorus intake increased linearly (P < 0.10) as urea level decreased for each NBCP. Fecal P output increased linearly (P < 0.10) in all NBCP, and urinary P excretion in NBCP 1 and 2 increased linearly (P < 0.10) as urea level decreased. Phosphorus retained (% of intake) decreased linearly (P < 0.10) as urea level decreased for NBCP 3. Results suggest that as dietary CP level increased, N retention decreased, and as supplemental CP supplied by urea decreased P balance decreased in feedlot steers. As days on feed increased, less N and P were retained, suggesting the potential to decrease N and P excretion by feeding less N and P as the feeding period progresses.

Keywords: Feedlot, Nitrogen, Phosphorus

Effect of water and mineral source on performance of growing heifers.

Texas Tech University

Ninety-six beef heifers (British x Continental; average initial BW = 335.54 kg) were used in a randomized complete block design to determine the affects of water sulfate concentration and supplemental mineral source on animal performance. Two water and three mineral sources were applied in a 2 x 3 factorial arrangement. Water treatments contained either 39.5 mg/kg sulfate (no added sulfate; NS) or 1,810 mg/kg sulfate (added sulfate; WS). Mineral treatments were: no supplemental Zn, Cu, Mn, and Co (NTM); inorganic sources of Zn, Cu, Mn, and Co (ITM); and organically complexed sources of Zn, Cu, Mn, and Co (CTM). Mineral treatments were supplied via three separate supplements included in a 90% concentrate finishing diet. Heifers were fed for 56 d and weights were recorded on d 0, 28, and 56. Average daily gain of heifers consuming NS water was greater (P = 0.04) than WS heifers (1.83 and 1.61 kg/d, respectively) for the first 28 d, however, water source had no effect (P = 0.07) on ADG for the 29-56 d period or for the entire 56-d trial (P = 0.77). Mineral treatment had no effect (P = 0.31) on ADG for the length of the study. Dry matter intake was not affected by either water (P = 0.70) or mineral source (P = 0.18) for any period of the trial. Heifers consuming NS water were more efficient (P = 0.01) than heifers consuming WS water (4.41 and 5.01, respectively) for d 0-28. However, water source had no effect on feed to gain for d 29-56 (P = 0.06) or 0-56 (P = 0.44). Mineral source had no effect (P = 0.39) on feed to gain for the length of the study. Results from this trial indicate that heifers introduced to high sulfate drinking water (~1,800 mg/kg) require an adjustment period, but soon perform at levels similar to animals consuming water with very low sulfate levels. Moreover, neither level nor source of supplemental trace minerals affected heifer performance, however, this may be a result of the relatively short duration of the trial.

Key words: Heifers, Sulfate, Mineral source.
Bovine respiratory disease in receiving heifers: effects on weight gain and carcass characteristics
S. P. Montgomery, J. S. Drouillard, J. J. Sindt, M. A. Greenquist, W. F. Miller, J. N. Pike, E. J. Good,
Kansas State University, Manhattan.

Crossbred beef heifers (n = 665, initial BW = 495 lb) were used in a completely randomized design to determine the effects of bovine respiratory disease (BRD) on ADG and carcass characteristics. Heifers were processed within 24 hours of arrival and processing included vaccination against common viral and clostridial diseases, recording of rectal temperature and sampling of whole blood for analysis of plasma glucose, lactate, and urea N concentrations. Heifers were subsequently monitored for clinical signs of BRD including depression, lethargy, anorexia, coughing, rapid breathing, and nasal or ocular discharge. Heifers exhibiting signs of BRD received antibiotic therapy and the number of times a heifer was treated for BRD was recorded and ranged between zero and three. Following the 36-day receiving period heifers were allowed to graze native range for 136 days and then transported to a commercial feedyard where they were fed a common series of diets throughout a 124-day finishing period. Plasma glucose and lactate concentrations measured at time of initial processing were greater (P < 0.1) for heifers not treated for BRD than the mean of heifers subsequently treated for BRD, and decreased (linear, P < 0.01) as treatment for BRD increased. Rectal temperature measured at time of initial processing increased (linear, P < 0.03) with increased treatment for BRD. Initial BW, ADG, and final BW during the receiving period decreased (linear, P < 0.01) as treatment for BRD increased, while grazing period ADG was increased (linear, P < 0.01). Finishing period ADG, final BW, hot carcass weight, fat thickness, and marbling score were decreased (linear, P < 0.05) with previous incidence of BRD. These data suggest that initial plasma glucose and lactate concentrations may be indicative of health status of newly arrived receiving cattle and that increased incidence of BRD in cattle decreases ADG and carcass quality.

