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The 2008 Plains Nutrition Council Spring Conference  
April 10-11, 2008

Thursday, April 10
8:30 – 11:30 Pre-Conference Symposium

2008 Plains Nutrition Council Spring Conference
1:00 – 1:10 Welcome and Introduction Dr. Clint Krehbiel, President Plains Nutrition Council, Oklahoma State University, Stillwater

1:10 – 1:50 Antimicrobial Drug Resistance, Production Practices, and Issues with Public Health Dr. Jason Osterstock, Texas AgriLife Research, Amarillo

1:50 – 2:30 Preconditioning Programs: Approaches, Economics, and Subsequent Performance Dr. Clay Mathis, New Mexico State University, Las Cruces

2:30 – 3:10 Stocker Programs, Feedlot Performance and Carcass Merit Dr. James W. Oltjen, University of California, Davis

3:10 – 3:40 Break and View Posters

3:40 – 4:20 Economic Aspects of Stocker Programs Dr. Dillon Feuz, Utah State University, Logan

4:20 – 5:00 Opportunities for U.S. Beef in a Dynamic Global Marketplace Clint Peck, Montana State University and Montana Stockgrowers Association, Bozeman

5:00 View Graduate Student Posters

5:30-7:30 RECEPTION (SPONSORED BY CARGILL ANIMAL NUTRITION)

Friday, April 11
8:00 – 8:15 PNC Business Meeting

8:15 – 9:30 University Updates Dr. Nathan Elam, New Mexico State University Dr. Galen Erickson, University of Nebraska Dr. Jim MacDonald, Texas A&M REC, Amarillo

9:30 – 10:00 Break and View Posters

10:00 – 10:45 Random Ruminations and Implications of Feeding Distiller’s Co-products Dr. Fred Owens, Pioneer Hi-Bred Int'l, a DuPont Business, Johnston, IA

10:45 – 11:30 Utilization of Crude Glycerin in Feedlot Cattle Dr. Jim Drouillard, Kansas State University, Manhattan

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Antimicrobial Drug Resistance, Production Practices, and Issues with Public Health

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Texas AgriLife Research
Amarillo

Antimicrobial resistance is among the most widely researched and controversial subjects facing animal agriculture. The emergence of resistant pathogens of consequence to human health has sparked debate regarding the role of antimicrobial use in livestock in the development of resistant bacterial populations and dissemination of resistant phenotypes. In concert with the increased pressure on animal agriculture to address this issue has been a movement for judicious use of antimicrobials in both human and veterinary medicine. However, we are perhaps less prepared to mitigate the development of resistant bacterial populations as a result of this social awareness and the resulting pursuits. Our improved understanding of the genetic basis of antimicrobial resistance and the development of more sensitive diagnostic methods has certainly raised more questions than have been answered. Perhaps this reflects an appropriate research paradigm, but it very well may measure the challenge we face in addressing this issue.

There are many facets of antimicrobial use that have fueled the development of an increasing number of antimicrobial resistant bacteria. Undoubtedly, antimicrobial use in any form contributes to development of resistant bacterial populations. Any bacteria unaffected by exposure to an antimicrobial regardless of therapeutic, prophylactic, or metaphylactic use is by definition resistant. This may be of limited consequence, particularly in the application of antimicrobials with narrow spectrum for specific indications, but this clearly illustrates that any antimicrobial use selects for resistance. The features that characterize the importance of this resistance include which bacterial species develop resistance, how long this resistance persists in the bacterial community at large, and the extent to which the genes associated with resistance are disseminated among bacterial populations.

Perhaps the most important factor affecting the severity of the present antimicrobial resistance dilemma is the limited development of novel antimicrobials by pharmaceutical manufacturers. In 2004, five antimicrobial products were in development phases of production. Contrast this to the four products developed to address erectile dysfunction over the same period (Spellberg et al., 2008). The reason for this disparity is for the most part economics. Pharmaceutical development of a single antimicrobial will typically cost hundreds of millions of dollars. The application of these products is primarily for treatment of acute infections with a short duration of therapy. Return on drug development is much larger for products developed with the specific intent of prolonged or even life-long therapy. Coupled with the increased requirements for development of antimicrobial agents including risk assessments for development and dissemination of resistance, the development of new novel antimicrobial agents simply does not pencil out. It is unlikely that development of new antimicrobials will play a significant role in mitigation of resistance, but the static repertoire of available antimicrobials will undoubtedly contribute to the problem.

Another aspect of antimicrobial use that contributes to development of resistant populations is lack of compliance. The impact of this practice is difficult to measure, but includes inappropriate prescription to treat viral infections, prescription of the wrong
antimicrobial due to misdiagnosis or incomplete diagnostics, inappropriate dosing regimens, and failure to complete the prescribed course of antimicrobial therapy. The issues are not unique to human medicine or livestock production.

**Development of resistance to antimicrobials in bacteria**

Bacteria use three basic methods of resisting the actions of antimicrobials (Croft et al., 2007). The first is by production of peptides that directly change the structure of antimicrobials rendering them ineffective. A classic example is β-lactamases that form the basis of resistance to penicillin. A second mechanism of resistance is the development of efflux pumps that reduce the concentration of antimicrobial at the site of action until it is no longer effective at the resulting concentration. A final mechanism is by receptor modification. Many antimicrobial agents recognize specific bacterial receptors for attachment and specificity of activity. Modification of these receptors prevent antimicrobial attachment and, subsequently, antimicrobial activity. An example is methylation of 23S ribosomal RNA to prevent macrolide activity.

Genetic polymorphism forms the basis of all antimicrobial resistance in bacterial populations. Genes encoding resistance are often found on bacterial plasmids. Resistant bacterial populations can develop through spontaneous mutation, clonal expansion, and horizontal transfer; listed in increasing order of significance. Spontaneous mutation likely contributed to the earliest development of resistant genotypes and is characterized by changes in DNA sequences that result in functional changes in the proteome of the organism. Mutations can result from “errors” in DNA replication or may be triggered by environmental exposures. Spontaneous mutations during replication occur at a rate of approximately $10^{-9}$ per cell per generation. However, mutations that result in functional changes and antimicrobial resistance properties would be exceedingly rare and account for a very small proportion of newly observed antimicrobial resistance in bacterial populations.

Clonal expansion is the reproduction of bacteria from a single cell resulting in a population of bacteria with identical genotypes. Clonal expansion of antimicrobial resistant bacteria has the opportunity to expand the proportion of resistant organisms in bacterial communities. However, the extent of this expansion is limited by other forces that control bacterial replication including competition for resources, general fitness, and sustained pressure to maintain selection.

The most important mechanism for transfer and maintenance of antimicrobial resistance traits in bacterial communities is horizontal transfer. Bacteria have the ability to share portions of their genome with other bacteria of varying species. Much of this transfer occurs via transfer of small genetic elements from one bacterium to another. These genetic elements often have flanking regions that contribute to their ability to insert and excise the segment from the bacterial genome. Of note is the fact that these genetic elements, commonly referred to as plasmids and integrons, may include genes encoding resistance to multiple antimicrobials. These combinations may be “inherited” en bloc and allow the dissemination of resistance to antimicrobials with diverse spectrum and mechanism of action. This phenomenon is recognized clinically by emergence of resistance to specific antimicrobials despite lack of direct exposure to those drugs. A study of antimicrobial resistance among subspecies of *Salmonella enteritica* identified high proportions of multi-drug resistant (MDR)
isolates that contained large plasmids presumably containing several genes conferring resistance to a large array of antimicrobial agents (Davis et al., 2007).

It should be noted that multiple mechanisms for development of genotypes associated with antimicrobial resistance may be recognized simultaneously in the same bacterial population. Alcaine et al. (2005) examined Salmonella enterica subtypes to examine the evolution of ceftiofur resistance in dairy cattle. Ceftriaxone resistance was highly correlated with the presence of a specific gene (blaCMY-2) and was commonly associated with resistance to a wide array of antimicrobials including amoxicillin, ceftriaxone, chloramphenicol, streptomycin, and tetracycline. Analysis of genetic diversity among resistant strains suggested that resistance emerged through horizontal transfer of the blaCMY-2 gene between bacterial strains followed by clonal expansion of the respective strain types.

**Significance of antimicrobial resistance in livestock production to human health**

Antimicrobial use in livestock populations has the opportunity to influence human health in several ways. Generally, the prevailing concern is that antimicrobial use in livestock results in selection for resistant bacterial populations that may 1) enter domestic food supplies through contamination of meat and dairy products; 2) gain direct exposure to humans engaged in livestock production; and 3) contribute to dissemination of antimicrobial resistance to bacterial communities at large through horizontal transfer. The ability to affect change in antimicrobial resistance patterns among pathogens of significance to human health largely depends on the rate of horizontal transfer (Smith et al., 2005).

The primary pathogens of interest when examining the effects of antimicrobial use in livestock on human health are Salmonella enterica and Campylobacter spp. Typically, human infections associated with these organisms when derived from animal products are self-limiting and do not require antimicrobial therapy. However, strains associated with infections that are more severe and do require therapy are often characterized by MDR patterns. These infections exert substantial social pressure to address antimicrobial resistance issues because of the increased mortality associated with these infections, increased duration of hospitalization, and increased cost of therapy. The contribution of beef and dairy products to the incidence of human salmonellosis is difficult to estimate, but the CDC (2008) reported that 5.3% of all Salmonella outbreaks for which a vehicle could be identified were attributable to beef or dairy products and several included MDR strains. Veterinary diagnostic laboratory submissions found that 82% of Salmonella isolates were resistant to at least one antimicrobial and 70% were resistant to three or more (Zhao et al., 2007). The antimicrobials most frequently associated with resistance included tetracycline (78% of isolates), streptomycin (73%), sulfamethoxazole (68%), and ampicillin (54%). Ceftriaxone resistance was encountered in 17% of isolates and was most often observed in bovine specimens. In total, 77% of bovine isolates were resistant to at least one antimicrobial. These results likely overestimate the proportion of isolates with resistant phenotypes because submissions to diagnostic laboratories are more likely to originate from animals with clinical disease. Frye and Fedorka-Cray (2007) estimated that 18.5% of clinical Salmonella isolates demonstrated some degree of antimicrobial resistance compared to 3.4% of isolates from health animals.

An interesting collection of “natural experiments” have been performed in Europe to estimate associations between antimicrobial use in livestock and prevalence of resistance isolates in human populations (Phillips, 2007). The use of antimicrobials as growth
promotants was banned in Sweden in 1986, Denmark in 1995, and in all of the European Union by the late 1990’s. The antimicrobials included in these bans were avoparcin, bacitracin, spiramycin, tylosin and virginiamycin. After the ban, a substantial increase in the therapeutic use of macrolides was observed. Resistance of enterococci to virginiamycin and tylosin decreased significantly after the ban. However, increases have been observed in vancomycin resistant enterococci and fluoroquinolone resistance in animal isolates have been observed following the ban and highlight concerns that human antimicrobial use still plays a major role (as in vancomycin use for methicillin resistant *Staphylococcus aureus* (MRSA)) and decreased use of antimicrobials in feed may have resulted in increased use of antimicrobials for therapeutic intervention at the individual animal level.

The primary concerns in human medicine related to antimicrobial resistance independent of livestock production are MRSA, resistant *Streptococcus pneumonia*, resistant strains of *Mycobacterium tuberculosis*, and resistant gram-negative bacilli (Spellberg et al., 2008). The role of livestock production in emergence of these resistant pathogen variants is likely limited to contributions to horizontal transfer of resistance genes among microbial communities. A study of methicillin resistant coagulase-negative *Staphylococcus* spp. found that 13% of dog and 50% of horse nasal cavities contained resistant organisms (Bagcigil et al., 2007). Resistant coagulase-negative *Staph* were not isolated from swine and cattle.

A specific antibiotic that has been under increased scrutiny because of its use in livestock is ceftiofur. Despite having limited efficacy against *Pseudomonas* spp., ceftiofur is considered a third generation cephalosporin. This drug class, specifically ceftriaxone, is of particular importance in human medicine because of its use in treating salmonellosis and other resistant infections. The use of ceftiofur in cattle increased substantially following its introduction in the late 1990’s because of its short drug withdrawal, particularly for dairy cattle where some formulations have no milk withdrawal. Ceftriaxone resistance has been associated with the bla\textsubscript{CMY-2} gene and the majority of resistant isolates carry this genotype (Frye and Fedorka-Cray, 2007). Data including reports from the National Antimicrobial Resistance Monitoring System (NARMS) has observed increases in ceftiofur resistance temporally associated with introduction of this drug for use in food animal production (Davis et al., 2007; Frye and Fedorka-Cray, 2007; NARMS, 2005; Douris et al., 2008). To date, resistance to ceftriaxone has remained low (Frye and Fedorka-Cray, 2007; Douris et al., 2008). Use of this drug in cattle has been associated with increased prevalence of resistant *E. coli* in feces of treated calves that has also demonstrated evidence of co-selection for resistance to other antimicrobials (Lowrance et al., 2007).

**Antimicrobial resistance and cattle health**

The use of antimicrobial drugs in livestock production has the same opportunity to disseminate resistant genotypes affecting cattle health as animal health. Fortunately for veterinarians and cattle producers, the most common bacteria encountered in cattle health are generally very responsive to a wide array of antimicrobials and resistance has not emerged as a substantial challenge. Bovine respiratory disease complex (BRDC) remains the most significant infectious disease problem. National Animal Health Monitoring System (NAHMS) data indicated that approximately 15% of all feedlot placements are diagnosed with respiratory disease and almost 100% of those animals receive an antimicrobial as part of their therapy (USDA-APHIS, 1999). The primary bacterial pathogens included in BRDC are
Mannheimia haemolytica, Pasteurella multocida, and Histophilus somni. Generally, these bacteria are susceptible to a wide range of antimicrobials and limited resistance has been observed among these pathogens (Wallman, 2006). Treatment of BRDC with ceftiofur has been associated with transient increases in resistance among fecal pathogens (Lowrance et al., 2007), but sustained resistance among respiratory pathogens has not been reported. Estimating the role of antimicrobial resistance as a contributing factor in treatment failure is difficult. It is likely that misdiagnosis or late diagnosis play a far more substantial role in treatment failure than the presence of resistant pathogens. Resistance to tetracycline and penicillin is most commonly reported for respiratory pathogens (Rice et al., 2007). Of note is that these are among the most common resistance profiles for a host of bacteria isolated from cattle.

The largest, and most contentious, use of antimicrobials in livestock production is mass medication. There are many different forms by which antimicrobial drugs are delivered to large populations of cattle. The largest is the use of antimicrobials in feed for prevention of liver abscesses, improved performance, and the management of BRDC. Antimicrobials used in the U.S for these indications include tylosin, chlortetracycline, and ionophores (monensin sodium and lasalocid). Another form of mass medication is metaphylactic use of injectable antimicrobials for the treatment and prevention of BRDC in high risk groups of cattle. Of feedlots participating in the most recent NAHMS survey, 42% used metaphylaxis as a tool to prevent BRDC in calves at arrival (USDA-APHIS, 1999). Several studies have reported increased prevalence of resistant isolates associated with mass medication in livestock (Inglis et al., 2006; Edrington et al., 2006; Emborg et al., 2007; Rosengren et al., 2007). The most common antimicrobials associated with resistance include tetracycline, sulfadimethoxine, spectinomycin, and tylosin. The significance of these patterns of resistance on treatment failure associated with therapeutic use of these products is unclear.

The use of mass medication practices in livestock production is a primary concern for the development of antimicrobial resistance among human isolates. The most common resistance patterns observed among all isolates (animal and human) include tetracycline, spectinomycin, and macrolides such as tylosin. These drug families are among the most commonly used as feed additives in livestock species. This correlation appears to be a primary driving force for pressure to eliminate feeding antimicrobials to livestock for non-therapeutic indications. However, some have noted that in addition to performance gains and disease prevention, feeding of antimicrobials can also be a useful tool to reduce shedding of fecal microbes that may pose a threat to human health and the potential loss of this benefit following a feed ban is seldom considered (Phillips, 2007).

The last decade or so of agricultural production has introduced a new comparison that may be useful in assessing the role of antimicrobial use in livestock on the emergence of resistant isolates. Increased consumer demand for organic food products has lead to an increase in the number of organic farms in the U.S. Organic production restricts the use of antimicrobials as defined by the National Organic Program (USDA-AMS, 2008). Several studies have compared the proportion of antimicrobial resistant isolates between organic and conventional farms. Salmonella isolates from conventional dairies showed increased proportion of spectinomycin resistant isolates compared to organic dairies, although resistance to all other antimicrobials tested was similar (Kay et al., 2006). The proportion of resistant Campylobacter jejuni isolates was slightly higher for conventional (9.9%) than organic (8.9%) dairies (Halbert et al, 2006). Among resistant Campylobacter jejuni isolates, the minimum inhibitory concentration for reduction in growth of 50% of organisms (MIC50) for
tetracycline was four times greater for conventional dairies (32µg/mL) compared to organic dairies (8µg/mL). In a study of Minnesota dairies, conventional production was associated with a higher proportion of Shiga toxin-producing *E. coli* (STEC) resistant to at least one antimicrobial (62%) than organic dairies (48%) (Cho et al., 2007). However, no difference was observed in proportion or MDR isolates.

One key pathogen whose resistance has a direct impact on cattle health is *Salmonella*. Over the last decade, the *newport* serotype of *Salmonella* has emerged as a significant cause of clinical disease, particularly in dairy cattle. Other important serotypes with primary impact on cattle health include *dublin* and *typhimurium*. Clinical salmonellosis attributed to these serotypes can be severe and often antimicrobial therapy is necessary to treat septicemic manifestations of the infection. Results of the NARMS 2005 Final Report indicate that resistance in *Salmonella* serotypes *newport*, *typhimurium*, and *dublin* is commonly encountered with large proportions of isolates demonstrating resistance to ceftiofur, sulofnamides, tetracyclines, and β-lactams (NARMS, 2005). This may have a direct impact on success of therapeutic intervention in these patients. Environmental dissemination and persistent of fecal shedding of *Salmonella newport* has been observed in herds with clinical outbreaks of disease and MDR strains are common (Cobbold et al., 2006).

**Summary and knowledge gaps**

Clearly, the emergence of antimicrobial resistance in veterinary and human medicine is a complex problem and there is no single culprit or management practice that has created the present challenge. Antimicrobial use in all forms in humans, pets, and livestock by definition exerts selection pressure on bacterial communities. The relevant questions for livestock producers and veterinarians are how does our use of antimicrobials including mass medication and individual therapy contribute and what can we do to help mitigate the problem? However, despite a rapidly accumulating body of knowledge related to these questions, the answers are probably less apparent now than ever.