Key Words: Beef Cattle, Health, Daily Gain, Carcass Quality

Effects of starch-based versus fiber-based receiving diets on nitrogen status and blood metabolites in lambs subjected to transit stress.
South Dakota State University, Brookings

Three groups of twelve crossbred wether lambs (BW = 27.3 ± 0.5 kg) were stratified by BW within group and randomly assigned to one of three treatments. Two treatments involved subjecting lambs to 10 h of transit stress (S), and then providing either a pelleted starch-based receiving diet (HC) or a pelleted fiber-based receiving diet (HF). The third treatment was not subjected to transit stress (NS) and was provided the same fiber-based diet as SHF lambs. Diets were formulated to be isonitrogenous (15% CP) and contained 20% alfalfa meal with the remainder consisting of either ground corn-soybean meal (HC diets) or soybean hulls-dried corn gluten feed (HF diets). Non-stressed lambs were allowed access to water while S lambs were in transit. Lambs were then placed into total collection crates and evaluated for 14 d. Blood samples were collected prior to transit (PRE) and on d 1, 2, 3, 7, 10 and 14 post-transit (PT1, PT2, PT3, PT7, PT10 and PT14). No body weight gain differences were detected (P > 0.10) between SHC and SHF or between SHF and NSHF. Nitrogen retention (NR) was greater (P < 0.05) for SHC during PT2 and PT3 compared to SHF, but was similar (P > 0.10) throughout the remainder of the receiving period. Urinary nitrogen (UN) as a percent of nitrogen intake (NI) was similar (P > 0.10) between SHC and SHF during the receiving period, but fecal nitrogen (FN) as a percent of NI was higher (P < 0.05) in SHF compared to SHC. No differences (P > 0.10) were detected for NR and for UN and FN as a percent of NI between SHF and NSHF during the receiving period. Plasma urea nitrogen (PUN) levels were higher (P < 0.05) at PT7 and PT14 for SHF compared to SHC. Non-esterified fatty acid (NEFA) levels were higher (P < 0.05) in SHF compared to SHC during PT1 and PT2, and tended (P < 0.10) to be higher during PT3. Plasma glucose levels tended to be higher (P < 0.10) in SHC at PT10, but not during any other period. No differences (P > 0.10) were detected for PUN, NEFA and glucose levels between SHF and NSHF during the receiving period. The greater nitrogen retention and lower PUN levels in SHC lambs indicate that starch-based diets may improve nitrogen utilization during the post-stress receiving period.
Instrument versus manual sortation of feedlot steers and heifers.
R.E. Peterson*, D.R. Gill†, C.R. Krehtbiel and H.G. Dolezae,
*Oklahoma State University and †Excel Corporation

The objectives of this study were 1) to assess the effectiveness of sorting feedlot steers and heifers by traditional practices (visual appraisal and manual sortation) versus using ultrasound (scanned once or twice) for projected yield grade; 2) to determine the success of sorting based on ultrasound measures for feedlot steers and heifers obtained once (reimplant time) versus twice (upon arrival and again at reimplant time); and 3) to calculate correlations among ultrasound and vision grading variables (i.e. fat thickness, ribeye area, marbling, and yield grade). Cattle were either manually sorted (pen riders) or sorted using objective ultrasound technology (scanned once or twice) to predict yield grade. One thousand two hundred and seventy seven animals representing two commercial feedlots and ten lots of cattle were utilized for this experiment. On May 14 and 15, 2002, animals were sorted into one of two treatment groups. Treatment groups were: 1) ultrasounded and placed into one of three ultrasound harvest, or market groups, (n=239 heifers; n=390 steers), or 2) not ultrasounded and marketed through traditional subjective appraisal and manual sortation (n=232 heifers; n=419 steers). Randomization of treatment groups was accomplished by ultrasounding every other calf that entered the chute at processing. All cattle in the experiment were harvested at Excel Corporation’s Friona Packing Plant, Friona, TX, and carcass measures were collected using Video Image Analysis. Ultrasound sortation (scanned once) resulted in lower carcass weight (P<0.001), greater ribeye area (REA)/100 kg of carcass weight (P<0.001), lower 12th rib fat thickness (FT; P<0.001), lower vision scan calculated yield grade (YG; P=0.01), and lower quality grade (QG; P<0.001). These trends were similar for feedlot steers and heifers. On July 18, 2002, five lots of cattle that had previously been ultrasounded were randomly selected for second scan ultrasound data collection. These five lots of cattle resulted in second scan ultrasound data for 86 total animals (n=64 steers; n=22 heifers). Randomization of treatment groups was accomplished by ultrasounding every other calf that had previously been ultrasounded. There were no differences (P>0.20) in carcass characteristics between cattle ultrasounded once compared with cattle ultrasounded twice. However, correlation R-values were improved for ultrasounding cattle a second time. For cattle ultrasounded once or twice, correlation R-values for FT, REA, QG, and YG were 0.27, 0.34, 0.18, and 0.22, and 0.53, 0.42, 0.50, and 0.42, respectively. Based on the results of this experiment, we conclude that the use of ultrasound technology to predict days on feed to optimize yield grade resulted in feedlot cattle being harvested too early in the feeding period. Adjusting the parameters of the ultrasound prediction equations or ultrasounding cattle closer to the projected harvest date might improve the accuracy of ultrasound sortation of feedlot steers and heifers.

Key Words: Ultrasound, Yield Grade, Days on Feed, Carcass Characteristics

Effect of Wet and Dry Distillers Grains Plus Solubles and Supplemental Fat Level on Performance of Finishing Cattle
K.J. Vander Pol, G.E. Erickson, T.J. Klopfenstein, C.N. Macken
University of Nebraska, Lincoln

Two finishing trials were conducted to determine if the additional energy value of wet distillers grains plus solubles (WDGS) or dry distillers grains plus solubles (DDGS) compared to corn is related to the higher fat content of WDGS and DDGS, or acidosis control. Trial 1 utilized 60 crossbred yearling heifers in a 2 x 3 factorial arrangement of treatments, with factors being source (WDGS and corn oil) and level. Treatments consisted of zero corn oil (0FAT), zero WDGS (0DG), 2.5% corn oil (2.5FAT), 20% WDGS (20DG), 5% corn oil (5FAT), and 40% WDGS (40DG). Alfalfa hay was included in all diets at 7.5% of DM, and high-moisture corn and dry-rolled corn were fed at a 1:1 ratio (DM-basis). Diets were formulated so that 2.5FAT and 20DG, as well as the 5FAT and 40DG diets contained the same amount of ether extract (EE). However, EE analysis of the diets indicated that the 2.5FAT and 5FAT diets were higher in EE than the 20DG and 40DG diets, respectively. Heifers were individually fed and implanted on d 28 with Synovex-Plus. There were no significant differences observed (P > 0.10) for the main effects or interaction for initial weight, final weight, hot carcass weight, or yield grade. Significant interactions were observed (P < 0.10) for ADG and feed efficiency. The simple effects from Trial 1 indicate that increasing the level of fat in the diet by the addition of corn oil, linearly reduced ADG (P = 0.04) and feed efficiency (P = 0.10), while increasing the level of fat in the diet by the addition of WDGS numerically increased ADG, and feed efficiency. Trial 2 utilized 234 crossbred yearling steers in a 2 x 2 plus 1 factorial. Treatments consisted of a high-moisture corn control (CON), 20% DDGS (20DG), 1.3% tallow (1.3TAL), 40% DDGS (40DG), and 2.6% tallow (2.6TAL). All diets (DM basis) contained 20% wet corn gluten feed (WCGF), 10% corn silage, 3% dry supplement, and high-
moisture corn. Diets were balanced so that the 1.3TAL and 20DG, as well as the 2.6TAL and 40DG diets contained the same amount of EE. No significant (P > 0.10) differences in performance parameters or carcass characteristics were observed between the CON and other treatments. However, cattle consuming the high level of either DDGS or tallow had numerically higher feed efficiencies than the CON (0.188 vs 0.182). Results from Trial 2 indicate that incorporating tallow in feedlot diets equal to that provided from DDGS results in similar performance and carcass characteristics of feedlot steers. Based on Trial 1, WDGS contained 14.5% more NE₃ than HMC:DRC combination. Furthermore, feeding corn oil depressed performance at high levels, suggesting the oil in WDGS is protected. In Trial 2, when the possibility of acidosis is minimized by feeding WCGF, tallow and DDGS (which is lower energetically than WDGS) are similar, indicating that a portion of the elevated energy in WDGS is due to acidosis control.