A substantial proportion of total antimicrobial use can be attributed to livestock production. This use has the greatest potential to affect microbial ecology and human health by contributing to dissemination of resistant genotypes through horizontal transfer. We have an obligation to utilize antimicrobial therapy to alleviate animal suffering due to bacterial infections. This use should be responsible and judicious including appropriate selection of antimicrobial agents considering the necessary spectrum and distribution of drug in the affected organ system, appropriate dose and route of administration, and appropriate compliance related to duration of therapy and drug withdrawals. Generally, we should select the minimum spectrum necessary to provide effective therapy and should use susceptibility data, when available, to make these decisions. Similar principles can and should be applied to treatment of humans and pets.

The future of mass medication for prevention of disease and improved performance remains unclear. Research to date suggests that this does, as expected, result in increased proportions of resistant isolates in target bacterial species and that resistance correlates well with the antimicrobials used in animal feed. However, it is unclear how large an impact eliminating the feeding of antimicrobials to livestock may have on the entire antimicrobial resistance and human health picture. The European data indicates that the proportions of isolates with some resistance profiles may decrease, but is clear that the consequences of these
bans cannot be interpreted independent of concurrent human antimicrobial use or subsequent increases in therapeutic use in livestock. Further, the impact of decreased antimicrobial use on rates of shedding of potentially pathogenic bacteria must also be considered.

There are several aspects of antimicrobial resistance that must be addressed to improve our ability to accurately assess the risk of antimicrobial use on the emergence of resistant variants. Acquisition of resistance genes by bacteria is associated with a penalty in the relative fitness of the organism due to increase in its genome size and the resulting resource demands for replication (Walk et al., 2007). It is unclear how long a clone containing resistance genes will be maintained in the community in the absence of selection pressure. Lowrance et al. (2007) found that ceftiofur resistance levels returned to pre-treatment levels within approximately two weeks of therapy. However, others have observed tetracycline resistance that has persisted for decades following cessation of use (Harvey, R. personal communication).

There is also need for consensus in determining the definition of resistance based on clinical or epidemiologic breakpoints. Disparity has been observed between countries and between veterinary and human definitions of susceptibility for some antimicrobial drugs (Phillips, 2007). Further, it is clear that a primary concern is the dissemination of resistant genotypes between bacterial species through horizontal transfer. Therefore, the relevant measure of dissemination of antimicrobial resistance may be identification of specific genes with bacterial communities rather than phenotypic characterizations. Microarrays have been developed to interrogate for large numbers of defined antimicrobial resistance genes (Frye et al., 2006).

One of the biggest challenges to defining the role of antimicrobial use in livestock in the emergence of antimicrobial resistance is quantifying drug use. The bulk of livestock antimicrobial use is non-prescription and quality of records regarding individual animal consumption of antimicrobials varies widely. Some have utilized manufacturing and distribution records to quantify the “dose” of antimicrobial drugs that enter a given environment, but this is obviously a crude measure that may substantially bias estimates of effect. It would behoove the relevant agriculture industries to explore methods to better quantify the amounts of antimicrobials administered on a level that allows consideration of concentration and drug form to allow appropriate estimation of distribution of active compound and mean exposures at the individual animal level.

In summary, the specific contribution of antimicrobial use in livestock to global antimicrobial resistance is unclear. However, there is substantial evidence that resistant phenotypes are encountered among bacterial populations of significance to human and animal health associated with animal production. Further, the most common antimicrobial resistance profiles include those antimicrobials most commonly used in veterinary medicine and livestock production. Animal agriculture must be prepared to address the concerns of external stakeholders, including those that oppose the use of antimicrobials in livestock feed for non-therapeutic indications. Among the issues we must prepare to address are improved methods for accounting of drug use, clear justification of decisions regarding therapeutic and non-therapeutic use, and our responsibility for antimicrobial resistance at all levels of health care. There are clearly many contributing factors to the evolution and dissemination of resistant genotypes among bacterial communities and the answer is undoubtedly somewhere in the middle of human medicine and animal agriculture concerns.
Literature Cited


Preconditioning Programs: Approaches, Economics, and Subsequent Performance

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Las Cruces

In the Beef Industry the term “preconditioning” generally indicates management practices implemented around weaning that are intended to optimize the immune system and nutritional status of calves, while minimizing stress (Lalman and Smith, 2001). Conventional preconditioning programs included vaccination against clostridial and respiratory diseases, parasite control, castration, and dehorning (AABP, 1968). These programs also commonly included weaning calves at least three weeks prior to shipping and training calves to eat from a feed bunk and drink from a trough. Cole (1985) reviewed controlled experiments that compared preconditioned to non-preconditioned calves and found little difference in performance when evaluated over the entire feeding period, but that morbidity and mortality rates were lower for calves that were preconditioned. During the last 20 years preconditioning has developed into, in cases like the “Value-Added Calf” programs, more rigid vaccination and management protocols. However, ranch resources, management systems, cattle-types, and potential markets vary, thus a single preconditioning management protocol does not fit all operations or market environments. Producers preconditioning calves prior to shipping are challenged to identify practical preconditioning approaches that can be implemented within their management system and yield sufficient price premiums to be cost-effective.

The objective of this paper is to discuss preconditioning approaches, the impact of preconditioning on subsequent performance, and the cost-effectiveness of preconditioning calves.

Value Added Calf Programs

In the 1990’s, Extension Specialists at Texas A&M University developed a set of standardized calf health management protocols to guide producers in adding value to calves. The “Value-Added Calf” (VAC) guidelines were created based partly upon observations of calf performance in the Texas Ranch to Rail program. Table 1 lists the VAC guidelines for raised calves (Anonymous, 2005). The VAC-PreWean and VAC-PreWean Plus programs were designed for operations that ship calves at weaning. The VAC-45 Pre-Wean and VAC-45 Weaning options are preferred over the VAC-PreWean and VAC-PreWean Plus programs because both VAC-45 options separate weaning and shipping by a minimum of 45 days. Since weaning and shipping are both stressful events in a calf’s life, the duration from weaning to shipping is important. By separating these stressors, the combined immunosuppressive impact of each event may be reduced. Therefore, separating weaning and shipping, when combined with a sound vaccination protocol, further enhances value of calves and is rewarded in the marketplace.

In conventional preconditioning programs, only 30 days or less generally separated weaning and shipping. The 45-day requirement for VAC-45 programs was established because health records from Texas Ranch to Rail calves indicated that calves entering the
feedlot within 14 days after weaning, and even from 31 and 45 days after weaning had medicine costs 4-fold and 2-fold greater, respectively, than calves entering the feedlot more than 45 days after weaning (McNeill, unpublished). Waggoner et al. (2005) provided further support for extending the separation of weaning and shipping beyond 30 days, showing that New Mexico Ranch to Rail steers weaned 41 days or more before entering a feedlot generated greater net income during finishing than steers weaned 21 to 40 days prior to shipping, or less than 20 days (Figure 1).

**Premiums for Value-Added Calves**

The VAC guidelines have served as a foundation for numerous “certified” preconditioning programs. In fact, price premiums for VAC-45 and VAC-34 (Superior Livestock version of VAC-PreWean Plus) calves marketed through Superior Livestock Auction video sales increased from 2000 to 2004, with annual average price premiums ranging from $3.66 to $7.91/cwt for VAC-45 calves, and from $1.76 to $3.47/cwt for VAC-34 calves (King and Seeger, 2005). Since 2004, average price premiums for VAC-45 calves have remained between $6.50 and $8.00/cwt, and for VAC-34 calves ranged from $2.45 and $4.68/cwt (King, 2005, 2006, 2007). Calves marketed as VAC-45 and VAC-34 comprised about 25 and 50 percent, respectively, of calves sold through Superior Livestock video auctions in 2007 (King, 2007).

**Impact of Preconditioning on Subsequent Performance**

Preconditioning trials reviewed by Cole (1985) comparing performance of preconditioned vs. non-preconditioned calves revealed little difference in ADG or feed:gain over the entire feeding period. However, morbidity and mortality were 6.1 and 0.7 percentage units lower, respectively, for preconditioned than non-preconditioned calves. During the last 20 years, additional studies have been conducted comparing preconditioned to non-preconditioned calves (Pritchard and Mendez, 1990; Cravey, 1996; Roeber et al., 2001; Lalman et al., 2005). In a controlled experiment where calves were randomly assigned to treatments within source, Pritchard and Mendez (1990) evaluated the effects of preconditioning on post-shipping performance. They found that even though preconditioned calves had inferior feed:gain over the entire feeding period compared to non-preconditioned calves (Table 2), there was no difference in cumulative feedlot ADG or days on feed, nor were there differences in morbidity and death loss attributable to pre-shipping management (Table 3). They concluded that performance differences between preconditioned and non-preconditioned calves were lost if calves were fed for more than 56 days, and that the 25 to 30 day preconditioning program employed did not improve beef production efficiency.

Results of other studies have revealed some substantial positive impacts of preconditioning on subsequent performance (Cravey, 1996; Roeber et al., 2001; Lalman et al., 2005); however, it must be noted that in these studies preconditioning is completely confounded with source. Thus, it is not possible to fully separate the impact of preconditioning from that of other potential management or genetic differences among sources of calves. Nevertheless, Roeber et al. (2001) compared feedlot performance and end product characteristics of calves purchased from a certified preconditioning program to calves with no known history. The study revealed that the preconditioned calves had a 0.22 lb ADG advantage during the finishing period, and had a 42.6 and 10.3 percentage unit lower
morbidity and death loss, respectively, than calves of unknown history. However, there was no difference in marbling score, yield grade, or palatability traits of beef when compared between preconditioned and non-preconditioned calves.

Very few reports evaluating calves preconditioned for 45 days or more are available. Cravey (1996) compared feedyard closeouts from 1,685 calves preconditioned for 45 to 50 days according to the Hi-Pro Producer’s Edge protocol of the 1990s to closeouts from lots totaling 1,492 head of feedyard-started (non-preconditioned) calves. Preconditioned calves had a 0.29 lb ADG advantage and 7.2 percent better feed efficiency; coupled with, $29.47/hd lower medicine cost and a 3.1 percentage unit lower death loss. Lending further credit to the value of preconditioning calves for 45 days or more, Lalman et al., (2005) reported that calves preconditioned according to Oklahoma Quality Beef Network guidelines had a 22.4 and 2.9 percentage unit lower morbidity and death loss, respectively, than similar calves with little or no health management history.

These studies represent a wide variation in preconditioning systems, from differences in vaccination protocols to nutritional management approaches. There is no consistent cumulative post-shipping ADG, feed conversion, or days on feed advantage attributable to preconditioning. Other than the work of Pritchard and Mendez (1990), all studies included in Table 3 indicated a marked benefit of preconditioning in reducing morbidity and death loss.

**Comparison of Preconditioning Approaches**

Producers must define their objectives before implementing a post-weaning management program. For example, a producer may precondition calves with the intent of selling for a premium immediately after preconditioning; being most interested in low-cost gain. On the other hand, a producer may retain ownership of calves and choose to precondition them for the sole purpose of optimizing calf health to improve overall performance and profit through harvest; therefore, being less interested in weight gain during preconditioning. The preconditioning approach may be vastly different for these two scenarios.

Pasture-based preconditioning programs are generally perceived to be less stressful because the environmental change from pre-weaning to post-weaning is minimal. However, calves are commonly fed a forage-based or concentrate-based preconditioning ration and confined to a drylot for the entire preconditioning period. Some trade-offs between preconditioning management approaches exist.

<table>
<thead>
<tr>
<th><strong>Pasture Preconditioning</strong></th>
<th><strong>Drylot Preconditioning</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>+ less environmental change</td>
<td>+ often more gain</td>
</tr>
<tr>
<td>+ less dietary change</td>
<td>+ trained to eat from a bunk</td>
</tr>
<tr>
<td>+ less dust or mud control</td>
<td>- greater environmental change</td>
</tr>
<tr>
<td>+ lower cost</td>
<td>- more dust or mud control</td>
</tr>
<tr>
<td>- often less gain</td>
<td>- greater feed cost</td>
</tr>
<tr>
<td>- often not trained to eat from bunk</td>
<td></td>
</tr>
</tbody>
</table>
A study conducted at New Mexico State University (Mathis et al., 2008) compared a low-input pasture preconditioning approach to a high-input drylot preconditioning approach. Performance and profit were evaluated during the preconditioning and finishing phases. Treatments were: 1) high-input drylot preconditioning system (corn/wheat midds-based pellet plus 1.5-2.5 lb/day of alfalfa hay) or 2) low-input pasture preconditioning system (native range pasture plus 1.25 lb/day of a 32% CP range cube delivered 3×/wk). All calves qualified as “VAC-45.” After preconditioning, all steers were fed at a commercial feedlot then sold on an individual carcass basis.

During the preconditioning phase the drylot preconditioned calves gained 0.32 lb/day more, and were worth an additional $6.90/hd (Table 4). The higher value of the drylot calves was offset by $52.76 greater cost for drylot preconditioning. Consequently, net income during preconditioning was $44.59 greater for pasture preconditioned calves even though they gained less weight than the drylot preconditioned calves. These results support the findings of St. Louis et al. (2003) that showed lower feed cost and greater net return ($43.17/hd) for a 30-day ryegrass pasture preconditioning program compared to a higher input 30-day drylot preconditioning program.

During the finishing phase, Mathis et al. (2008) reported no differences in overall feedlot ADG, finished body weight, DOF, or any measured carcass characteristics. There was a tendency for drylot preconditioned steers to have more sickness (48% vs. 34%) than pasture preconditioned steers. The drylot preconditioned steers also had greater death loss (7.6% vs. 0%). During finishing, the pasture preconditioned steers profited $103/hd more than the drylot preconditioned steers. The authors suggested that the additional stressors of greater dietary and environmental change experienced by drylot-preconditioned calves during the 45-day preconditioning phase possibly yielded a long-term susceptibility that rendered the drylot-preconditioned steers less competent than the pasture-preconditioned steers to withstand immune challenge during the finishing phase.

Boyles et al. (2007) conducted a study in Ohio that compared health performance of calves that were: 1) shipped at weaning, 2) preconditioned for 30 days on pasture (fescue pasture + supplement) with fenceline contact to their dams for the first 7 days, and 3) preconditioned for 30 days in a drylot (hay + supplement) with no contact to dams. During the following 28-day receiving period, 15% of the pasture preconditioned/fenceline weaned calves were treated for sickness, whereas 28% of calves shipped at weaning and 38% of calves preconditioned in a drylot were treated for sickness. The fenceline-weaning, pasture-based preconditioning approach better prepared calves to withstand the immune challenge they faced during the feedlot receiving period, yet weaning calves for 30 days in a drylot provided no benefit in reducing morbidity compared to the calves that were shipped at weaning.

There are differences of opinion in the industry regarding how calves should be managed between weaning and shipping. It is also clear that management approaches that work well for some calves may not be the best approach for calves from a different source, management system, or region. However, there is mounting scientific evidence indicating that managing calves on pasture between weaning and shipping may render calves more competent to withstand subsequent immune challenge.
Cost vs. Premiums for Preconditioning

There is no universally accepted best approach to preconditioning calves, even though there is evidence that some approaches better prepare calves for the challenges of shipping and commingling. Ultimately, managers considering preconditioning calves prior to shipping must weigh the cost of implementing the preconditioning program with the additional value that will be garnered by the preconditioned calves.

The component that prevents most producers from preconditioning is holding the calves for 30 to 45 days after weaning, which likely explains why there are approximately twice as many VAC-34 as VAC-45 calves sold through Superior Livestock video auction (King, 2007). The VAC-34, or similar VAC-PreWean Plus, is considered by some to be the best of the defined health programs available for calves that are shipped at weaning. Since separating weaning and shipping by 45 days or more is preferred, it is logical to evaluate the cost-effectiveness of preconditioning by comparing a VAC-45 preconditioning program with the more commonly implemented VAC-34 health program that requires substantially less input. During the post-weaning portion of a VAC-45 preconditioning program, targeted ADG typically ranges from 1.0 to 3.0 lb/day, depending on the level of nutritional input. Because performance can be programmed at different rates and feed commodity and calf prices significantly impact costs and returns, the relationship between calf performance and the value of additional gain are important in determining the optimal level of input and potential for profit to the preconditioning enterprise.

Illustrated in Figure 2 is the calculated value addition of VAC-45 preconditioned calves above that of VAC-34 calves at three rates of ADG during the 45-day post-weaning period. The increase in gross value was calculated using a 550 lb weaned calf weight valued at $120/cwt as a base ($660/hd). Prices at different weights were calculated using three-year average price premiums for VAC-34 ($3.51/cwt) and VAC-45 ($7.36/cwt; calculated from King, 2005, 2006, 2007), and a $6.50/cwt price slide. Under these assumptions, a VAC-45 program with calves gaining 1.0 lb/day would be cost-effective if the cost of VAC-45 preconditioning is not more than $61/hd ($740 - $679/hd) over VAC-34 costs. If the calves gained 3.0 lb/day during the 45-day period, then additional costs would need to remain below $133/hd ($812 - $679/hd).

The difference in gross value in these comparisons is primarily a function of weight gain, not the VAC-45 price premium. Increasing rate of gain during preconditioning considerably increases gross value, but the marginal value of the additional gain declines as rate of gain increases (Figure 3). In fact, employing the same assumptions used in Figure 2, the calculated marginal value of gain during a VAC-45 preconditioning program is 33 to 45 percent greater for 1.0 lb than 3.0 lb ADG, depending upon the 550-lb calf base price.

Both St. Louis et al. (2003) and Mathis et al. (2008) reported lower comparative costs when calves were preconditioned in pasture-based systems than in a drylot. This is not to suggest that drylot preconditioning programs cannot be cost-effective, rather that when considering current grain and hay prices, the input costs of drylot-based preconditioning programs should be evaluated closely relative to projected performance during preconditioning.
Conclusions

Even though “preconditioning” remains without strict definition in the beef industry, efforts like the development of the Value-Added Calf guidelines have lead to increased uniformity in practices that prepare calves for the challenges they will face once they leave the ranch of origin. The primary value of preconditioning programs to the cattle industry is reducing the risk of subsequent sickness in calves. Preconditioning practices are justified and rewarded in the marketplace; however, the premium received for preconditioned calves may not always off-set the cost of preconditioning. In the current era of higher feed prices, cost-effective preconditioning of calves on the farm or ranch of origin will likely prioritize minimizing costs above adding weight during the preconditioning process.

Literature Cited


### Table 1. Value Added Calf (VAC) Vaccination Program Guidelines$^a$

<table>
<thead>
<tr>
<th>Program</th>
<th>2-4 mo. of Age$^b$</th>
<th>4-6 weeks$^b$</th>
<th>Weaning</th>
<th>2-3 wks Post-weaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAC-PreWean</td>
<td>MLV Respiratory$^c$ Clostridial 7-way</td>
<td>Ship</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAC-PreWean Plus</td>
<td>MLV Respiratory Clostridial 7-way</td>
<td>Ship</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAC-45$^d$ Pre-Weaning Option</td>
<td>Initial vaccination given at Branding or Pre-weaning</td>
<td>MLV Respiratory Clostridial 7-way</td>
<td>MLV Respiratory Clostridial 7-way</td>
<td></td>
</tr>
<tr>
<td>VAC-45$^d$ Weaning Option</td>
<td></td>
<td>MLV Respiratory</td>
<td>MLV Respiratory</td>
<td>Clostridial 7-way Clostridial 7-way</td>
</tr>
</tbody>
</table>


$^b$A bovine veterinarian should be consulted for guidance on the use of MLV vaccines in nursing calves.

$^c$MLV Respiratory = Modified Live Virus vaccine for IBR, PI3, BRSV, BVD; a combination vaccine may be acceptable.

$^d$Calves are not shipped until $\geq 45$ d post-weaning.

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**Figure 1.** Impact of time separating weaning and feedlot entry on net return of steers in the New Mexico Ranch to Rail program from 2001 to 2004.
Table 2. Impact of preconditioning on cumulative finishing period performance.

<table>
<thead>
<tr>
<th></th>
<th>Preconditioned</th>
<th>Non-Preconditioned</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pritchard and Mendez, 1990</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADG, lbs</td>
<td>3.02</td>
<td>3.06</td>
<td>NS</td>
</tr>
<tr>
<td>Feed:Gain</td>
<td>6.44</td>
<td>6.24</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Days on Feed</td>
<td>242</td>
<td>243</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Roeber et al., 2001</strong>&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADG, lbs</td>
<td>3.55</td>
<td>3.73</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td><strong>Cravey, 1996</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADG, lbs</td>
<td>2.88</td>
<td>2.59</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Feed:Gain</td>
<td>5.98</td>
<td>6.45</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Days on Feed</td>
<td>205</td>
<td>217</td>
<td>NS</td>
</tr>
</tbody>
</table>

<sup>a</sup>Data from Exp. II. (4 ranches, 2 yrs); Preconditioned = calves vaccinated against respiratory and clostridial diseases and dewormed 3 wks preweaning, and 25-30 d prior to shipping were weaned and fed a commercial pellet + grass hay. Non-Preconditioned calves were weaned and shipped.

<sup>b</sup>Preconditioned = Certified Preconditioned for Health (weaned ≥30 d prior to shipping); Non-Preconditioned = No previous history.

<sup>c</sup>Preconditioned = Hi-Pro Producers Edge Program (weaned 45 to 50 d prior to shipping + vaccinated 2x with MLV respiratory and 2x with Past. haemolytica vaccine); Non-Preconditioned = feedyard started.

Table 3. Impact of preconditioning on subsequent health.

<table>
<thead>
<tr>
<th></th>
<th>Preconditioned</th>
<th>Non-Preconditioned</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pritchard and Mendez, 1990</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morbidity, % (Exp. I)</td>
<td>21</td>
<td>19</td>
<td>NS</td>
</tr>
<tr>
<td>Morbidity, % (Exp. II)</td>
<td>45</td>
<td>47</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Roeber et al., 2001</strong>&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morbidity, %</td>
<td>35</td>
<td>77</td>
<td>-</td>
</tr>
<tr>
<td>Death Loss, %</td>
<td>1.1</td>
<td>11.4</td>
<td>-</td>
</tr>
<tr>
<td><strong>Cravey, 1996</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medicine Cost, $/hd</td>
<td>$13.74</td>
<td>$30.66</td>
<td>-</td>
</tr>
<tr>
<td>Death Loss, %</td>
<td>0.5</td>
<td>2.6</td>
<td>-</td>
</tr>
<tr>
<td><strong>Lalman et al., 2005</strong>&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morbidity, %</td>
<td>7</td>
<td>29</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Death Loss, %</td>
<td>0.1</td>
<td>3.0</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

<sup>a</sup>Preconditioned = calves vaccinated against respiratory and clostridial diseases and dewormed 3 wks preweaning, and 25-30 d prior to shipping were weaned and fed a commercial pellet + grass hay. Non-Preconditioned calves were weaned and shipped.

<sup>b</sup>Preconditioned = Certified Preconditioned for Health (weaned ≥30 d prior to shipping); Non-Preconditioned = No previous history.

<sup>c</sup>Preconditioned = Hi-Pro Producers Edge Program (weaned 45 to 50 d prior to shipping); Non-Preconditioned = feedyard started.

<sup>d</sup>Preconditioned = Oklahoma Quality Beef Network-certified (weaned ≥45 d prior to shipping); Non-Preconditioned = little or no health management history; morbidity and death loss values for 90 d post-shipping.
Table 4. Impact of preconditioning system on performance and profit during the preconditioning and finishing phases

<table>
<thead>
<tr>
<th>Item</th>
<th>Drylot Preconditioning</th>
<th>Pasture Preconditioning</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preconditioning Phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of head</td>
<td>125</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>ADG, lb/day</td>
<td>1.42</td>
<td>1.10</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$66.77</td>
<td>$14.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Net Income, $b</td>
<td>($28.87)</td>
<td>$15.72</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Finishing Phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># steers</td>
<td>66</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>ADG, lbs</td>
<td>2.93</td>
<td>2.98</td>
<td>0.32</td>
</tr>
<tr>
<td>Days on Feed</td>
<td>168</td>
<td>173</td>
<td>0.36</td>
</tr>
<tr>
<td>% Treated for sickness</td>
<td>47.6</td>
<td>34.3</td>
<td>0.14</td>
</tr>
<tr>
<td>% Death loss</td>
<td>7.6</td>
<td>0.0</td>
<td>0.02</td>
</tr>
<tr>
<td>Net Income, $</td>
<td>($98.33)</td>
<td>$4.68</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

aMathis et al., 2008.
bPrice premium for “VAC-45” was not included in the analysis.

![Figure 2. Value addition from VAC-45 above VAC-34 at three 45-day preconditioning rates of ADG and base weaning prices of $105, $120, and $135/cwt.](image-url)
Figure 3. Marginal value of additional gain from VAC-45 above VAC-34 at three 45-day preconditioning rates of ADG and base weaning prices of $105, $120, and $135/cwt.
Stocker Programs, Feedlot Performance and Carcass Merit

James W. Oltjen, PhD
University of California
Davis

In evaluating the effects of various stocker cattle programs on subsequent feedlot and carcass performance, we are generally considering the phenomenon of compensatory growth and its accompanying increased feed intake and rate of gain; less clear are its effects on composition and efficiency of growth. Even the NRC (2000, 1984) has been inconsistent in its recommendations for compensating growing animals—in 1984 net energy for growth and in 2000 net energy for maintenance requirements were reduced. This was done largely to account for observed changes in body composition. For compensating cattle, Smith et al. (1977), Mader et al. (1989), and Carstens et al. (1991) found cattle to be leaner. Cattle were fatter for Tudor et al. (1980) and Abdalla et al. (1988). Fox et al. (1972) and Rompala et al. (1985) found no differences. However, the latter two studies found initial compensatory gains were leaner and later gains fatter. This observation was confirmed by Oltjen and Garrett (1988), using the Davis Growth Model (Oltjen et al., 1986). They showed the energy content of gain of compensating yearlings, although initially smaller, increased to values higher than those for normally grown calves as the animals became larger, suggesting that final body composition of yearling cattle should become similar to those put on feed as calves (Figure 1). Whether yearling cattle achieve the same final body composition as calves thus depends on the length of the feeding period. How soon this is achieved may also depend on the severity and timing of restriction. Further, limit feeding high energy diets may confound these results (Sainz et al., 1995). Holsteins (Schoonmaker et al., 2004a), early weaning (Schoonmaker et al., 2004b), and implant regimen (Bruns et al., 2005) may also be influential but are beyond the scope of this paper. Rather, we will use the Davis Growth Model to evaluate the effect of various stocker programs on subsequent finishing performance and carcass merit.

Diet Quality during Growing Period

Using the intake data from Sainz et al. (1995) who fed British breed calves diets of 3.06 and 1.86 Mcal ME/kg DM from 237 to 327 kg, finishing period performance was simulated beginning at 327 kg body weight to either equal weight or body fat content for different stocker phase diets. Stocker cattle’s rate of gain is usually a function of diet energy concentration assuming cattle are fed ad libitum or have adequate forage availability (Figure 2), and is linear from 2 to 3 Mcal ME/kg DM. Finishing daily gain, however, is inversely and nearly linearly related to previous growing phase performance (figure 3). Exhibiting compensatory growth, cattle finishing between 327 and 481 kg had daily gains of 1.75 and 1.36 kg/d when previously fed rations of 2 and 3 Mcal ME/kg DM, respectively. This hardly varied whether cattle were fed to equal body weight or fat content endpoints.

More interestingly, the choice of endpoint differentially affected finishing days on feed (figure 4). Steers fed to an equal body weight endpoint of 481 kg were more sensitive to previous growing phase ration energy, requiring 88 and 113 d for 2 and 3 Mcal ME/kg DM in the growing phase, compared to 95 and 91 d for a constant fat endpoint, respectively. This result suggests that the previously restricted British breed steers had increased gains compared
to those not so restricted. This allowed the previously restricted animals to reach desirable slaughter weights and carcass composition. Those fed higher energy diets as calves reached acceptable carcass fatness at much lighter weights. Feeding larger frame cattle as calves, as has become much accepted in the past ten years or so, has partially solved this problem. Note the simulations in Sainz et al. (1995) are for nonimplanted animals—thus, slaughter body weights for normally implanted steers would be higher than shown in Figure 5. Recent trends to lower energy growing diets due to high grain prices may result in inadequate fat at content acceptable carcass weights. This may be accompanied by further deteriorating quality grades.

Diet Quantity during Growing Period

Another possible growing program that has received attention has been to limit feed high concentrate rations. Sainz et al. (1995) also fed the same finishing ration (3.06 Mcal ME/kg DM) at intakes (CL) to match the gain of steers fed a high forage ration (1.87 Mcal ME/kg DM) ad libitum (FA). Rates of body weight gain were 0.72 and 0.81 kg/d for the CL and FA steers, respectively. Intake was slightly greater and gain lower for finishing FA steers (Table 1), but steers previously fed the limited concentrate diet grew faster (10%) with improved feed efficiency (15%). When composition of gain was taken into account, the authors concluded that increased maintenance requirements of the FA group accounted for the observed performance differences. Some of this might be explained by the 14% larger viscera in the FA steers at slaughter, following 19% larger viscera in the FA at the beginning of the finishing phase in agreement with Hersom et al. (2004). Again, due to high relative grain prices, limited feeding higher energy diets will likely be little utilized.

What about limit feeding lower energy diets? When Nebraska workers used cornstalks to limit winter gains, subsequent slaughter quality grades were decreased after a finishing period compared to those supplemented with corn or wet corn gluten feed during the winter (Jordon et al., 2001). Sainz and Vernazza (2004) compared short yearlings finished after either three months of irrigated pasture to long yearlings finished after three months of irrigated pasture, nine months of dry range, and three months of irrigated pasture. Slaughtered at a constant backfat endpoint, short yearlings averaged 158 and long yearlings 94 days on feed in the finishing phase with slaughter weights of 489 and 538 kg, respectively. Gains were 7% faster for the long yearlings, and marbling score was 10.9 and 9.8 for the short and long yearlings, respectively (9 select+, 10, choice-). One wonders whether animals challenged immediately after weaning by early or aggressive implanting have similar mechanisms that also decrease carcass marbling at harvest (Bruns et al., 2005).

Length of Growing Period

Again using the intake data from Sainz et al. (1995) who fed 237 kg British breed calves diets of 1.86 Mcal ME/kg, finishing period performance was simulated beginning after various growing periods before being finished on a 3.06 Mcal ME/kg DM ration to either equal weight or body fat content. Growing phase performance and hence, initial body weight and empty body fat content for the finishing phase, are shown in figure 6. Although body weight increases to 333 kg by 150 days, body fat only increases from 11.8 to 14.1%.

The choice of endpoint differentially affected finishing days on feed (figure 7). Steers fed to an equal body weight endpoint of 481 kg were more sensitive to the length of the
growing period, just as with energy concentration in the growing ration. They required 171 and 102 d for 0 (calf fed) and 150 d in the growing phase, compared to 123 and 97 d for a constant fat endpoint, respectively. For these non-implanted British steers, body weight at slaughter increased over 50 kg (422 to 474 kg) for growing periods of 150 days at an equal body composition endpoint (figure 8). Empty body fat at a constant 481 kg body weight decreased 3.2% from 0 to 150 days in the growing period. That calf fed’s reach carcass fatness before desirable slaughter weights is thus predicted, confirming previous work that medium or small frame steers require a growing period before slaughter, particularly if not implanted.

Residual Feed Intake and Variable Maintenance

Residual feed intake (RFI), or that amount of intake not accounted for by a linear regression of body weight and rate of gain within a group of similarly fed animals, has been related to feed efficiency and other factors. In a recent study at Davis, Castro et al. (2004) showed that more efficient steers with negative RFI ate less (12%) and that RFI was related to maintenance energy requirements ($r=0.42$). There was no significant association with carcass traits. Interestingly, myofibrillar protein degradation rates were positively related to maintenance energy requirements ($r=0.76$), but were not related to RFI ($r=-0.14$). Thus, a genetic trait related to RFI should be used in prediction models to account for differences in maintenance, and with more research provide even more precision by adjusting for protein synthesis/degradation rate differences which are explicitly represented in the Davis Growth Model.

Fat Depots

Some of our most recent work has been to model how fat is distributed in the various fat depots of growing cattle. Jones et al. (2006) showed that in steers of both high and low growth potential, lower energy diets during the growing phase decreased rate of both subcutaneous and intramuscular fat in the finishing phase. This effect of impaired adipocyte development during the growth phase thus has lingering effects and McPhee et al. (2007) has incorporated these effects in an addition to the Davis Growth Model to represent four fat depots—intermuscular, intramuscular, subcutaneous, and visceral. On average the model over-predicts intramuscular, subcutaneous, and visceral fat; however, the model tends to under-predict total fat as fat increases in the carcass. This under-prediction as fat increases in all four fat depots could possibly be due to a secondary phase of hyperplasia that is not currently represented but has been hypothesized for rapidly growing cattle.
Literature Cited


Table 1. Growth performance of finishing steers previously fed a forage diet (1.87 Mcal ME/kg DM) ad libitum (FA) or a high concentrate diet (3.06 Mcal ME/kg DM) at intake levels (CL) to achieve similar growing phase gains (Sainz et al., 1995).

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¹ 0, devoid; 1, practically devoid⁶; 2, practically devoid⁵⁰; 3, practically devoid¹⁰⁰; 4, traces⁰; 5, traces⁵⁰; 6, traces¹⁰⁰; 7, slight⁰; 8, slight⁵⁰; 9, slight¹⁰⁰
Figure 1. Energy concentration and composition of empty body weight gain (1 kg/d, EBWG) for steers of different body weight: MC = medium-frame calves, MY = medium-frame compensating yearlings, LC = large-frame calves and LY = large-frame compensating yearlings from Oltjen et al. (1986).

Figure 2. Gain of growing steers fed rations of varying energy concentration from 237 to 327 kg body weight.
Figure 3. Gain of finishing steers with initial weight of 327 kg to a 481 final body weight or 30% empty body fat that were previously fed rations of varying energy concentration from 237 to 327 kg body weight.

Figure 4. Days required for finishing steers with initial weight of 327 kg to achieve 481 final body weight or 30% empty body fat; animals were previously fed rations of varying energy concentration from 237 to 327 kg body weight with resulting days required to reach 327 kg shown (growing line).
**Figure 5.** Body weight (solid line) and empty body fat content (dashed line) for finishing steers with initial weight of 327 kg to achieve 30% empty body fat or 481 final body weight, respectively; animals were previously fed rations of varying energy concentration from 237 to 327 kg body weight.

**Figure 6.** Body weight (solid line) and empty body fat content (dashed line) of growing steers fed rations of 1.87 Mcal ME/kg DM for varying time from initial body weight of 237 kg.
Figure 7. Finishing period length of growing steers fed rations of 1.87 Mcal ME/kg DM for varying time from initial body weight of 237 kg before receiving a 3.06 Mcal ME/kg DM ration during finishing to 481 kg body weight or 30% empty body fat.