**Key Words:** Wet/Dry Distillers Grains Plus Solubles, Supplemental Fat, Feedlot Cattle

---

**Examination of the effects of *Eschericha coli* O157:H7 shedding on performance and carcass characteristics of beef cattle**

J.D. Rivera, J.T. Richeson, N.A. Elam, M.M. Brashears, and M.L. Galyean

*Department of Animal and Food Sciences, Texas Tech University, Lubbock*

Data from two studies (n = 416 steers) were pooled and analyzed to determine whether shedding of *E. coli* O157:H7 affected performance and carcass characteristics of finishing beef steers. These studies examined the effects of direct-fed microbials on performance and incidence of *E. coli* O157:H7 shedding by beef cattle. In both studies, fecal samples were obtained at various times (seven times for study A; and three times for study B) throughout the finishing period and analyzed for the presence of *E. coli* O157:H7. Performance data and carcass characteristics were modeled, accounting for the effects of treatment, the incidence of shedding at any time during the finishing period, and the interaction. All data were analyzed using mixed models methodology using block and pen, nested within block x study, as the random effects. Shedding of *E. coli* O157:H7 decreased (P < 0.002) ADG from d 0 to 56, and resulted in a numerically lower overall ADG for the entire finishing period. Carcass characteristics between animals shedding *E. coli* O157:H7 at any time and animals not shedding did not differ (P > 0.10). However, the incidence of *E. coli* O157:H7 shedding resulted in numerically lighter final body weights, lighter carcass weights, a smaller longissimus muscle area, and a lower yield grade. Results suggest that infection with *E. coli* O157:H7 may have a metabolic cost that results in decreased performance early in the feeding period.

**Key Words:** Beef Cattle, *E. coli* O157:H7, Performance

---

**Effect of age at feedlot entry on performance and carcass characteristics of bulls and steers**

J.P. Schoonmaker, F.L. Fluharty, and S.C. Loerch

*The Department of Animal Sciences, The Ohio State University*

There are concerns over the use of growth promoting hormone implants for beef cattle. Decreased marbling and tenderness result, and there is a perception by consumers that hormone treatment is not natural, and that the beef may be unsafe. Reluctance of the European Union to accept beef produced in the United States is an indication of this perception. Feeding bulls may be an alternative to hormone supplementation; however, concerns also exist over the use of bulls in a feedlot situation. Bulls are more aggressive and may be more dangerous to handle compared to steers, and like unplanted steers, produce carcasses that are lower in marbling and less tender relative to carcasses from non-implanted steers. As a result, bulls are not eligible for USDA quality grade. Earlyweaning bulls and aggressively implanted steers, and placing them on a high calorie diet before they have significantly increased in size, may alleviate some concerns. **Exp. 1:** Seventy Angus x Simmental crossbred calves (initial BW 366 ± 9.3 lb) were placed in the feedlot at 110 d of age (EW), 202 d of age (NW), or 371 d of age (Y) to determine the effect of age at feedlot entry and castration on growth, performance, and carcass characteristics. Steers were implanted with Synovex-S (20 mg estradiol benzoate, 200 mg progesterone), and with a Revalor-S (24 mg estradiol, 120 mg trenbolone acetate) 93 d later. **Exp. 2:** Insulin-like Growth Factor-1 (IGF-I) was measured in 10 non-implanted early-weaned bulls and 10 early-weaned steers implanted with Synovex-S at 130, and with Revalor-S at 200, and 277 d of age. Feeding bulls was an effective alternative to feeding steers implanted with exogenous hormones, when fed a high calorie diet starting at a young age. Bulls had a gradual increase in IGF-1 concentration as testicles grew, whereas steers had large fluctuations in IGF-1 concentration as they were implanted.
**Effect of processing methods on the characteristics of steam-flaked corn.**