Figure 8. Empty body fat (dashed line) or final body weight (solid line) of growing steers fed rations of 1.87 Mcal ME/kg DM for varying time from initial body weight of 237 kg before receiving a 3.06 Mcal ME/kg DM ration during finishing to 481 kg body weight, or 30% empty body fat, respectively.
Economic Aspects of Stocker Programs

Dillon M. Feuz
Marketing Specialist
Utah State University

Outline
- Historical Commodity Prices
- Ethanol Policy Impacts
- Historical Stocker Returns
- Current Stocker Returns
- Implications

Grain Prices

Hay and Pasture Prices

Cattle Prices

Grain vs Forage vs Cattle Prices
Corn vs. Grass
Cost per cwt. of Gain

Calf-fed vs. Long Yearling
Cost per cwt. of Gain

Energy Policy
National Corn Growers Ethanol Policy

US Energy Policy & Ethanol
- Energy Security Act 1979
- $0.40/gal of ethanol subsidy to blenders
- $0.54/gal tariff on imported ethanol
- Subsequent acts increased subsidy up to $0.60/gal
- It is currently at $0.51/gal
- Energy Policy Act of 2005
  - Mandated use of renewable fuels (primarily corn based ethanol)
  - Increased and expanded renewable fuels mandates

Energy Policy Act of 2005
Mandates

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Source: Renewable Fuels Association

Corn Growers Vision 2007

NCGA’s Vision
“15 x 15 x 15”
- 15 billion bushel corn crop
- 15 billion gallons of ethanol
- ...by 2015
  - 8 Years for Infrastructure Development
  - 33% of gasoline replaced
  - 9 billion vs. demand
Energy Independence & Security Act 2007

Mandates

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<td>2.0</td>
<td>12.75</td>
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Source: Renewable Fuels Association

Energy Summary

- 30 million acres of corn needed for energy
- 1/3 of corn acres
- How many more crop acres for cellulosic ethanol and other bio-fuels?
- 21 million acres if 2X more efficient than corn ethanol
- About 10 million acres if 4X more efficient than corn ethanol
- There will be a battle for crop acres between energy, feed and food uses. Higher crop prices will be the result

Dec Corn Futures

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Impact of Higher Corn Prices on Cattle Industry

- Feedlot Cost of Gain
- Calf fed versus Stocker Programs
- Market Risk
- Profitability
Feedlot Cost of Gain
- Total Cost of Gain $45/cwt with Corn <$2.00/bu
- Total Cost of Gain $65/cwt with Corn >$3.00/bu
- Total Cost of Gain $75/cwt with Corn >$4.00/bu
- Total Cost of Gain $85/cwt with Corn =$5.00/bu
- Total Cost of Gain $90/cwt with Corn =$5.50/bu

Calf Feds vs Stocker Programs
- Higher feedlot cost of gain will encourage heavier placement weights
- Cost and availability of other feeding programs
  - Wheat Pasture
  - Winter Pastures
  - Corn Stalk and DDG
  - Dry lot hay and DDG
  - Summer Grass

Historical Stocker Analysis
- Based on Fall Calf Prices from 1999-2005
  - Texas Combined Auctions
- Feeder Cattle Prices from 2000-2006
  - Texas Combined Auctions
- Fat Cattle Prices from 2000-2006
  - Texas-Oklahoma Live Fed Cattle

Stocker Programs Considered
450, 550, 650 lb Steer Calves
- Calf fed to Finish, 192-282 days
- Wheat Stocker, 180 days
  - Feedlot Finish, 113-130 days 293-330 total days
  - Wheat Stocker, 120 days
  - Feedlot Finish, 130-180 days 250-300 total days
  - Summer Grass, 130 days 350 total days
  - Feedlot Finish, 106-125 days 356-375 total days
  - Winter Pasture, 150 days
  - Feedlot Finish, 130-180 days 280-330 total days
  - Summer Grass, 150 days 300 total days
  - Feedlot Finish, 106-129 days 400-429 total days

Simulated Returns
- ADG
  - Expected gain based on University Budgets
  - Variability based on various feeding trial data
- Market Price
  - Expected price is the 7 year average
  - Variability based on previous 7 years and number of days fed
- Feedlot cost of gain
  - Expected values based on 7 year average corn price
  - Variability based on corn price fluctuations

Historical Stocker Programs
450 lb Steers

[Graph showing historical stocker programs]
Historical Stocker Programs

550 lb Steers

Historical Stocker Programs

650 lb Steers

Historical Simulation Summary

1999-2005 Fall Weaned Calves

- Stocker Programs for 450 lb steers were generally profitable
  - Less than a 10% chance of loss for many alternatives
  - Most alternatives were superior to placing calf directly in the feedlot
- Stocker Programs for 550 lb steers were generally profitable
  - A 10-20% chance of loss for many alternatives
  - Only a few alternatives were superior to placing calf directly in the feedlot
- Stocker Programs for 650 lb steers were only marginally profitable
  - A 20-50% chance of loss for most alternatives
  - Placing calf directly in the feedlot generally more profitable

Stocking Simulation Based on Current Market Conditions

- ADG the same as for historical simulation
- Market Price
  - Expected value based on current price levels using the futures market and historical basis data
  - Variability the same as for the historical simulation
- Cost of gain feedlots
  - Expected value based on current corn price
  - Variability increased compared to historical simulation
- Cost of gain for Stocker programs updated to current values

Current Stocker Programs

450 lb Steers

Current Stocker Programs

550 lb Steers
Current Stocker Programs
650 lb Steers

Current Simulation Summary
2007 Fall Weaned Calves
- Stocker Programs for 450 lb steers were generally profitable
  - A 10-20% chance of loss for some alternatives
  - All alternatives were superior to placing calf directly in the feedlot
- Stocker Programs for 550 lb steers were generally profitable
  - A 5-20% chance of loss for many alternatives
  - All alternatives were superior to placing calf directly in the feedlot
- Some stocker Programs for 650 lb steers were profitable
  - A 0-10% chance of loss for depending upon alternative
  - Most alternatives were superior to placing calf directly in the feedlot

Current vs Historical Stocker Returns
- Stocker programs for 450 lb steers
  - Many are less profitable now
  - All are more profitable relative to placing calf directly in feedlot
- Stocker programs for 550 lb steers
  - Some more profitable, some less profitable
  - All are more profitable relative to placing calf directly in feedlot
- Stocker programs for 650 lb steers
  - Most are slightly more profitable now
  - Most are more profitable than placing calf directly in feedlot

Cautions
- Current stocker returns are based on fall 2007 calf prices and current futures prices adjusted for basis
- Deferred Live Cattle Futures are quite optimistic compared to current cash values
  - Favours stocker programs that delay entry to feedlot and hence fed cattle sales
  - These prices and hence returns may not be realized
  - If Corn prices continue to rise...
    - Feedlot costs of gain will be higher than used in the simulation
    - There will also likely be a decline in feeder cattle prices

Cattle Futures on April 3, 2008

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OCT Feeder Cattle
As of April 2, 2008
Summary

- Corn for energy has changed the grain markets
- Corn for energy is changing the cattle industry
- Many stocker programs more profitable than feeding calves in feedlot
  - Can you add weight for less than the cost of gain in a feedlot?
  - If yes, these should be an economic return to do so
- If you make production decisions based on futures markets, you may want some form of price protection for cattle sale price and feed costs
Opportunities for U.S. Beef in a Dynamic Global Marketplace

Clint Peck  
Montana State University and Montana Stockgrowers Association  
Bozeman

Nobody ever said the cattle business was going to be easy. But, who knew even 20 years ago how complicated it would be to raise a calf and get it sent off to market. At every juncture, the beef industry is facing mounting and intense competition. No long ago, the only competition or pressure cattle ranchers in the West really had to worry about was white meat – and maybe white-gloved environmentalists. Today, slugging it out for market share with chicken and developing a nutrient management plan seems like a snap.

Certainly, as our population drifts away from the farm and settles into the fast-lane of suburbia – and as horizontal and vertical integration in food service and retail food increases – consumers are increasingly confused, and ignorant, as to where their food comes from.

And, relentless throughout in the food chain, led by nearly every other consumer good, is the trend toward globalization. The Doha Round of trade negotiations of the World Trade Organization (WTO) has been labeled the “development round” – a key aim of which is to increase developing countries’ access to developed-country agricultural and processed food markets (McCorriston, 2003).

The Global Trade Agenda

Thinking back, the 1989 Canada/U.S Free Trade Agreement and the ensuing North American Free Trade Agreement (NAFTA) seem like a cakewalk compared to the complexity of the new millennium trade picture. In 2001, World Trade Organization (WTO) members, including the United States, met in Doha, Qatar, and agreed to begin talks to lower tariffs and other barriers to free and fair agricultural trade.

The U.S. trade strategy under the Doha Round has been to pursue multiple market-opening initiatives on a global, regional and bilateral basis. The U.S. position has been to not only to help its farmers, ranchers, and growers export more, but also to improve the lives of producers and consumers in the developing world and around the globe (USDA-FAS, 2008).

Therefore, the U.S. has attempted to negotiate agreements on export competition, market access, and domestic support. Taken as a package, the U.S. proposals are intended to result in reductions in trade barriers for agricultural products, greater equity in world agriculture, and expanding growth opportunities for the sale of agricultural products.

The U.S. has entered negotiations with 33 other nations in the Western Hemisphere to form a Free Trade Area of the Americas (FTAA). Since 2004, the U.S. completed and implemented more than a dozen trade agreements globally – with several others on tap through the decade. Also, new rules for sanitary and phytosanitary (SPS) measures were established by the Uruguay Round, as well as other technical regulations in the SPS and the Technical Barriers to Trade Agreements.

In addition to health and safety issues, meat trade flows are often impeded by protectionist government policies that insulate domestic crop and livestock producers from world market forces. Import restrictions and tariffs are two of the most commonly used border measures for protecting a domestic industry.
But, with past trends in global economic growth, and the projections of steady economic growth over the next decade, expanding world production and trade in meat and meat products is upon us.

In fact, global meat consumption from 1960 through 2005 has changed dramatically. Beef consumption in this time frame increased, on average, 1.8% per year, pork 3.3%, and poultry 5.0% per year, making global meat consumption, overall increase over 10%. Over the past 10 years, global beef production has increased 24% or 7.2 million metric tons or 16 billion pounds. Population has also increased 78 million people per year and over the next decade we can expect to add 1 billion more global consumers. The question is: Will they eat beef? (Blach, 2008)

Within a more free trade environment, the most important variables that will shape the global meat complex in the near term will be positive macroeconomic growth and market disruptions due to disease outbreaks. Macro-growth will spur new investments that expand and modernize production, while consumer demand will provide new and growing markets for a variety of meat and dairy products. At the same time, red meat and poultry meat prices for major exporters will continued to be influenced by disease-related trade disruptions (Steiger, undated).

Global beef markets will increasingly be consumer-driven with product safety, wholesomeness, quality, and price being key determinants of international competitiveness. Processors, retailers, and food service corporations will continue to consolidate, expand and integrating the global beef market, bringing efficiency and lower-cost protein to both developed and developing countries around the world.

Where The Cattle Are…

The dynamics of global competition in the beef industry pivots around where the cattle are raised and the beef is produced. But, cattle populations notwithstanding, productivity in terms of beef and beef products produced within the confines of a national cowherd plays a significant role in the comparative and competitive advantages.

Of course, India, with the largest cattle population in the world is a not a player in the commercial beef marketplace. The architect of modern India’s spirituality, Mahatma Gandhi once said, “The cow to me means the entire sub-human world, extending man's sympathies beyond his own species. Man through the cow is enjoined to realize his identity with all that lives.”

A world away from Gandhi’s India though, is the South American continent – the carnivore capital of the world. Brazil leads the way with a cowherd estimated at 175-190 million head. Since the early 1990s, Brazil’s national cattle herd has grown at the rate of about 5 million head per year. Today in Brazil, 70% of an estimated 190-200 million cattle are raised in the hot and humid tropical regions of the sub-Amazon Cerrado. This vast region commands a dependence on Bos indicus breeds – mostly Zebu cattle types. The size of Alaska, the Cerrado is characterized by large grassland/scrubland plateaus with intermittent forest networks and river valleys. The annual wet-dry rainfall cycle typical of tropical climates presents unique challenges to season-long grazing.

The Chinese cattle industry today groups domestic bovines into yellow cattle, dairy cattle, water buffalo, and yak. Historically, every farmer had a cow, not for food but for work. After 1949, when farming was gradually collectivized, most cattle were reserved for draught
animals held in group ownership by the communes. Restrictions existed on the slaughtering of livestock prior to 1980 when only culled draught animals were harvested for beef. For centuries in China it’s been either immoral or illegal to kill your “tractor” for food.

The beginning year 2008 total U.S. cattle inventory of about 96.7 million head was slightly below the 97.0 million head counted on Jan. 1, 2007. The inventory is contracting after only three years of slight expansion. Since 1980, there have been inventory peaks in 1982, 1996 and 2007. Two expansions lasted three years and one lasted six, but the two contractions lasted eight years each.

U.S. beef cow numbers on Jan. 1, 2008 dropped to 32.6 million head, the lowest number of cows since 1991. Beef cow numbers reached a cycle low in 2004 and started to expand in 2005 and 2006. However, that has reversed with lower numbers in 2007 and again this year.

Producers say they have reduced the number of replacement heifers by 4%, which means the cow herd will continue to drop in 2008. The decline of 338,000 beef cows was somewhat offset by an increase of 92,000 milk cows. Strong export and domestic demand enabled milk prices to rise more rapidly than feed costs in 2007. The result was a 1% increase in the number of milk cows. Three percent more milk replacement heifers are being retained suggesting, the milk cow herd will continue to expand in 2008 (C. Hurt, personal communication).

Canada’s cattle herd also continued to decline during 2007, as exports to the U.S. accelerated. The year 2007 marked the second full year that the border has been open to Canadian cattle shipments since 2002. As of Jan. 1, 2008, Canadian cattlemen reported 13.9 million head on their farms, down by 210,000 head, or 1.5%, from Jan.1, 2007, according to the annual January livestock survey of 10,000 producers.

In January 2005, a record year, there were almost 1 million more cattle held on Canadian farms as closed borders forced producers to keep much of their farm stock off the market. Despite the decline, the Jan. 1, 2008 inventory was nevertheless 479,000 head above the level as of January 1, 2003, prior to the border closure.

In 2007, Argentina’s cattle population was about 52 million head raised on about 190,200 cattle farms. About 35% of Argentina’s cattle are in the province of Buenos Aires. About 10% of cattle in Argentina are dairy cows, primarily Holsteins. About 50% of cattle are Angus, 25-30% Herefords, and the remainder are mostly Brahman or Brahman-crosses with Angus or Hereford (Matthews and Vandever, 2007).

Even with 2.75 times the number of cattle as the U.S., the three South American countries – Argentina, Brazil and Uruguay – together just barely out-produce the U.S. in terms of beef volume (12.5 million metric tones in 2007 versus an estimated 12.0 for the U.S.). And, they don’t come close with respect to the value of the beef they produce.

The list of productivity differences runs deep.

First, Zebu heifers reach puberty at an older age than heifers of *Bos taurus* breeds. Brazilian ranchers struggle to get their heifers bred as two-year-olds – let alone as yearlings.

Even in Argentina and Uruguay, sexual precocity is a problem, mostly due to nutrition but also because of within-breed type; and first-service conception rates will not stand up to North American standards. Mating of heifers averages 36 months and with a normal calving rate of 65%.

While the more progressive Argentine or Uruguayan rancher will boast higher weights, most calves destined for grass finishing pastures are weaned at 300-400 lbs.
In Uruguay average slaughter age remains 36-48 months – with 800-1,000 lb. slaughter weights the norm. But, in Argentina age of slaughter has dropped dramatically in the past decade from 36-40 months to 20-24 months with slaughter weights similar to Uruguay.

In Brazil average harvest age has dropped from 54 months to 38 months in the past 10 years. Slaughter weights there tend to be lower than typical live weights entering U.S. packing plants. And, Brazilians continue to take a hit with a 53% average dressing ratio versus about 63% in North America.

When talking beef production efficiencies, it would be a mistake not to mention Brazil’s growing environmental movement and its impact.

Today in Brazil, depending on the ecological region, landowners must maintain 20%-80% of their private land in “environmental preserve.” This does not include riparian zones where grazing prohibitions exist. In fact, no economic activity can occur within these mandatory preserves – and government and environmental watchdogs are making sure Brazilian landowners abide by the law.

Consumption and Imports

The U.S., not surprisingly, is also the largest beef consuming nation in the world. Even with its production capacity the U.S., much to the consternation of many producers, is the largest beef importer. U.S. processing companies buy about 31%, by volume, of all beef that enters international trade.

But, what are the drivers of U.S. beef imports?

With the highest wholesale beef prices of any major trading country, the U.S. is a virtual economic sponge for global beef supplies. In the spring of 2006 when U.S. fed beef prices were hovering around the $90/cwt. mark, in Uruguay slaughter cattle were fetching $42/cwt. Even given transportation costs and in-quota and out of-quota import tariffs $100 million in 2005 paid to the U.S. Treasury, this price differential makes Uruguayan beef a great buy for U.S. importers.

Related to the economic driver is our nation’s insatiable appetite for ground beef. A recent national eating trends study shows that ground beef makes up 59% of all fresh beef eatings in the U.S (NPD Group, 2004). And, this trend shows no sign of slowing. Therefore, about half of all beef imports are lean (90% lean) beef trimmings used to blend with higher-fat domestic trimmings to produce typical 75%-85% lean ground beef for retail and food service.

The trend toward fewer dairy animals nationally (thus fewer “lean” culls cows), a smaller domestic cow herd and high-fat trimmings from fed animals create a shortfall in domestic lean trimmings. Adding to the lean trimmings shortfall is higher-value uses for chuck, plate, flank and other lean cuts that historically were destined for the grinder.

U.S. vs. The World

U.S. beef production systems vary a great deal geographically as ranchers and farmers have adapted to varying environmental conditions. But, overall, the U.S. has a highly differentiated beef production system compared to most other beef producing nations.
This difference can be summed up in one word – corn. The colossal feed grain resources granted by the U.S. Corn Belt shape the large majority of domestic beef production systems. Beef producers put this unique advantage to work in creating beef products that virtually no one else in the world enjoys. Even in Canada most grain finishing systems center on barley. But, while there are significant nutritional differences between feeding corn and barley to cattle in finishing diets, “barley fed” beef just doesn’t have the same ring to it inside and outside the beef sector as “corn fed” beef.

For a variety of environmental and socio-economic reasons, other cattle countries, mainly those in South America and Oceana are relegated to growing and finishing beef cattle primarily on forages – or grass. They simply don’t have the vast climactic resources and production infrastructure to support a massive corn industry. And, they don’t have the economic foundations that make raising corn for feed as feasible or practical.

It makes sense in developing countries as well as developed countries where corn resources are lacking, that corn (or food crops) for human use will be grown on the best land first. While people will, conceptually, get the corn first; if there is corn “left over” it’s most likely to be fed to the best “converters” first – poultry and pigs, in that order.

Then if there’s still corn available – and its feed value exceeds its value on cash markets – it can be used for “finishing” beef cattle. Few countries have the literal luxury of being able to turn corn protein into beef protein on a scale large enough to define an industry.

**Take a Virtual Tour**

A virtual tour of most other beef producing nations often includes Australia/New Zealand (Oceania), Brazil, Argentina and Uruguay. Of course these country’s beef systems are based mainly on grass finishing. In Australia, the beef cattle industry can be defined by three major factors:

- Relatively strong cattle prices, but hampered by persistent drought.
- Export demand boosted by the absence of competitors.

One can argue that Australia’s beef system is a hybrid of grass and grain. The cattle feeding sector grew three-fold from 1996 to 2006, reaching a capacity of 1 million head. The growth in the Australian feedlot sector is tied to increased export demand – particularly the Asian Rim countries of Japan and Korea. Nearly half of all Australian feedlot cattle are finished for export.

In Australia, feed grains are mainly grain sorghum, wheat and barley. This mix underscores the fact that Australia is a very arid country where persistent meteorological and hydrologic drought is a way of life. Lack of water impacts nearly every Australian to some degree might be the leading factor in restricting growth of many major industries nationwide.

While water is a limiting factor for long term growth in Australia’s cattle industry, Food and Agriculture Organization of the United Nations statistics indicate that grazing land is limited and under pressure throughout Oceania. The good pasture land is being converted into cropland, leaving increasingly poorer land for grazing and farming.

Moving across the globe to Brazil, anecdotally, 180-200 million acres of land could be developed for grazing systems. But, much of this vast land resource lies in remote sub-tropical scrub and brush land in need of clearing, seeding to adapted forages, watering and fencing. And, as Brazil’s comparative advantage globally lays in low-cost grass-fed beef
production, expansion into the frontier regions means distance from terminal markets and packing/processing facilities. It also means infrastructure must follow.

Of course, the limiting competitive factor throughout South America is the existence of foot-and-mouth disease (FMD). Uruguay (12 million head) is the continent’s only major beef producing nation that enjoys a FMD-free (with vaccination) status. Brazil and Argentina have fallen victim to recurring FMD outbreaks and continue to be shut out of North American and most Asian fresh beef markets. Most observers feel until the disease is controlled continent-wide, Brazil and Argentina will struggle to totally overcome the FMD threat.

The growth in Brazil’s beef herd is slowing, driven by skyrocketing world grain prices and ethanol energy demand, enormous tracts of cattle pasture in the South and Central regions of the country are being converted to crop production at warp speed.

As a result, cattle herds are being driven north and northeast from the traditional beef states of São Paulo and Paranã where farmers can make more money with a plow than with a cow. As this shift continues Brazilian ranchers become more reliant on the Nelore breed. The result is diminished prospects for grain finishing and intensive cross-breeding as herds move deeper into the tropical regions. In those regions, transportation, energy and processing infrastructure has been slow to maintain pace with the expansion of the cattle industry. Compare it to the post-Civil War expansion of the U.S. cattle industry into the U.S. West.

A similar crop/livestock land-use tug-of-war exists in Argentina. But unlike in Brazil, government policies have worked to stifle Argentina’s position in global beef trade. In 2005 the Argentine government initiated a series of economic reforms designed to provide domestic consumers food at reasonable prices by first implementing measures to discourage beef exports.

The government has since set maximum feeder and slaughter cattle prices and minimum cattle slaughter weights. Then, adding to the chagrin of beef producers, it capped wholesale and retail beef prices for a dozen of the more popular beef cuts.

Consequently today, growing cash crops such as soybeans and corn is more profitable in the Pampas than raising livestock. Interestingly, 10 years ago grain finishing in Argentina was seldom mentioned in the same breath as beef. Today, the feeding picture is changing. To maintain beef production on less land – and poorer land – many cattle farmers are using corn and other feeds under “hybridized” fattening systems for two or three months before slaughter.

Argentina has a small but growing confined feedlot sector where about 100 facilities supply 300,000 of the country’s 13 million slaughter cattle annually. Cactus Argentina, a 25,000-head feedlot in Villa Mercedes – a joint venture with Cactus Feeders, Tyson Foods and a local company – is Argentina’s largest feedlot.

Cattle feeders are currently compensated by the government for feed corn purchases – as long as the beef they produce does not go into export channels. Ranchers finishing on corn under the hybrid systems are not eligible for the compensation.

In Uruguay, beef exports from its English-based breeds are the name of game. A majority (80%) of Uruguay’s beef production is exported – with about 78% of that going to North America. Like Brazil and Argentina, anabolics and growth hormones are banned and animal protein banned in feed.

Like Brazil and Argentina, Uruguay does not have a significant grain-based cattle feeding industry. And, in these countries where cost-of-production is a comparative advantage, added costs associated with concentrated feeding quickly erode this advantage.
Traceability and Trust

Common to each of the countries discussed is that each has a working or work-in-progress national cattle ID and traceability system.

Australia is a world leader in cattle ID with its National Livestock Identification Scheme (NLIS). Australia exports approximately 70% of livestock production and while not all producers there like the system, they agree that whole-of-life traceability systems for livestock are necessary to maintaining a competitive advantage in a growing export markets.

In October 2005 Brazil’s traceability system helped contain an FMD outbreak to a few local regions in three states. Uruguay boasts that its traceability system tied to a national brand image that helps consumers globally identify Uruguay as “clean” and environmentally “green” source of beef products.

On December 19 the European Commission (EC) informed the Brazilian government of restrictions placed on exports of Brazilian bovine meat to EC countries, on the basis of alleged failings in the Brazilian system for animal tracing (SISBOV). Based on previous inspection missions, the EC decision stated that by Jan. 31, 2008 the Ministry of Agriculture, Livestock and Supply must, as a provisional measure, present a list of farms whose herds could be sent to slaughterhouses authorized for export. Traceability is being demanded to prove that Brazilian animals slaughtered for export to the EU are from regions that are free from FMD, and whose facilities comply with EU SPS standards.

In 2006, during the World Meat Congress, Brisbane, Australia cattle traceability was summoned up in two short sentences by Marcos Fava Neves, University of São Paulo (Brazil) professor of food marketing strategy. “Traceability is the non-negotiable foundation of trust,” he said. “Without traceability how can you be held accountable for what you produce? How else can you be rewarded for what you produce?”

In Canada, a national mandatory livestock traceability program was fully implemented on July 1, 2002. Canadians claim world leadership in animal identification and traceability, guided by national standards. Operating under the regulations within the Federal Health of Animals Act, the Canadian Cattle Identification Agency, in partnership with the Canadian Food Inspection Agency, has achieved 99-100% compliance nationally (Stitt, 2008).

The Canadian system incorporates the three key pillars for traceability: Animal Identification, Premises Identification and Animal Movement. Additionally, it offers value-added services, as required by industry. Age verification is one example of a value-added service assisting in assuring market access.

Defining “Quality” Beef

All too often the term “quality beef” is used within the industry very loosely and rhetorically. It makes us feel good to proclaim that U.S. beef is the highest quality in the world. But, to be fair to everyone we need to ask ourselves what this term really means – and, put the term quality beef” into perspective.

So, what is “quality” beef? I once asked a college class if someone could define “quality beef.” A sleepy male voice in the back row answered, “It depends on the cook.” What a great definition!

Quality beef consistently satisfies customer expectations for eating and preparation characteristics. These expectations may include tenderness, flavor, juiciness, color and
leaness. The definition also can include type of packaging, ease of preparation and, of course, price. This definition, though, is very subjective and can be fluid. Different consumers have different tastes and preferences. Brazilian beef eaters generally prefer their ultra low-fat grass fed over higher-fat U.S. corn fed beef. They say our leaner beef lacks taste and texture.

On the other hand, U.S. beef eaters visiting Brazil often claim that country’s beef is tough with a strong beef flavor. Most Brazilian beef must be slow-roasted, sliced and served very thin. A one-inch steak from a typical Brazilian steer would require far more jaw-force than most of us possess.

Domestic consumer expectations also vary as prices vary for cuts, grades and styles of beef. A tour through any supermarket meat case will drive this point home.

Flavor is provided by compounds in intramuscular fat or marbling of beef muscle tissue, and varies with genetics, nutrition, health and several other factors. Juiciness is determined by the amounts of moisture and marbling in the muscle after it has been cooked. Tenderness is determined by the amount of connective tissue, the amount of marbling, and the activity of enzymes that breakdown muscle proteins after slaughter. Temperament, handling, castration, growth implants, and intramuscular injections all play a role in palatability.

Quality beef products are harvested and processed under strict government inspection systems that ensure it is safe, wholesome, and correctly labeled and packaged. The USDA Food Safety and Inspection Service (FSIS) is charged with the ultimate responsibility for protecting the U.S. meat supply. FSIS is also charged with making sure all imported beef is safe and wholesome. With this definition there’s virtually no wiggle room. While we are all aware breaches in beef safety do occur, by law there’s no tolerance with regard to the production of unsafe or unwholesome beef. It’s why we see recalls. Every meat processing facility – domestic and foreign – supplying beef to American consumers must follow an approved beef safety plan.

Often overlooked is the demand by regulators for proper labeling and documentation of beef products as they enter commerce. Meat inspectors are bound to get just as cranky when they see labeling errors as when they see obvious safety violations.

Quality beef can be identified through USDA’s official beef quality grading system. A Quality Grade (Prime Choice, Select, etc.) is a composite evaluation of factors that affect palatability of meat (tenderness, juiciness, and flavor). These factors include carcass maturity, firmness, texture, and color of lean, and the amount and distribution of marbling within the lean.

Beef quality grades are one of the main determinants in the value of a beef carcass. Two factors, marbling and maturity or age of the carcass, determine beef quality grades. Marbling is the intramuscular flecks of fat dispersed in the lean tissue. The degree of marbling is measured when a carcass is ribbed or split between the 12th and 13th ribs.

Improving beef quality and consistency begins with understanding the industry targets. These targets include the elimination of injection site blemishes and lesions, bruises, dark cutters, and liver condemnation to name a few.

A series of landmark studies called the National Beef Quality Audits (NBQA) have taken a closer look at the quality and consistency of production practices. The 1991 NBQA demonstrated that U.S. beef was too fat, too tough and too inconsistent to be competitive with pork and poultry in the marketplace. Significant progress has been made by all segments of the beef industry to improve the overall acceptance of beef carcasses that enter the fabrication
sections of our processing facilities. But, the 2005 NBQA suggests there is still work to be done.

To improve quality and consistency, it is necessary to receive feedback on the performance of cattle that leave the ranch. Getting and using this information as a basis for setting goals to increase performance is often difficult, but certainly not impossible in today’s beef production world.

The 2005 NBQA concluded a 19.2% occurrence of average and high Choice, and only 2.9% Prime beef. The majority of carcasses range between Select (36.7%) and low Choice (35%), with only slight or small amounts of marbling. The true challenge for the U.S. beef industry in producing quality beef lies in eliminating the 6.2% of Standard carcasses that more often lead to an unsatisfactory eating experience.

**Global Export Outlook**

One of the big stories of the past decade has been the shift of the European Union (EU) from a net exporter of beef to a net importer of beef. All expectations are that beef production will continue to drop in the EU and the need for imports will continue to rise. Historically, Brazil and Argentina are the leading suppliers of beef to the EU. Currently, two-thirds of the beef supplied to the EU arrives from Brazil (200,000 metric tons annually).

So, why doesn’t the U.S. export more beef to the EU? The main reason for limited exports to the EU from the U.S. is that a vast majority of U.S. beef is still produced with the use of growth promotants. Even if the U.S. was to win the debate over this with WTO and even if the EU was forced to open its border to beef from cattle treated with hormones, “you wouldn’t be able to sell it (Brook, 2008).” From surveys conducted, 68-82% of consumers in the UK, Germany, Italy, Spain, and the Netherlands would not purchase beef produced under hormone treatment if it was in the meat case.

In addition, U.S. beef is still too expensive compared to other origins, such as South America; there are not enough cattle in the Non-Hormone Treated Cattle (NHTC) system; and there are not enough plants approved to ship product to the EU. Despite these challenges, exports to the EU doubled from 2006 to 2007 and are projected to double again in 2008.

There are several key drivers for a resumption of pre-BSE U.S. meat exports to Asia Haggard, 2008). These include the political situation, economic variables, domestic production, market access, consumer trends and competitor developments. These drives appear to be the basis for the four major themes that impacted beef marketing in the Asia Pacific in 2007 and will continue to impact the market in 2008.

The first major theme is that the U.S. has been subject to continued industry losses associated with access constraints, especially from Korea and Japan. This partial market access has reduced sales to 60% of the capacity that was seen before the BSE case was identified in Washington in 2003, this is equivalent to $50 million in sales per week lost.

Additional themes relate to: 1) solid regional macro fundamentals and a weak U.S. dollar; 2) the growing market potential in China, and; 3) new demand points as a result of new markets in, for example, Vietnam and Macau. Currently, the cuts exported to Asia seem to vary by country. Irrelevant of country, the Asia Pacific region trends towards a preference for marbling equivalent to USDA Choice or higher product.

In Mexico, beef production, although increasing in terms of pounds, still leaves a shortfall relative to consumption. This gap between production and consumption resulted in
nearly 270 million kg of beef imports in 2006. Of the 270 million kg, the U.S. was responsible for sending over 223 million kg of beef to Mexico, not including the 160,000 metric tons of beef variety meats (Recio, 2008).

With an increase in population expected, the projected beef demand in 2025 in Mexico will be 1.95 million metric tons, an increase of over 390,000 metric tons over production in 2005 (if per capita consumption decreases to 15 kg). So, where is the 390,000 metric tons going to come from to suffice the Mexican population?

Mexico will produce some of this difference with an increase in efficiency and by growing production approximately 1.25%. However, this still leaves a gap and there are challenges for Mexico. Challenges include high U.S. calf prices, a high percentage of cattle in the hands of small producers, high relative cost of grain, and the U.S. cutout value for USDA Select carcasses is lower than local carcass price.

A new player to beef imports into Mexico in 2007 was Uruguay. However, while Uruguay increases, New Zealand and Australia exports to Mexico will decrease because of price competitiveness and duties paid for Australian products.

**Challenges and Advantages**

As U.S. beef producers address the growing global competition – for markets here and abroad – they face some “good news-bad news” scenarios with some “caution” signals. The *good news* items include:

- Globally unique grain fed beef production. U.S. beef producers are increasing their attention to establishing and exceeding benchmarks for production of safe and wholesome beef that increasingly satisfies consumer expectations for eating characteristics.
- World’s leading infrastructure. No nation can match the private/public sector investment into programs and facilities that provide a foundation for beef production systems. U.S. producers are the envy of the world when it comes to transportation, storage and transfer, government production support and, historically, energy prices.
- Per cow productivity. Related to infrastructure, U.S. producers, along with their Canadian counterparts, yield more beef per cow than producers virtually anywhere else in the world.

The *bad news* items include:

- Lack of organized traceability. The U.S., especially now that the federal government has pulled the plug on support for a national ID system, is the only major beef exporting nation without organized traceability for disease management. That said, private market-driven ID systems are evolving – allowing producers to participate in domestic and global supply chains.
- A “global” outlook. For decades the U.S. beef industry has been focused on the huge domestic market potential – fighting for market share against the poultry industry. The USMEF has been the Lone Ranger in beef export development – with little attention and relatively little assistance from beef producers and processors.
- Competition for land and water. Nearly every U.S. beef producer is troubled by increasing land prices and lack of water. U.S. producers are not alone in this dilemma though, competition for the better land by higher-return industrial, recreational and urban use is ringing a global agricultural alarm.
The caution signs include:
- Increasing cost of production. Energy prices, feed and forage prices and prices for fossil-energy inputs lead the list. Machinery and equipment parts and repair follow.
- Uniformity and consistency of product. The 2005 National Beef Quality Audit identifies consistency of product as a continuing concern. Consumers simply want every steak to eat the same every time. This is a huge challenge for producers and processors alike.
- Animal welfare issues were raised to a new level with the recent “downer” debacle in Chino, CA. Producers have a responsibility and commitment to send healthy animals to processors. Those processors in turn have a responsibility to provide adequate employee supervision to insure that animals are treated properly and humanely.

Addressing the Challenges

In order to maintain a comparative/competitive advantage and address the challenges ahead, it’s suggested that beef producers nationwide consider the following:
1) Become Beef Quality Assurance (BQA) certified. Participation in the BQA is totally voluntary – and it is not a “government” program. BQA links beef producers with livestock production specialists, veterinarians, nutritionists, marketers, animal health companies and food purveyors interested in maintaining and improving the quality of cattle and the beef produced in the U.S.
2) Carefully measure/monitor input and output. This means keeping better records and spending time in developing cost-benefit analysis for every production enterprise. A part of BQA, verification of production practices through auditable records will soon become a necessity.
3) Evaluate your genetic package. Certain supply chains are already mandating adherence to specific genetic systems. Attention to beef cattle genetics selection and management will become even more critical than in the past as “program” beef production increases and replaces commodity beef production.
4) Maintain a sound herd health program. “Management over medicine” will become more critical as our ability to use pharmaceutical products comes under increasing scrutiny. U.S. beef producers must work with their veterinarians to learn more about disease management and reducing treatment for disease. Biosecurity programs, including judicious vaccination for disease, must become a way of life on U.S. cattle operations.
5) Evaluate your pre-weaning/weaning protocol. This is probably the easiest way to manage weather-related variables as well as address marketing opportunities. Traditional weaning programs should be carefully and continually evaluated.
6) Establish source/age verification. This does not have to be high-tech or costly. Work with your local sale barn, order buyer or join a program or alliance to learn more. But, don’t expect market “premiums” to last forever – this niche will become the norm.
7) Continually seek better market opportunities. Think “supply chain” management. Don’t think you’re simply a rancher who turns grass into feeder cattle – manage for the end product and continually demand that your efforts be recognized and rewarded.
In the words of Dr. Gary Smith, meats scientist, Colorado State University, “In today’s world, if you’re producing a commodity product, you’d better expect to receive a commodity price.”

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Random Ruminations and Implications of Feeding Distiller’s Co-products

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Compared with the closely coordinated, complex choreography consistent with ruminal fermentation, non-ruminant animals should be considered subordinate and truly deserve the title of “sub-ruminants”. Among the animals that serve mankind, herbivores including ruminants are customized to harvest, consume, digest, and utilize protein and energy from forages and feeds not directly used by humans due to inaccessibility of forages or the high fiber or water content of feeds. In addition to grazed forages, fibrous byproducts of cereal production or processing and surplus quantities of concentrates readily serve as the dietary fuel for ruminant production. Ruminal microbes upgrade low quality protein sources and non-protein nitrogen to the well balanced, complete proteins found in ruminant food products prized worldwide by humans. Except during the short period when ruminants are fed concentrate feeds, feedlot ruminants do not compete directly with humans for dietary sources of energy or protein; instead, they efficiently convert materials of limited commercial value, often with high potential for environmental pollution, into quality foods desired by both omnivores and carnivores.

Relative to some non-ruminants (poultry, swine, and fish), ruminants often are criticized for their low efficiency of conversion of gross energy or dietary protein into products for human consumption. Yet, ruminants are quite efficient relative to most animals on earth, i.e., humans on a diet and pets including pleasure horses and goldfish, particularly when efficiency is calculated on the basis of non-competitive foods, those foods and feeds not readily harvested, consumed or digested by humans. Therein, ruminants exhibit a marked advantage over other food-producing animals. However, the reasons behind the inefficiencies in use of both protein and energy by ruminants deserve consideration in the hope that efficiency can be improved. Like administrative overhead and indirect costs entailed by research at public and governmental institutions, ruminants have large overhead and indirect expenses that should be minimized in order to maximize return on investments. The magnitude of these costs in terms of metabolic efficiency must be balanced carefully against the need to minimize risks from digestive and metabolic disorders. The objective of this review is to examine specific energetic and environmental inefficiencies of digestion and metabolism of ruminants, discuss concepts that may deserve increased research attention, and to explore nutritional limitations of by-products of ethanol production for feedlot cattle.

Large body size of ruminants – A Mixed Blessing

Specially equipped to retain feeds within their digestive tract to allow microbes a sufficiently long time to ferment cell wall components of forages, all herbivores support and maintain a huge, metabolically active digestive tract and organ mass relative to herbivores and carnivores. Maintaining this mass and providing culture conditions for cellulose-digesting microbes while avoiding metabolic disorders markedly increases the maintenance energy cost for ruminants. Besides expansions in mass of the rapid turnover organs involved with digestion (for masticating and ruminating feeds, for churning digesta, for neutralization and absorption of fermentation products, and for maintaining continuous flow of digesta and
removal of gaseous, liquid, and solid wastes), ruminants are well equipped to withstand environmental challenges, for locomotion necessary for crop harvest, and for nutrient storage or secretion. When summed, these physiological modifications add greatly to the maintenance energy cost for ruminants. Although basal metabolic rate (BMR) per unit of metabolic size ($W^{0.75}$) is quite similar for ruminants and non-ruminants, that index of metabolism is measured when animals are fasted and not productive. The difference in energy expenditure between a) basal metabolic rate and b) energy requirements of maintenance, primarily those associated with digestive metabolism, is much greater for ruminants than for non-ruminants. And energetic inefficiencies of ruminants expand further when ruminants are fed to attain high rates of production due to reduced digestibility of coarse diet components.