J. J. Sindt, J.S. Drouillard, S. P. Montgomery, and E. R. Loe

*Kansas State University, Manhattan*

We evaluated surfactant (SRF) concentration, tempering (TMP) moisture concentration, duration of steam (STM) conditioning, and flake density (DEN) as variables that potentially influence characteristics of steam-flaked corn. Samples of whole corn (n=12; 89% DM; 4.5 lb/sample) were weighed and placed into individual glass jars (1 gal). Samples were then tempered in water (6, 10, or 14% added water to achieve 17%, 21%, and 25% moisture after TMP) containing 0 or 0.09 oz/gal of SRF and rotated continuously for 2 h at 70° F. Samples were then subjected to STM for either 20 or 40 min in a 12-chamber STM conditioner. After STM conditioning, samples were flaked to a common DEN. This procedure was replicated three times daily using three flake DEN (28, 26, and 24 lb/bushel) and repeated for three consecutive days to complete a 2 x 3 x 2 x 3 factorial arrangement of treatments. Samples of corn were collected following TMP, STM, and flaking. As expected, TMP increased (linear, P<0.001) flaked-corn moisture content, however, moisture content was not altered by SRF (P=0.38), STM (P=0.17) or DEN (P=0.86). Adding the SRF during TMP reduced (P<0.05) the amount of moisture lost from corn between steaming and flaking. In vitro gas production was not affected by TMP (P=0.62), SRF (P=0.31), or STM (P=0.33), however, decreasing DEN increased (linear, P<0.01) the volume of gas produced. Flake durability was tested by tumbling the flakes for 10 min in a commercial durability tester and measuring the amount of flakes retained on a 9.5 mm screen. Increasing TMP moisture concentration (linear, P<0.05), STM conditioning corn for 40 minutes compared to 20 minutes (P<0.05), and decreasing DEN (linear; P<0.05) increased flake durability. Fermentation characteristics were most influenced by DEN, and flake integrity can be increased by increasing TMP moisture, by increasing STM conditioning time from 20 to 40 minutes, or by decreasing DEN.