**Puzzling observations**  Basal metabolic rate usually is considered to be proportional to body surface area or metabolic size. But rather than a function of surface area or weight alone, the minimum energy expenditure of animals more logically should be proportional to activity of mitochondria providing energy for necessary muscular activity, for tissue turnover, and replacement of tissues inevitably lost. Because mitochondrial activity is greater for muscle than depot fat, leaner animals should have a higher BMR and maintenance requirement than fatter animals. Consequently, BMR and maintenance requirements should consider body composition, not merely metabolic size.

The low reproductive rate of ruminants results in a very high energy cost for maternal maintenance and replacement. Though potentially stressful for cows, nutritional or hormonal modification to reduce cow size while maximizing sire size and muscling should improve overall production efficiency. Rather than concentrating simply on “growth stimulants” for cattle, “growth retardants” should be sought to reduce beef cow size and herd maintenance costs.

For lactating dairy cows, current formulas to calculate the net energy values of feeds (NRC, 2001) include adjustments both for level of feed intake (multiples of maintenance) and for feed processing. Granted, feed intake proportionally are lower for feedlot cattle than for lactating cows and most feedlot cattle are fed processed grains where starch is digested extremely well. Yet, digestibility depressions associated with elevated feed intakes likely are associated with dietary NDF and grain processing that is readily apparent as the negative associative effects of feeds. Most published values for energy availability of diets for beef cattle (NRC, 1996) were derived from TDN measurements where feed intake was limited and, with forages and roughages, where NDF concentration of the diet was high; thus, values may not apply directly to feedlot cattle with high intakes of diets low in roughage content. Trials are needed to examine effects of intake level of feedlot cattle on 1) rate of passage from the rumen, 2) ruminal pH, 3) responses to differences in feed composition (hemicellulose vs. cellulose), and 4) the time lag before digestion begins (perhaps being related to rate of water uptake by feed) and examine how each influences site of digestion and total tract energy digestibility. Indeed, diet digestibility by feedlot cattle when measured directly often falls considerably below the values calculated from feed ingredient tables. Deeper knowledge of these effects should enhance the precision of predicting, explaining, and minimizing negative associative effects. Such information also should improve the accuracy of predicting net energy values of feeds, particularly if net energy values for beef cattle feeds in the future are to be predicted from nutrient composition as currently is the case for dairy cattle feeds. One novel measure of feed efficiency, residual feed intake, being used to appraise and select cattle
lines for improved efficiency, typically favors cattle with low feed intakes. This may be due partially to the depression in digestibility associated with high feed intakes. To assess differences among animals in efficiency of use of ME rather than GE (or feed dry matter), this digestibility depression should be considered. Otherwise, long term selection may result in such low feed intakes that feedlot performance is depressed. Indeed, digestibility benefits from low intakes may not apply under feedlot conditions where grain is extensively processed.

Unfortunately, productive efficiency cannot be based on digestibility estimates alone due to other metabolic losses associated with digestion (e.g., methane, urine, heat) and tissue metabolism (heat). Although such inefficiencies are considered within the net energy (NE) system, certain factors related to NE relationships need further refinement (e.g., ME adjustment for levels of feed and roughage intake and roughage source; feedlot-verified equations that relate NEg intake more precisely to retained energy). Although direct measurements of retained energy through serial slaughter procedures are extremely complex, NE values for diets can be calculated readily from feedlot performance data if measurements (feed intake and animal performance) accurately predict energy retention. Past summaries of University trials with small feedlot pens relating NEg supply to performance of cattle based on current NE equations detected a bias related to animal weight (Owens et al., 1997), so updating the current NE formula that predict energy retention from cattle weight and rate of gain appears justified. Re-evaluation of the accuracy of current equations to relate NEg intake to performance based on close-out records from over 15,000 pens of commercial feedlot cattle currently is underway (R. A. Zinn, personal communication).

Ruminal metabolism: Physical constraints – One way traffic

The active reticulo-rumen represents a fermentation vat with semi-continuous input of solids and liquids and continuous output. The sheer volume of digesta combined with frequent meals of feedlot cattle and recycling of nutrients to the rumen makes one question the relevance of the concept of synchronizing the nutrient supply to improve efficiency of ruminant production. Experiments with batch cultures, particularly with ruminal liquor obtained from animals not adapted to feeds being tested, are unlikely to yield applicable digestibility estimates and realistically predict responses to improved synchrony. Unlike a fermentation vessel with a fixed size that is continuously full, volume of ruminal contents is not constant but can vary by 50% within a day (DelCurto et al., 1990; Gasa et al., 1991); volume also can adapt over time. Besides consumed feed and water, large amounts of saliva are added during a meal and during rumination. Depending on osmolality of ruminal contents, fluids will diffuse between ruminal contents and the blood stream. Typically measured with undigested, non-absorbed soluble marker compounds, ruminal liquid outflow normally is calculated from dilution of this marker within the rumen and is expressed as a fractional dilution rate (percent or fraction per hour) that typically ranges from 6% to 15%. An expansion of ruminal contents or an increased outflow rate will have similar effects on the calculated dilution rate! Consequently, evacuation of ruminal contents with a ‘Shop-Vac’ (preferably not subsequently used for cleaning one’s house or garage) provides a more robust index of volume and outflow rate. However, disturbing ruminal contents also has physiological consequences; the day following ruminal evacuation, water intake typically is doubled! Dilution or outflow rate of ruminal liquid depends primarily on two factors: fluid
input (saliva and imbibed water) and rumen volume; diurnal changes in ruminal rumen presumably reflect temporally controlled changes in outflow rate. Outflow of solids from the rumen represents flushing of undigested products in a fashion paralleling that of Thomas (aka John) Crapper’s marvelous invention. Though very large particles may be retained in the rumen due to screening at the reticulo-omasal orifice, appearance of whole corn particles in feces indicates that omasal screening is neither complete nor efficient. Instead, all particles suspended within flushed fluid appear to pass from the rumen; hence, particle separation is largely dependent on flotation of large, fibrous particles and formation of a ruminal mat. The concept that forage particles with greater potential digestibility are preferentially retained within the rumen further complicates estimates of outflow rate and extent of digestion of particles.

Ruminal output includes not only the undigested products that are flushed from the rumen, but volatile fatty acids absorbed through the ruminal wall in exchange for blood bicarbonate. Continuous muscular activities that involve churning and mixing of ruminal contents are coordinated precisely with eructation reflexes for removal of fermentation gases.

**Puzzling Observations**  With forage-based diets, bulk fill of the rumen (or rate of removal of undigested components from the rumen) appears to be the primary bottleneck to energy intake and production. Indeed, with cattle fed low quality winter-harvested forage, locating any free fluid within the rumen to sample often proves impossible; this suggests that fluid outflow with low quality roughages is insufficient to remove undigested feed components. Surprisingly, at the onset of lactation, forage intakes increase. Might that response be due simply to increased fluid (milk) secretion that causes fluid intake to increase? Might rumination time be limited by high blood osmolality that reduces production of saliva? How much of the intake response to supplemental dietary protein or urea can be attributed to increased urine excretion that in turn increases intake of water and ruminal outflow rate? Water consumption appears to be regulated with a surprising degree of accuracy. In one trial where we placed 4 kg of water in the rumen daily, the amount of water these steers drank was decreased between 3.9 and 4.1 kg! In contrast, supplementing the diet with salt or protein may increase water intake markedly. Rate of particle passage from the rumen increases when intakes of NDF and of DM are increased, probably due to increased intake of water and increased saliva production. Increasing passage of digestible nutrients, like starch from flaked or high moisture grain, should improve energetic efficiency by reducing heat and methane losses associated with ruminal fermentation, but if feed components flushed to the small intestine are not well digested, increased bypass is a losing proposition. Nevertheless, in some cases, as with grinding alfalfa hay, the brown midrib trait in forages, and ammoniation of wheat straw, efficiency of feed use may increase even when digestibility is decreased if intake of feed overcompensates so that intake of digestible nutrients is increased.

The relationship of water intake to acidosis deserves deeper study, both from the standpoint of dilution ruminal acids and potential effects on ruminal mixing and outflow of fermentable carbohydrate. When cattle are switched from roughage- to concentrate-based diets, water balance and ruminal and blood osmolality change markedly. A decrease in water intake not only decreases dilution of ruminal acids, but also lengthens the time period that small concentrate particles remain in the rumen to be fermented. Perhaps substances like slaframine (Froetchel et al., 1989) that stimulate saliva flow, feed additives that absorb fluid (e.g., sodium polyacrylate, “super slurper”), or compounds that alter blood osmolality or urine output (e.g., ammonium salts) to help maintain water intake could reduce the incidence of
acidosis during the adaptation period. Management to assure that feedlot cattle have free and easy access to a supply of clean water, particularly immediately after a meal, may be as useful to reduce metabolic problems as to maintain high feed intakes. In one trial where we fed steers manually every 2 hours throughout the night, my grad students and I in the barn were quite surprised to be kept awake for nearly an hour after each meal as steers drank substantial amounts of water following each meal. So timing of water access and availability relative to feeding also may be important.

With high concentrate diets, what limits ruminal outflow rate? Studies several decades ago from Russia indicated that despite wide fluctuations in other nutrients, protein content of duodenal digesta was surprisingly constant; this observation was confirmed by Zinn (personal communication). Such control seems evolutionarily meritorious. It seems desirable to retarding ruminal outflow to increase the extent of digestion of low quality, high fiber diets, but with high quality, high protein diets, higher passage will permit forage intake to increase to aid in survival and competitiveness. Might the stimulation in feed intake often seen with higher protein levels be due simply to faster ruminal clearance of dry matter?

The omasum also appears to play some role in feed intake control based on trials where cottonseed hulls were fed. Intakes with diets based on cottonseed hulls appear unusually high. Indeed, with cottonseed hulls fed alone, feed intakes by steers over 5% of body weight daily have been observed. At harvest, steers fed concentrate diets supplemented with cottonseed hulls often have omasa stuffed full of hulls. The omasum generally is considered to be a primary site of water and VFA absorption. Perhaps packing the omasum alleviates a physical bottleneck or a reduction in VFA absorption from the omasum reduces feedback inhibition of ruminal contractions. Similarly, feedback controls might be expected from the large intestine that will repress digesta passage rate when energy supply to the large intestine is high.

Mathematical models designed to simulate ruminal fermentation and digestion used widely for diet formulation are based on two assumptions that seem questionable: first, that ruminal volume (pool size) is constant and second, that all material entering the rumen mixes with ruminal contents and is subject to a specific calculated passage rate derived for either liquids, forage particles, or concentrate particles. Examination of ruminal contents reveals both horizontal (rumen mat) stratification as well as vertical stratification associated with distance from the cardia where material is high in water content. As with esophageal groove closure, this physical arrangement allows fluids and small particles to sluice through the rumen without fully mixing with rumen contents. With steers given free choice access to forage, abomasal fluid will contain components of a protein supplement within minutes after that protein supplement is fed. Consequently, physical factors that alter particle and liquid distribution within the rumen can markedly alter ruminal retention time.

**Carbohydrate Fermentation – Carb-Loading Ruminants**

Ruminants are produced to utilize resources economically simply because humans place greater value on ruminant products than on the feeds and forages that are fed. The greatest worldwide threat to ruminant production is OPEC. High cost of fossil fuels, exacerbated by federal mandates and programs, have had a trickle down (or a deluge) effect on the cost and availability of energy sources for ruminants. Efficient bioconversion of grains and harvested cellulosic products directly into fuels (ethanol, methane) and direct combustion
of cellulose byproducts to generate electricity are further threats to the sustainability of ruminant production; these factors place increased emphasis on capacity of ruminants to harvest forages and to digest fibrous feeds and byproducts.

The primary loss of energy with both high concentrate and high roughage diets is energy lost in feces. Extent of digestion of grains and forages can be limited by time for digestion and fermentation (primarily with forages), by enzyme activity, or by accessibility of feed components for microbial or enzyme attack; accessibility is the most frequent limitation for digestion of forage and incompletely processed grains. Resistance to fluid uptake, particularly with vitreous endosperm grains and physical barriers (cell walls) of forages are the two major factors that restrict access. Well equipped to ferment accessible hemicellulose and cellulose fractions of plant cell walls, ruminal microbes also rapidly ferment cell contents. Rapid fermentation of cell contents places ruminants at risk of metabolic disorders including bloat, acidosis, ruminal and liver abscesses, and laminitis. Management and feed additives have assisted ruminants to meet these challenges but not without some cost in terms of productive capacity.

During conversion of dietary carbohydrates to volatile fatty acids within the rumen, the microbial mass generally is considered the primary product; byproducts include volatile fatty acids that are used by the host animal, heat that can be either useful or costly as a byproduct, and methane, a waste byproduct. Within the primary product, ruminal bacteria, stored lipids and polysaccharides become useful as energy sources for the host ruminant, microbial protein and vitamins potentially also can prove useful, but nucleic acids are wasted. Although practices that reduce the yield of useless microbial byproducts theoretically should improve efficiency of ruminant production, potential detriments of inhibiting specific metabolic steps also must be considered.

To obtain energy for growth, anaerobic ruminal microbes hydrolyze carbohydrates (primarily starch, hemicellulose, cellulose, pectin) to hexoses and pentoses and catabolize these sugars to form volatile fatty acids, acetate, propionate, and butyrate. Under ideal conditions, nearly 30% of the dry weight of substrate is converted to microbial mass. The remaining 70% becomes volatile fatty acids, methane, and carbon dioxide. Energy from substrates not incorporated into ruminal microbes is released as heat.

**Puzzling observations** When fed concentrate diets, the population of starch-fermenting bacteria in the rumen increases but, surprisingly, the total population of cellulose-fermenting bacteria does not decrease even though its proportion of total bacteria decreases. Why do cellulose-fermenting bacteria remain present and what are they fermenting?

Most ruminal protozoa might be considered micro-ruminants, harvesting and digesting ruminal bacteria and feed particles. Protozoal populations fluctuate wildly with time after a meal; where do they go? Populations generally are greatest with high roughage diets where a floating raft provides a haven against washout from the rumen. Therefore, the contribution of protozoa to the supply of protein and energy appears nil. Do protozoa wear a white or black hat? How would reduction in the population of protozoa, possible with certain fatty acids (from supplemental plant oils and myristic acid), detergents, precipitating agents (possibly fructose) and chemicals alter feedlot performance and health? Or would an increase in the protozoal population, possible through supplementing with sulfur-containing amino acids, prove useful at certain stages of production. Like miniature ice-breakers, protozoa aid in physical disruption of feed particles enhancing access for fermenting bacteria and increasing extent of NDF digestion. And by consuming small starch particles, protozoa attenuate the
rate of starch fermentation to reduce the potential for acidosis. High populations of protozoa generally are associated with higher ruminal ammonia concentrations and increased methane production; this suggests that protozoa themselves or associated bacteria actively degrade dietary proteins and are methanogenic. In addition, protozoa survive by consuming and digesting bacteria and small feed particles. By increasing bacterial turnover rather, harvest of bacteria increases the bacterial turnover rate and efficiency of bacterial growth. But digestion of bacteria by protozoa decreases ruminal protein yield and efficiency. Based on this reasoning, protozoa might prove useful for younger, growing cattle starting in the feedlot but undesirable later during finishing; to date few studies have explored potential benefits from manipulating the protozoal population.

All fiber in plants classified as neutral detergent fiber (NDF) is not the same. With intact cell walls, chemical linkages and proximity of hemicellulose with cellulose and lignin inhibit access to and fermentation of hemicellulose. But is digestion of hemicellulose limited by a low pH that reduces activity of cellulose fermenting bacteria? Digestion of the individual components of NDF from various roughages processed by different methods under varied ruminal incubation conditions should help pinpoint when specific roughages are best utilized. The ideal roughage moisture, level, composition, and particle size appears to vary with the grain processing method. If capacity of roughage to stimulate rumination and prevent acidosis is of primary concern, one should monitor rumination frequency; if reduction of particle separation of the diet either in the truck or the bunk is of concern, physical tests can be used to measure the separation of fine particles could be used. Greater reliance on animal observations and physical measurements rather than chemical assays alone should improve our ability to determine the optimal levels and sources of dietary roughage in feedlot diets.

Ruminal microbes – The good, the bad, and the ugly

Like all living species, microbes expend energy for maintenance; this reduces the amount of energy available for growth. Consequently, harvesting microbes more rapidly increases the efficiency that available energy is used for growth. Increasing the bacterial dilution rate increases the efficiency with which fermented organic matter is converted into microbial protein. However, if an increased ruminal dilution rate for feed particles substantially reduces the amount of organic matter available to ferment, total yield of microbial protein can decrease. This illustrates how efficiency of microbial protein production must not be confused with total yield of microbial protein. In addition to using available energy for growth, ruminal microbes have been reported to spin off excess energy when certain nutrients like ammonia are deficient. Indeed, when supply of glucose is in excess relative to ammonia, certain ruminal bacteria produce compounds (e.g., lactic acid, methylglyoxal) that prove toxic for most bacterial species in the rumen. Indeed, methylglyoxal presence in ruminal fluid appears to reflect a deficiency of ruminal ammonia (Lodge-Ivey et al., 2004). Although microbially synthesized and stored carbohydrate can prove useful post-ruminally for the host animal, carbohydrate storage by microbes represents an inefficient process energetically, potentially using one-third to one-half of the its available energy simply for storage! So again, carbohydrate accumulation within ruminal microbes may an inefficiency related to specific nutrient deficiencies. Ruminal microbes also have been reported to spin off excess energy, perhaps through the use of futile cycles similar to that used for fatty acid oxidation by brown fat of newborn ruminants.
Puzzling observations  The impact of specific nutrient deficiencies on microbial composition and products deserves detailed attention. Indeed, production of harmful compounds (lactic acid; methylglyoxal) may reflect either high concentrations of free glucose within the rumen or specific nutrient deficiencies or stresses. Performance benefits observed with dietary urea concentrations far beyond those presumably required for microbial protein synthesis to meet needs for growing steers might reflect the prevention of localized ammonia deficiencies. Conversely, attempting to reduce N pollution by decreasing dietary protein concentrations may have adverse effects on efficiency and on animal health.