**Key Words:** Steam-flaked corn, Moisture, Surfactant, Grain processing

---

**Effects of Grazing Management and Subsequent Finishing on Gene Expression in Adipose Tissue from Steers**


*Oklahoma State University*

The objective was to evaluate differential gene expression in subcutaneous and intramuscular fat depots of steers before and after feeding a high-grain diet. Thirty Angus X Angus-Hereford steer calves (initial BW = 231 ± 25 kg) were randomly allotted to one of three winter grazing treatments. Winter grazing treatments consisted of: 1) grazing winter wheat pasture to achieve a high rate of BW gain (HGW; stocking density = 0.49 ha/steer); 2) grazing winter wheat pasture and adjusting stocking density to maintain a low rate of BW gain (LGW; stocking density = 0.34 ha/steer); or 3) grazing dormant tallgrass native range (NR; stocking density = 0.63 ha/steer). Steers in the NR treatment were provided 0.91 ha/steer of a 41% CP cottonseed-meal supplement. Following the 144-d grazing period, steers were sorted by weight within winter grazing treatment and randomly assigned to feedlot pens. Steers received a Revalor-S implant and were fed to a common endpoint of 1.27 cm of backfat between the 12th and 13th rib as determined by ultrasound. Steers were gradually adapted to the final finishing diet by replacing ground alfalfa hay with corn. Four steers from each treatment were harvested at the end of the grazing period, and the remaining six steers from each treatment were harvested at the pre-determined compositional endpoint. Intramuscular and subcutaneous fat samples were collected from each steer at harvest, and total RNA was extracted. Pools of RNA were prepared for HGW and NR subcutaneous adipose tissue from steers harvested before finishing. Suppression Subtraction Hybridization (SSH) was performed utilizing the Clonetech PCR-Select cDNA Subtraction Kit. Following SSH, differential screening was performed to confirm that subtracted genes were differentially expressed. Templates confirmed differentially expressed were subjected to dideoxy chain termination sequencing. Quantitative RT-PCR analysis was performed on three differentially expressed clones of interest; osteonectin, ferritin heavy chain (ferritin HC) and decorin. For fed steers, osteonectin, ferritin HC, and decorin gene expression were greater (P < 0.05) in subcutaneous than in intramuscular adipose tissue. For both osteonectin and ferritin HC, gene expression was greater (P < 0.05) in subcutaneous adipose tissue from HGW steers than in subcutaneous adipose tissue from NR steers harvested before finishing. A significant depot X background interaction for osteonectin (P < 0.01) and ferritin HC (P = 0.03) gene expression was observed for steers harvested before finishing, indicating that nutritional management affects adipose tissue depots differently. For intramuscular adipose tissue collected from fed steers, no differences in gene expression for either osteonectin, ferritin HC, or decorin were observed due to differences in...
pre-feeding nutritional background (HGW, LGW, or NR), which might have resulted from feeding steers to the same compositional endpoint as determined by 12th-rib fat thickness.

**Keywords:** Steers, Adipose Tissue, Gene Expression

**Performance of crossbred steers grazing photoperiod sensitive and non photoperiod sensitive Sorghum Sudangrass hybrids.**

J. T. Vasconcelos*, L. W. Greene, F. T. McCollum, III, B. W. Bean and R. Van Meter
Texas A&M University Agricultural Research and Extension Center, Amarillo, Texas

Twelve 2.23 ha pastures were seeded with 28 kg/ha of two non photoperiod sensitive (PP) sorghum sudan hybrid (SS), SS 200 BMR or SS 201 BMR, or two PP SS, Mega Green (MG) or PS 210 BMR (n=3 pastures/hybrid). SS 200 BMR, SS 201 BMR and PS 210 BMR contained the brown midrib gene. Pastures were irrigated with 49.4 cm/ha and fertilized with 336 kg/ha of 20-10-0 before planting. Crossbred steers (n=132; avg BW=251 kg) were allotted to the pastures using a ‘put-and-take’ pasture management. On d 0 and the last day of the grazing period, forage availability was determined by hand clipping six predetermined areas in each pasture. For the forage samples collected on d 0, leaf and stem percentages were determined. Grazing was terminated when forage growth and availability did not support steer growth. Amount of available forage at the initiation of grazing was greater (P=0.0464) for SS 201 BMR (3,002 kg/ha) than MG (2,163 kg/ha) or SS 200 BMR (2,206 kg/ha) with PS 210 BMR being intermediate (2,500 kg/ha). No differences (P=0.3869) occurred in the initial percentage of leaf or stem. Grazing head days/ha were greater (P=0.0234) for MG than for PS 210 BMR, SS 201, BMR and SS 200 BMR (447 vs 382, 373, and 373 d/ha). Amount of available forage at the conclusion of grazing was similar (P=0.2414) for the hybrids (1,763, 1,253, 1,186, and 868 kg/ha for MG, PS 210 BMR, SS 201 BMR and SS 200 BMR, respectively). Steers grazing SS 200 BMR had a greater (P=0.0086) ADG than those grazing MG, PS 210 BMR or SS 201 BMR (1.38 vs. 1.02, 1.05, and 1.16 kg/d, respectively). Gain per ha was greater (P=0.1010) for steers grazing SS 200 BMR (515 kg/ha) than PS 210 BMR (404 kg/ha) with MG (456 kg/ha) and SS 201 BMR (436 kg/ha) being intermediate. These data show that grazing SS 200 BMR resulted in greater ADG and gain/ha than PS 210 BMR.

**Effect of flax supplementation and growth promotants on steady-state lipoprotein lipase and glycogenin mRNA concentrations in finishing cattle**

A. T. Waylan*, J. P. Kayser, J. D. Dunn, E. K. Sissom, and B. J. Johnson
Kansas State University, Manhattan

Insufficient marbling and reduced quality grades are severe quality problems in the beef industry. The study of lipoprotein lipase (LPL) is of particular interest to the feedlot industry, since LPL controls the partitioning of triacylglycerols (TG) between adipose and muscle tissues. The LPL hydrolyzes TG into monoacylglycerol and fatty acids, which are taken up by the tissues and utilized for energy. Growth promoting implants may contribute to dark cutting beef, which is a result of reduced glycogen stores. Therefore, the concentration of glycogenin, the core protein upon which glycogen molecules are synthesized, may indicate the likelihood of dark cutting beef. The objective was to investigate the effect of feeding flax, a source of polyunsaturated fatty acids, and administering growth promotants on steady-state LPL and glycogenin mRNA content of muscle in finishing cattle. Sixteen crossbred steers (BW = 874 lb) given ad libitum access to a 93% concentrate diet for 28 d were used in a four-treatment, 2 x 2 factorial experiment with main effects of flax (non-flax or flax, 5% supplementation) and implantation (non-implant and implant of Revalor-S; 120 mg trenbolone acetate + 24 mg estradiol). Muscle biopsies were obtained from the longissimus muscle at 0, 14, and 28 d. Muscle samples were used to quantify LPL and glycogenin mRNA concentrations by using real-time quantitative PCR. Revalor-S did not affect LPL or glycogenin mRNA concentrations (P ≥ .13). A day x flax interaction (P ≤ .0001) was observed for both LPL and glycogenin mRNA concentrations. At 0 and 14 d, no differences (P ≥ .15) were observed between non-flax and flax steers. At 28 d, non-flax steers had a 4.1 and 5.7-fold increase (P < .0001) over flax steers for LPL and glycogenin mRNA concentrations, respectively. These data suggest that flax supplementation to finishing steers for 28 d reduced gene expression of both LPL and glycogenin as compared to non-flax steers. Alterations in local concentrations of these two proteins could impact beef carcass quality grade.

**Key words:** Lipoprotein lipase, Glycogenin, Growth promoting implants
Comparison of Dry and Liquid Protein Supplements Fed to Stocker Cattle Consuming Low-Quality Native Grass: Performance, Digestibility, and Rumen Kinetics.

Jeff Weyers
Oklahoma State University

Two studies were conducted to determine the effect of differing amounts of degradable intake protein (DIP) from liquid or dry supplements on performance, site, and extent of digestion by stocker cattle consuming low-quality forage. A metabolism study was conducted utilizing seven ruminally and duodenally cannulated steers (initial BW = 250 kg) that were allowed ad libitum access to low-quality forage (LQF; % N = 8). Steers were randomly allotted to one of four supplement treatments in a crossover design: 1) no supplement (CON), 2) a liquid feed (molasses/feathermeal; natural protein) providing .20 kg h^{-1} d^{-1} of DIP (LIQ1), 3) .73 kg h^{-1} d^{-1} of liquid feed (molasses/urea; NPN) providing .33 kg h^{-1} d^{-1} of DIP (LIQ2), 4) or a cottonseed meal/soybean meal (natural protein) blend providing .20 kg h^{-1} d^{-1} of DIP (DRY). Supplements consisting of a natural protein source (DRY, LIQ1) increased forage OM intake (FOMI) compared to CON. All supplemental treatments increased total digestible OM intakes (DOMI) compared to CON (2.17, 2.48, 1.85 and 1.56 kg/d, respectively for DRY, LIQ1, LIQ2, and CON; P<.05). Total tract digestibilities of OM were greater for N supplements compared to CON (P<.05) and ADF total tract digestibilities were similar for N supplements. Faster particulate passage rates for the cattle receiving supplements (4.78, 5.19, 5.55 and 3.59% h^{-1}, respectively for DRY, LIQ1, LIQ2 and CON; P<.05) supports the differences observed for DOMI and FOMI. Ruminal ammonia- nitrogen concentrations were significantly greater (P<.01) for cattle receiving supplemental N compared to CON with LIQ2 producing more free ammonia than DRY and LIQ1. During an individual feeding study, 50 steers (initial BW = 195 kg) were randomly assigned to one of the same four treatments as used in the metabolism study. Steers grazed tallgrass prairie and were fed supplements five days per week in individual stalls. All animals remained in the stalls for one and no more than four hours. Average intakes was only 80 and 30% of feed offered for LIQ1 and LIQ2, respectively. Total gain and ADG were greater (P<.05) for supplemented steers than for CON, and steers receiving DRY had greater (P<.05) total gains and ADG than steers receiving LIQ1 and LIQ2. There was no difference (P>.05) between LIQ1 and LIQ2 for total gain or ADG. These data suggest that the lower supplemental N intakes of the cattle receiving LIQ1 and LIQ2 limited their performance compared to DRY. Additionally, different sources and degradabilities of nitrogen will influence digestion, rumen kinetics and performance of steers grazing low-quality forage.