Despite wide acceptance of the concept of “energy spilling” by ruminal bacteria (Russell and Cook, 1995), this idea deserves further scrutiny. Why should ruminal microbes waste energy rather than use it productively for growth, except under conditions of nutrient deficiencies or external factors (e.g., effects of antibiotics, ionophores, bacteriocins, environmental stress)? The “energy spilling” concept conflicts with the basic tenet of “survival of the fittest.” Nevertheless, direct analysis of bacterial composition and of ruminal contents for compounds produced during periods of carbohydrate excess may serve useful as indices of specific nutrient deficiencies for ruminal bacteria.

The concept of inoculating ruminants with a “super bug” has been discussed for decades. To survive the cutthroat competition of the rumen, an inoculant would benefit from being able to catabolize some unused or underutilized substrate. With feedlot diets, such substrates would include cellulose or slowly digested fiber. To date, attempts to incorporate and express cellulose within acid-tolerant bacteria have not proven successful. However, ruminal inoculation with certain bacterial strains has increased hemicellulase activity within the rumen. Unfortunately, no benefits in hemicellulose digestibility were detected, perhaps because digestion was limited not by enzyme supply but instead by physical accessibility of hemicellulase. Direct diet addition of enzymes to digest hemicellulose (xylanases) and cellulose (cellulases), as reviewed by Beauchemin et al. (2003), occasionally has increased production by lactating cows (Tricarico et al., 2005), though activity of specific enzyme mixtures will vary with the feedstuff being tested. Because forage levels are lower and bulk fill is not likely to limit dry matter intake with feedlot diets, supplementation with fiber-digesting enzymes prove less effective with feedlot than dairy diets. Yet, ruminal digestion of NDF is quite low with feedlot diets, so the potential for increasing NDF digestion with exogenous enzymes tolerant of a low ruminal pH as suggested by Zinn and Salinas (1999) should not be overlooked. Supplementation of diets with amylase and other enzymes has been the topic of several recent patents, and certain beneficial “probiotics” produce amylase. Although most proteins and enzymes are rapidly degraded within the rumen, surprisingly long persistence of activity of fed enzymes in the rumen (Hristov et al., 1998) has led to speculation that some exogenous enzymes may affect unitization of nutrients in the small intestine. Increasing enzyme concentrations or activities may prove useful if enzyme concentration, not accessibility or wetability of feed components, limits the extent of digestion.

Predigesting forages with enzymes often has proven useful (Adesogan, 2005). For feeds that are stored moist prior to feeding, e.g., silage, time and moisture conditions should be ideal for enzyme action or bacterial growth (Kung, 2001). Hence, for stored moist feeds, direct addition of enzymes or of inoculants that produce specific enzymes has immense potential. However, simply pre-fermenting compounds that otherwise would be fermented within the rumen might prove deleterious by reducing the supply of energy available for
ruminal bacteria. Instead, bacteria or enzymes that attack the specific physical or chemical properties which resist ruminal digestion would be preferred. Linkages of specific interest are those that inhibit accessibility of compounds, e.g., prolamines, cell walls, or lignin. Bacterial strains isolated from silage with capacity to hydrolyze certain linkages within lignin (Nsereko et al., 2007) when used as silage inoculants have increased NDF digestibility by ruminants. A corn silage inoculant containing such bacterial strains that produce ferulate esterase currently is being marketed. Numerous field reports have detected increased feed intake and milk production by lactating cows fed corn silage produced with this inoculant, and several studies at universities have detected increased in situ NDF digestibility with silage produced from several different corn hybrids. Whether similar digestibility responses would be noted with high moisture ensiled cereal grains is not yet known, but products that enhance NDF digestibility certainly should prove useful with feedlot diets containing well processed grains because the primary undigested feed component with such diets is fiber.

**Methane production – The Silent Belch**

Two byproducts of microbial fermentation, methane and heat, represent sizeable energy losses; being a greenhouse gas, methane presents an additional environmental risk of considerable interest to governmental agencies. With anaerobic ruminal fermentation, an average of 6% of gross energy fermented is lost as methane and an additional 2% is lost as heat. Further heat is produced when oxygen enters the rumen with food or by diffusion through the ruminal wall allowing VFA to be catabolized to carbon dioxide.

Dietary and biotech approaches can reduce the amount of methane produced. Because the ratio of carbon to hydrogen in substrates must balance that of end-products, the ratio of carbon dioxide (with no loss of energy) to methane (with loss of energy) varies with the ratio of acetate and butyrate to propionate produced. This is because propionate is formed with no loss methane; all hydrogen is retained in the product. Consequently, procedures that increase the proportion of propionate increase retention of feed energy while simultaneously decreasing the quantity of methane produced. With extremely low ruminal dilution rates, as occurs with the sewage-type fermentation used for production of methane from livestock wastes, acetate is converted to methane and carbon dioxide. Within the rumen, such acetolysis results in complete loss of usable energy for the ruminant. Bioengineering the reverse reaction into ruminal microbes could prove as rewarding but also as challenging as development of hydrogen powered cars has been for the auto industry.

Increasing ruminal escape of digestible carbohydrate will preserve more of a carbohydrate’s energy for use by the ruminant. Additional techniques to reduce methane loss include 1) altering the microbial population by feeding ionophores or chemicals that to alter the propionate percentage, 2) feeding defaunating agents or myristic acid to selectively inhibit ruminal protozoa because protozoa usually are associated closely with methane generating bacteria, and 3) providing additional hydrogen sinks. Depending on the product employed, this third approach may or may not maintain energy for use by the animals. For example, feeding of compounds that trap energy as hydrogen through conversion of unsaturated to saturated fatty acids or conversion of malic to fumaric acid, reducing power is retained for the animal. Conversely, when hydrogen or reducing power is spun off as a gaseous or liquid waste, energy is lost even though methane production would be reduced. Substrates for reducing methane loss include nitrate (reduced to nitrite and ammonia), sulfate (reduced to
hydrogen sulfide), and specific brominated or chlorinated hydrocarbons that prevent methane production but instead result in release of the explosive gas hydrogen. Such by-products may be no more eco-friendly than methane which, if trapped, could be used as fuel.

**Puzzling observations** Relative to other sources of energy loss, methane reduction should be of prime nutritional and environmental interest. Effectiveness of certain ionophores to increase the propionate to acetate ratio of ruminal contents illustrates this response though some concerns have been raised about the persistency of the reduction in methane production by ionophores. Certainly, benefits from altering this ratio and decreasing methane loss will be greatest when the propionate proportion is low (e.g., with diets rich in forage and with low amounts of other hydrogen sinks like unsaturated fatty acids and sulfate). But even with high concentrate diets, only about 50% of methane production is inhibited by feeding monensin at 30 ppm. For each 6% vegetable fat or each 0.5% nitrate or sulfate in the diet, methane yield theoretically should be reduced by 21, 42, and 20%, respectively, though only fat would conserve energy for the host animal. How these hydrogen sinks compete with propionate with or without monensin is not certain and needs to be examined based on ruminal VFA concentrations. If dietary sulfate is increased from 0.1 to 0.5% of the diet by feeding dried distillers’ grains at 40% of the diet, formation of hydrogen sulfide could cancel 32% of the energetic benefit from feeding monensin, but relative competition of various pathways for reducing equivalents in vivo has not been studied extensively.

Environmental regulations or placing a tax on ruminant production based on methane release has been discussed by various governmental agencies. Because methane loss is greater with grazing cattle and with feeding of forage- rather than grain-based diets, supplying ionophores in the diet or by bolus to such animals is one partial solution. To be eco-friendly, grazing ruminants of the future may be equipped surgically with rumen cannulas and Bunsen values to burn methane similar to the gas flare stacks seen at oil refineries. Like a flock of lightning bugs, grazing ruminants equipped with small methane torches should prove quite productive because grazing time would no longer be restricted to daylight hours. Such an approach also might detect individual animals with lower methane yields though substitution of hydrogen for methane could prove disastrous for an animal. For feedlot cattle, future mandates to supplement diets with ionophores, plant oils, malic acid, and, as a last resort sulfate and nitrate someday may help reduce methane loss from the animal and from feedlot wastes. Further environmental research is needed to examine the relative effectiveness of controlling methane production by domestic and wild ruminants as compared to more stringent regulation of other sources of methane, i.e., wetlands, buried waste, and gas leaks associated with drilling and cooking.

**Ruminal protein synthesis – Bane or Blessing?**

Microbial crude protein, containing an ideal balance of essential amino acids for ruminant growth and production, is the fermentation product of prime nutritional interest for rapidly growing young ruminants (under 250 kg) and high producing lactating cows. Using nitrogen, sulfur, and phosphorus recycled to the rumen, microbes grow and produce protein allowing ruminants to survive with extremely low dietary protein concentrations. But besides chains of amino acids, some 20% of bacterial crude protein consists of nucleic acids. Though ruminants supposedly are not prone to gout, nucleic acids are catabolized partially so that phosphorus can be recycled to the rumen. Following degradation, derivatives of nucleic acid
derivatives are excreted in urine. Consequently, urinary energy loss typically is twice as great for ruminants as for non-ruminants. And, as with non-ruminants, high dietary protein intakes increase excretion of energy as urea. Relative to carbohydrates, proteins catabolism involves additional energy losses associated with synthesis of urea by the liver, clearance by the kidney, and energy excreted as urea. These costs appear to be insufficiently compensated by the higher gross energy content of protein relative to carbohydrates, and this additional loss may explain the lower metabolic efficiency of protein-rich diets. The metabolic cost for microbes to convert dietary carbohydrate to microbial protein that subsequently is metabolized for energy by ruminants is a little recognized but potentially important energetic cost that could be avoided IF intestinally digestible nutrients can be shunted, sluiced or shoved past ruminal microbes.

Tissues of all mammalian species have the capacity to catabolize most end-products of microbial fermentation of carbohydrate, the volatile fatty acids, albeit at greater energetic expense than direct utilization of glucose. Small amounts of fermentation acids can be lost through urine when production exceeds the ruminant’s metabolic capacity or with an imbalance among volatile fatty acids exists, but quantitatively such loss appears insignificant. Relative to directly absorbed glucose, absorbed volatile fatty acids are less efficiently utilized and abrupt changes in carbohydrate demands for lactation place ruminants with high glucose requirements at risk of ketosis. A classic paper by Baldwin et al. (1980) that defines and outlines efficiencies of nutrient interconversions can help explain many of the discrepancies involved with energetics of growth and production.

Distillers’ Grain Feeding Value – The Dilemma

For centuries, nutritionists have formulated laws that animals are required to obey. Energy that is not digested cannot be utilized or stored by an animal; conversely, digested energy must be utilized. Requirements for dairy cattle now are based on net energy values calculated from digestion coefficients for individual nutrients; for beef cattle, net energy values have been calculated largely from TDN (digestibility) measurements. Residues from ethanol production have most of the starch removed leaving a residue with triple the protein and NDF content of the starting grain. One would expect that removal of starch should decrease digestibility of energy. Yet, substitution of wet distillers’ grains for up to 40% of the dry rolled corn in the diet consistently has improved feed efficiency. In contrast, substitution of wet or dried distiller’s grains for flaked corn often has not improved feed efficiency. This difference in response was extensively and systematically discussed in a landmark paper at the Grain Processing Conference (Cole et al., 2006). They prepared a litany of potential explanations for this interaction including differences in caloric density of the different grains, differential responses to added fat, yeast, protein, ethanol, minerals including sulfur, and in physical characteristics of the diet, and methane production. No single explanation readily explained this interaction.

To examine the intake response and NEg value to various types of distiller’s grains, performance information from 23 trials cited in the references involving 41 different comparisons in which one or more levels of distiller’s grain was fed (127 total means) with high concentrate diets was assembled. Data were subdivided based on the source of distiller’s grain (sorghum versus corn), moisture content of the distiller’s grain (wet versus dry), and method of grain processing (steam flaked versus all other processing methods). Responses in
feed intake were calculated and net energy value of each diet was calculated based on mean weight, feed intake, and ADG of each set of cattle. The ME content of grain in the unsupplemented diet was calculated by subtracting ME from other diet components. Finally, by difference from the observed diet ME and the ME calculated for the grain plus other components, the ME and NEg content of the distiller’s grain in each diet was calculated. These NEg values at various dietary levels of wet and dry corn distiller’s grains when fed with steam flaked or other grain forms is plotted in Figure 1. Dashed lines represent the linear regression among the data points.

The calculated NEg value was extremely high at low dietary concentrations with wet corn distiller’s grains; NEg declined as dietary level increased for the wet corn distiller’s grains. This matches the relative feeding values thoroughly summarized by Klopfenstein et al. (2007). Overall the NEg value remained 15 to 20% greater for wet than for dry corn distiller’s grains. This difference can be attributed partially due to residual ethanol in the product as well as the potential for heat damage of the product during drying. The higher the moisture content of the wet distiller’s grain, the greater the ethanol as a percentage of dry matter. With up to 10% of dry matter present as ethanol, feeding of wet distiller’s grain at 40% of diet dry matter will provide cattle with a diet containing 4% ethanol, a level likely to keep cattle content and relaxed. But because it is lost during dry matter measurement, ethanol is ignored when efficiency is calculated on a dry matter basis, leading to higher values for wet than dried distiller’s grains. The NEg value for distiller’s grains tended to be lower when it was included in diets containing steam flaked corn grain. When compared to the NEg of the grain it displaces, corn distiller’s grain will have greater replacement value with dry rolled than steam flaked corn. Compared to the NEg value for dry rolled corn in these studies, the NEg value for both dry and wet distiller’s grain remained above this point when corn distillers
grain was fed at levels up to and over 50% of diet dry matter. Compared to the NEg for steam flaked and high moisture corn, the NEg value for wet corn distiller’s grain was about equal, but for dried distiller’s grains, the average NEg was lower whenever the dietary distiller’s grain level exceeded about 25%. The lower NEg value of distiller’s grain when fed with flaked grain agrees with previous feed efficiency responses reported by VanderPol et al. (2005), Corrigan et al. (2007), and May et al. (2008a).

An increase in feed intake usually improves rate and efficiency of gain. The effect of various levels of corn distiller’s grain on dry matter intake across these same trials is shown in Figure 2. Averaged across these studies, intake of dry rolled and high moisture corn was increased consistently by including dried corn distillers grains in the diet whereas with wet corn distiller’s grains, intake tended to be depressed whenever intakes exceeded about 20% of diet dry matter. Though data are scanty, feed intake was increased in only one study by addition of either wet or dry corn distiller’s grain to steam flaked corn diets.

![DMI of Diets Containing Corn Distillers' Grains](image)

**Figure 2.** Influence of corn distiller’s grains on dry matter intake by feedlot cattle.

Compared with corn distiller’s grains, sorghum distiller’s grain has received less research attention. The NEg value for sorghum distiller’s grain (Figure 3) appears considerably lower than for corn distiller’s grain. Except for one trial reported by Daubert et al. (2005), the NEg for sorghum distiller’s grain remained below that of the grain it displaced. The higher lignin content of NDF from sorghum than corn grain may explain why NEg of the residue remaining after starch removal is lower. Despite its lower energy value, feed intakes often were depressed when sorghum distiller’s grain was substituted for dietary grain, particularly at intake levels above 10% with steam flaked corn diets (Figure 4).
Figure 3. NEg of sorghum distiller’s grains versus its dietary concentration.

Figure 4. Influence of sorghum distiller’s grains on dry matter intake of feedlot cattle.
Several theories have been advanced to explain why the feeding value of distiller’s grains is lower with flaked corn than with dry rolled or high moisture corn grain. Corrigan et al. (2008) reported that addition of corn distiller’s grains (40% vs. 0%) increased the ruminal propionate percentage when it displaced dry rolled corn but not when it displaced steam flaked corn in the diet. Certainly, the potential to reduce methane production and increase propionate concentrations is considerably greater with diets based on dry rolled than on steam flaked corn. If true, diets that yield more methane, e.g., diets richer in NDF and pectin, should show greater benefit from supplemental distiller’s grains. May et al. (2008b) and Uwituze et al. (2008) noted that ruminal pH is lower with cattle fed steam flaked rather than dry rolled diets, and the reduced pH will reduce digestion of NDF; this in turn would reduce the quantity of energy available from NDF in the distiller’s grains. Uwituze et al. (2008) also noted that digestibility of crude protein was depressed when dried distiller’s grain was included in diets with either dry rolled or steam flaked grain; this depression supports the idea that feeding value is lower for dried than wet distiller’s grains. Finally, most of the trials using steam flaked corn have tested sorghum, not corn distiller’s grains. As noted above, the NEg appears considerably lower for sorghum than corn distiller’s grain.

Puzzling observations High variability in NEg values for distiller’s grain should not be surprising considering that it is a by-product with a wide range in composition (residual starch, moisture). The quantity of solubles re-added to moist distiller’s grain supposedly varies from 50 to 150% of the solubles removed from the product. Depending on the plant efficiency and the value of ethanol relative to the cost of grain and overhead, quantities of residual starch and ethanol can vary both across ethanol plants and within a plant over time. Very high NEg values at very low dietary levels of distiller’s grains might be attributed to added moisture that can enhance feed mixing and bunk management, to supplemental nutrients (protein, NDF) that enhance nutritional balance of the diet and rumen health, and to fat that can improve feed efficiency. The lower NEg at higher inclusion levels often is associated with reduced feed intakes; this might be associated with sulfur toxicity and to lower fat digestibility at higher fat intakes. The interaction with grain processing probably can be attributed partly to the higher NEg of the grain being displaced, to reduced potential for added nutrients to benefit well-balanced and supplemented flaked corn feedlot diets and for added fat to reduce methane losses, particularly with monensin-supplemented flaked corn diets, and greater potential for intake depression due to ruminal sulfur reduction and hydrogen sulfide release when excess reducing power normally used for methanogenesis is low. To improve our understanding about variation in feeding value of distiller’s products based on data amassed from multiple trials, it would be helpful for research reports to provide more complete information related to grain’s origin (corn versus sorghum or a mixture as being marketed by some ethanol plants), its moisture and ethanol content (for wet distillers grains) as well as starch, NDF, NDF digestibility, fat, and sulfur content of the product, and the protein content and pepsin indigestibility of the protein. Similar information also may prove useful for livestock producers to assess both quality and inconsistency among batches that may adversely alter cattle performance.
Literature Cited


**Distillers’ Grains References**


Utilization of Crude Glycerin in Feedlot Cattle

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Kansas State University
Manhattan

Glycerin (glycerol) can be derived through production of alkyl esters (biodiesel) from plant oils or animal fats. Of the three processes available for alkyl ester production--oil conversion to fatty acids followed by acid catalyzed esterification; direct acid-catalyzed esterification with methanol; and base catalyzed transesterification with methanol--the base-catalyzed esterification is most economical, and therefore the most frequently employed process for biodiesel production (Van Gerpen, 2005). In base-catalyzed esterification, fats and oils are reacted with methanol in the presence of potassium hydroxide, yielding glycerin (Figure 1) and alkyl esters. Residual methanol is reclaimed via distillation, and glycerin is recovered through evaporation following removal of methyl esters. Each 100 lb of oil or fat yields approximately 10 lb of glycerin (National Biodiesel Board, 2008).