Physiological indicators of performance traits and net feed efficiency in growing steers

M.B. White^1, G.E. Carstens^1, C.M. Theis^1, L.J. Slay^1, R.A. Hollenbeck^1, T.H. Welsh, Jr.^1,
^1Texas Agricultural Experiment Station, College Station, ^2Uvalde, ^3Overton,
^4Amarillo and ^5McGregor

Selection against net feed intake (NFI) has the potential to improve feed efficiency without affecting growth performance or body size, but measuring this trait in cattle is costly. Identification of physiological indicators that are predictive of NFI would be useful as early screening tests to reduce the number of animals that would have to be measured. The objective of this study was to examine phenotypic correlations between performance and efficiency traits measured in growing steers (Carstens et al., 2002), and blood constituents including hormones, metabolites and hemato logical parameters. Braunvieh-sired crossbred steers (N = 169) were individually fed a roughage-based diet (ME = 2.2 Mcal/kg; 15.7% CP, DM) using Calan gate feeders. Weekly BW and feed intake (FI) were measured for 77 d, and NFI calculated as difference between actual FI and FI predicted from multiple regression of FI on mid-test BW and ADG. Blood samples obtained at the start (day 0) and end of the study (day 70) were analyzed for cortisol, triiodothyronine (T3), thyroxin (T4), glucose, urea nitrogen (BUN), red (RBC) and white blood cell (WBC) counts and hemoglobin. Steers with NFI that were >.05 SD below the mean NFI of 0.0 = .82 SD (n = 53) gained at similar rates, but consumed 17% less feed and had 19% lower FCR compared to steers with NFI that were >.05 SD above the mean (n = 51). Serum cortisol concentrations (day 0) were negatively correlated with FI (r = -.2.3, P < .01) and ADG (r = -.30, P < .0001), and positively correlated with feed conversion ratio (FCR; r = .18; P < .05). Likewise, hemoglobin and RBC counts were negatively correlated with FI and ADG and positively correlated with FCR. Serum cortisol, hemoglobin, and RBC counts were not correlated with NFI. Plasma glucose concentrations (days 0 and 70), and BUN (day 70 only) were negatively correlated with FI and ADG, but were not correlated with either efficiency trait. Serum T3 and T4 concentrations (day 0 only) were negatively correlated with ADG (r = -.16; P < .05), and positively correlated with FCR (r = 0.16 to 0.20; P < .05). Although not correlated
with NFI, low NFI steers had lower (P < .05) serum T3 concentrations (182.9 vs 192.8 ± 5.3 ng/dL) and lower (P < 0.5) serum T4 concentrations (6.02 vs 6.51 ± .21 ug/dL) compared to high NFI steers. These results demonstrate that serum cortisol, hemoglobin and RBC counts were correlated with ADG, FI and FCR, but not with differences in feed intake independent of BW and ADG (NFI). Plasma metabolites and thyroid hormone concentrations were also not correlated with NFI, but low NFI steers had lower T3 and T4 concentrations than high NFI steers. Additional studies are warranted to identify physiological indicators that are predictive of NFI.