![Chemical structure of glycerin](image)

**Figure 1.** Chemical structure of glycerin.

Historically, glycerin has had a broad range of applications in human foods and pharmaceuticals, and has been used industrially for production of synthetic polymers, cosmetics, and personal care products. It can be modified to yield mono- and diglycerides, which are important classes of emulsifying agents. Glycerin is a sweet (~60% the sweetness of sucrose), viscous liquid that has been used in beverages as a thickening agent, and exploited in food systems as a result of its capacity to retain moisture (humectancy). This latter attribute makes it attractive as an addition to animal feeds for texturing properties and dust control. Figure 2 illustrates the effect of glycerin when added at 12% of the diet dry matter in a typical feedlot ration. Levels of 4% or more are relatively effective in aggregating small feed particles, thus reducing dust and fines. In its pure form, glycerin is colorless. The color of crude glycerin ranges from light amber to deep brown, and differences are largely attributable to varying concentrations of impurities within the co-product. Crude glycerin commonly contains 85-95% glycerin, with the balance of the crude liquid consisting of water, minerals, fatty acids, and low [normally] concentrations of methanol.
Figure 1. Effect of glycerin addition to a flaked corn finishing diet. Small particles are aggregated, reducing fines and dust.

Figure 2. Growth in biodiesel production (National Biodiesel Board, 2008).

Figure 3 illustrates the dramatic growth in demand for biodiesel in the U.S. over the past decade. Expansion of the biodiesel industry in the U.S. and abroad has resulted in large surpluses of crude glycerin, causing markets to plummet. Crude glycerin reached a low of 2 to 3 cents per pound in 2006, then stabilized at 6 to 8 cents per pound in 2007. The relatively low market value of glycerin has prompted interest in the co-product as a potential substitute for energy feeds in poultry and livestock diets. As of March, 2008, prices of crude glycerin have risen to 8 to 12 cents per pound, suggesting that the market has quickly discovered its value as an alternative feed resource, or that demand is increasing in other markets. Given the
large number of industrial applications for high purity forms of glycerin, it is probable that the value of crude glycerin will continue to increase as new markets are developed. That said, application rates in livestock and poultry diets will no doubt adjust over time.

Crude glycerin has been used effectively as an energy source for pigs (Maurot et al., 1994; Lammers et al., 2007), poultry (Simon et al., 1996; Cerrate et al., 2006), and cattle (Schröder and Südekum, 2007). Feeding rates generally have ranged from 0 to 20% of the diet. Cerrate et al. (2006) found that diets containing 2.5 to 5% glycerin improved daily gain and feed conversion in broilers, but 10% glycerin actually had a deleterious effect on efficiency. Lammers et al. (2007) found that the energy value of crude glycerin was approximately equal to that of corn, though its value was somewhat greater for growing pigs than for starter pigs. Kijora et al. (1995) recommended that glycerin could be added to pig diets at levels up to 10%, whereas higher levels were detrimental to efficiency. Dairy research has emphasized the potential to exploit glycerin as a glucogenic substrate, potentially providing protection against ketosis, which is one of the more important metabolic maladies afflicting transition dairy cows. Ogborn evaluated glycerin in transition dairy cows, fed at 3.3% of the diet dry matter, or as a 500 mL/day drench, and reported no particular benefits to supplementation. DeFrain noted that metabolic indicators of the severity of ketosis actually increased in response to glycerin feeding, and that there were no notable positive effects on lactation performance of dairy cows.

Groesbeck (2007) evaluated crude glycerin as a pelleting aid in corn-based swine diets, and observed that energy costs associated with pelleting decreased linearly in response to adding glycerin to the mash at concentrations of 0 to 15%. The same author investigated the impact of glycerin addition on pellet durability indices (PDI) and found that optimal PDI was achieved at with approximately 9% glycerin (Figure 4).

![Figure 4](https://example.com/figure4.png)

**Figure 4.** Effects of crude glycerin on pellet durability index of swine feeds.

The scientific literature pertaining to the use of glycerin in cattle is relatively sparse. Pyatt et al. (2007) fed 10% crude glycerin in diets that were either 70% rolled corn with 10% distiller’s grains, or 35% rolled corn with 30% distiller’s grains and 15% soybean hulls. Glycerin decreased dry matter intake by approximately 10%, but improved conversion efficiency by 19%. Elam et al. (2008) observed a linear reduction dry matter intake (P=0.09)
in heifers fed 0, 7.5, or 15% crude glycerin, but efficiency was unchanged. Of notable interest is the fact that glycerin, in spite of its glucogenic properties, actually tended to increase the percentage of cattle grading USDA Select or less (P=0.15). Parsons et al. (2008) conducted a dose titration of glycerin in flaked corn finishing diets for heifers, feeding concentration of 0, 2, 4, 8, 12, or 16% crude glycerin (dry basis). Results of this study are shown in Table 1. Dry matter intake, daily gain, and feed efficiency all responded in a quadratic manner to glycerin concentration. Optimal performance was achieved with 2% glycerin addition, and levels exceeding 10% of the diet depressed feed intake markedly. As in the study by Elam et al. (2008), the percentage of carcasses grading USDA select increased linearly in response to increasing glycerin level in the diet (P<0.10).

![Graph showing molar proportions of acetate and propionate after fermentation of glycerin by mixed cultures of ruminal bacteria from grain-fed cattle.](image)

**Figure 5.** Molar proportions of acetate and propionate after fermentation of glycerin by mixed cultures of ruminal bacteria from grain-fed cattle.

We have conducted a series of in vitro experiments to evaluate the fate of glycerin when exposed to a mixed ruminal inoculum from grain fed animals. Figure 5 summarizes results of a study in which we compared corn starch and glycerin as substrate for fermentation. Starch yielded a fairly typical A:P ratio, whereas glycerin was fermented almost entirely to propionate. Figure 6 illustrates the differences in acetate propionate ratio resulting from *in vitro* cultures in which starch was replaced with graded levels of glycerin. The A:P ratio decreased linearly as level of glycerin in the mixtures increased. Bergner et al. (1995) measured glycerin transformation by ruminal microorganisms using 14C-labeled glycerin, and observed that the majority of glycerin was converted to propionate, while no discernible amounts were converted to acetate. Similarly, Trabue et al. (2007) found that glycerol partially suppressed acetate production by ruminal microbes in inoculum taken from a dairy animal fed a diet consisting of approximately 50% concentrate. In contrast, Wright (1969) determined that radio-labeled glycerin was converted to acetate, propionate, and butyrate. The inoculum used in this study was extracted from cattle grazing clover-ryegrass pastures. Jarvis and co-workers utilized ruminal contents from red deer, and determined that a *Klebsiella planticola* strain transformed glycerin into approximately equimolar proportions of formate and ethanol. Collectively, these studies may suggest that metabolites of glycerin are influenced by the microbial milieu within the rumen, which obviously is a function of diet. Roger et al. (1992) reported that cellulolytic activity was depressed by glycerol, noting that
Figure 6. Acetate:propionate ratio following in vitro fermentation of starch:glycerin mixtures by a mixed ruminal inoculum from grain-fed steers.

the glycerin was far more inhibitory to cellulolytic ruminal fungi compared to cellulolytic bacteria. Paggi et al. (2004) noted similar inhibitory effects of glycerin on cellulolysis, and suggested that the concentrations necessary for inhibition were consistent with levels capable of suppressing *Neocallimastix frontalis*, a ruminal fungi integrally involved in cellulolysis. It is conceivable that these observations could have important implications for diets that contain substantial amounts of cellulosic materials, including certain byproduct feeds.

**Summary**

Crude glycerin is likely to increase in availability as a result of continued expansion of the biodiesel industry. Glycerin is an adaptable raw material suited to numerous industrial applications, perhaps suggesting that its use as a livestock feed may be quickly supplanted by higher value applications. As a feed resource, crude glycerin can be utilized effectively in diets for feedlot cattle to improve efficiency and rate of gain. Though glucogenic in nature, glycerin has not affected marbling favorably in the few studies that have examined carcass attributes. Concentrations less than 10% of the diet dry matter yield greater biological responses in cattle, and levels in excess of 10% may have deleterious consequences for feed intake and growth of cattle.
Table 1. Feedlot performance and carcass traits of heifers fed 0, 2, 4, 8, 12, 16% crude glycerin in flaked corn finishing diets (Parsons et al., 2008)

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<td>1165‡</td>
<td>1149§</td>
<td>1122**</td>
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<td>Average daily gain, lbs</td>
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abc: Means in rows not bearing a common superscript differ P < 0.05

Contrasts: * = P < 0.05, † = P < 0.10.

Calculated by dividing HCW by a common dressing percentage of 63.5%.

Marbling scores were obtained by a commercial abattoir; Slight=300-399, Small=400-499, Modest=500-599.
Literature Cited


## Regional Biodiesel Contacts

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<tr>
<td><strong>Colorado</strong></td>
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<td>American Agri-Diesel LLC &lt;br&gt;Burlington, Co &lt;br&gt;Kerry Rothergeb, Sales &lt;br&gt;719-510-0852 &lt;br&gt;<a href="mailto:krothgeb@americanagri-diesel.com">krothgeb@americanagri-diesel.com</a> &lt;br/www.americanagri-diesel.com</td>
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<tr>
<td><strong>Iowa</strong></td>
<td>Clinton County Bio Energy, LLC &lt;br&gt;Clinton, Iowa &lt;br&gt;<a href="mailto:ccbe@ccbebiodiesel.com">ccbe@ccbebiodiesel.com</a> &lt;br&gt;563-249-4216</td>
</tr>
<tr>
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<td>Freedom Fuels, LLC &lt;br&gt;4172 19th St SW &lt;br&gt;Mason City, IA 50401 &lt;br&gt;Telephone: 641-421-7590 &lt;br&gt;<a href="mailto:cmiller@freedomfuelsllc.com">cmiller@freedomfuelsllc.com</a></td>
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<td>Renewable Energy Group, Inc &lt;br&gt;PO Box 128 &lt;br&gt;Ralston, IA 51459 &lt;br&gt;(712) 667-3500 &lt;br&gt;Fax: (712) 667-3599</td>
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<td>Tri-City Energy &lt;br&gt;410 Johnson Street &lt;br&gt;Keokuk, IA 52632 &lt;br&gt;Telephone: (800)-979-2331 &lt;br&gt;(319)-524-2331 &lt;br&gt;Fax: (319)-524-5507</td>
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| Western Iowa Energy, LLC  
Larry Breeding  
712-664-2173  
lbreeding@westerniowaenergy.com |         |

<table>
<thead>
<tr>
<th>Kansas</th>
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| Healy Biodiesel, Inc.  
Ben Healy, President  
205 West 1st  
Sedgwick, KS 67135  
info@healybiodiesel.com  
316-992-3169 |         |

<table>
<thead>
<tr>
<th>Missouri</th>
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| Nat'l Biodiesel Board  
3337A Emerald Ln.  
P O Box 104898  
Jefferson City, MO 65110-4898  
(800) 841-5849  
(573) 635-7913 fax | Mid American Biofuels  
Cliff Smith  
Mexico, Mo  
573-581-7994 |

|               | Mid American Biofuels  
Cliff Smith  
Mexico, Mo  
573-581-7994 |
|---------------|-----------------------|
| Global Fuels LLC  
302 N Walnut St  
Dexter, MO , 63841-1748  
Phone: 573-621-8780 | Great River Soy Processing Coop  
P.O. Box B  
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(573) 471-3700 |

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Sikeston, MO 63801  
(573) 471-3700 |
|---------------|-----------------------|
| Heartland Biodiesel, LLC  
P.O. Box 232  
Rock Port, MO 64482  
(660) 744-2820  
info@heartlandbiodiesel.com | High Hill Biodiesel, Inc.  
13023 Tesson Ferry  
St. Louis, MO 63128 |

|               | High Hill Biodiesel, Inc.  
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|---------------|-----------------------|
| Missouri Better Bean, LLC  
136 Main  
Bunceton, MO 65237  
(660) 427-5444 | Missouri Bio-Products, Inc.  
7352 Shelby 156  
Bethel, MO 63434  
(660) 284-6250 |

|               | Missouri Bio-Products, Inc.  
7352 Shelby 156  
Bethel, MO 63434  
(660) 284-6250 |
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<tr>
<td>Kinney Drive</td>
<td>Dayton, TX</td>
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<td>Beatrice, Nebraska</td>
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<td><a href="http://www.beatricebiodiesel.net">www.beatricebiodiesel.net</a></td>
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<tr>
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<td>800-437-1479</td>
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<tr>
<td>Northeast Nebraska Biodiesel, LLC</td>
<td>137 Pebble St</td>
</tr>
<tr>
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<td>Scribner, NE 68057</td>
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<tr>
<td></td>
<td>Tel: (402) 664-3643</td>
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<tr>
<td></td>
<td>Fax: (402) 664-3663</td>
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<tr>
<td></td>
<td><a href="mailto:info@biodieselnebraska.com">info@biodieselnebraska.com</a></td>
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<td><a href="http://www.biodieselnebraska.com">www.biodieselnebraska.com</a></td>
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</tbody>
</table>
Research in the beef cattle nutrition program at Texas AgriLife Research at Amarillo has focused on incorporating wet distiller’s grains plus solubles (WDGS) into finishing diets in the Southern Plains. Efforts have focused on strategies to incorporate WDGS into steam-flaked corn (SFC) based diets and reconciling differences observed when incorporating WDGS into diets in the northern and southern plains.

**Trial 1: Effects of 20% corn wet distillers grain’s plus solubles in steam-flaked and dry-rolled corn- based finishing diets.** *J. C. MacDonald, K. H. Jenkins, F. T. McCollum III, and N. A. Cole.*

Two hundred sixty four crossbred yearling heifers (781 ± 35 lb) were blocked by weight and used in a 2X2 factorial arrangement of treatments to determine effects of WDGS derived from corn on animal performance, in SFC and dry-rolled corn (DRC) based finishing diets. Heifers were fed DRC or SFC based finishing diets with or without 20% WDGS (DM basis). Control diets with no WDGS were formulated to contain 13.5% CP. The WDGS replaced 15.2 percentage units of corn and 4.8 percentage units of cottonseed meal. All diets contained 10% alfalfa hay, 2% supplemental yellow grease, 4% glycerin, 1.2% urea, and 0.70% Ca. There were 24 pens (n=6 per treatment) that housed 8, 10, or 18 heifers with pen size serving as a blocking factor. Heifers were implanted once with Revalor-H® approximately 120 days before slaughter and were on feed for an average of 154 d. No corn processing method by WDGS inclusion interactions were found for any response variable (*P* > 0.34; Table 1).

<table>
<thead>
<tr>
<th>Item</th>
<th>0% WDGS¹</th>
<th>20% WDGS²</th>
<th>SEM</th>
<th>P – Value³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DRC</td>
<td>SFC</td>
<td>DRC</td>
<td>SFC</td>
</tr>
<tr>
<td>Initial BW, lb</td>
<td>780</td>
<td>781</td>
<td>781</td>
<td>781</td>
</tr>
<tr>
<td>Final BW, lb</td>
<td>1208</td>
<td>1204</td>
<td>1224</td>
<td>1223</td>
</tr>
<tr>
<td>ADG, lb⁴</td>
<td>2.82</td>
<td>2.76</td>
<td>2.90</td>
<td>2.90</td>
</tr>
<tr>
<td>DMI, lb/d</td>
<td>21.6</td>
<td>19.9</td>
<td>21.6</td>
<td>20.2</td>
</tr>
<tr>
<td>F:G⁴</td>
<td>7.63</td>
<td>7.24</td>
<td>7.42</td>
<td>6.93</td>
</tr>
</tbody>
</table>

¹Dry-rolled corn (DRC) or steam-flaked corn (SFC) based diets containing 0% wet distiller’s grains plus solubles derived from corn (WDGS).
²DRC or SFC based diets containing 20% WDGS.
³Corn = main effect of corn processing method (DRC vs. SFC); WDGS = main effect of WDGS inclusion; Int = interaction of corn processing method and WDGS inclusion.
⁴Final BW calculated by hot carcass weight/0.63. ADG and F:G were calculated using Final BW calculated in this manner.

WDGS inclusion interactions were found for any response variable (*P* > 0.34; Table 1). Heifers consuming SFC-based diets had lower DMI (*P* < 0.01), similar ADG (*P* = 0.71), and
decreased feed:gain ($P < 0.05$) than heifers consuming DRC-based diets. There was a slight
tendency for heifers consuming WDGS to have greater final BW ($P = 0.15$), and ADG ($P =
0.15$). Using the replacement method to calculate energy concentrations of ingredients,
WDGS appears to have similar energy content to SFC and greater energy than DRC. These
data indicate that corn processing method has a greater impact on animal performance than
does the inclusion of WDGS when WDGS is included at 20% of diet DM. However,
including WDGS did not negatively affect animal performance.

**Trial 2: Effects of 35% corn wet distillers grain’s plus solubles in steam-flaked and dry-rolled
corn- based finishing diets.** *J. C. MacDonald, K. H. Jenkins, F. T. McCollum III, and
N. A. Cole.*

Fifty four crossbred steers (678 ± 18 lb) were blocked by weight and used in a 2X2
factorial arrangement of treatments to determine effects of WDGS derived from corn on
animal performance, in SFC and DRC based finishing diets. Steers were individually fed
DRC or SFC based finishing diets with or without 35% WDGS (DM basis) using a Calan gate
system. Control diets with no WDGS were formulated to contain 13.5% CP. The WDGS
replaced 27.88 percentage units of corn, 3.5 percentage units of cottonseed meal, 2.76
percentage units of yellow grease (diets were equilibrated for ether extract), 0.50 percentage
units of urea, and 0.36 percentage units limestone. All diets contained 10% alfalfa hay, 5%
glycerin, and 0.70% Ca. Steers were initially implanted with Synovex S® and terminally
implanted with Revalor-IS®. Steers were on feed for 174 d. No corn processing method by

<table>
<thead>
<tr>
<th>Item</th>
<th>0% WDGS1</th>
<th>35% WDGS2</th>
<th>P – Value3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DRC</td>
<td>SFC</td>
<td>DRC</td>
</tr>
<tr>
<td>Initial BW, lb</td>
<td>675</td>
<td>683</td>
<td>677</td>
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<tr>
<td>Final BW, lb4</td>
<td>1240</td>
<td>1281</td>
<td>1282</td>
</tr>
<tr>
<td>ADG, lb4</td>
<td>3.25</td>
<td>3.44</td>
<td>3.46</td>
</tr>
<tr>
<td>DMI, lb/d</td>
<td>20.2</td>
<td>18.8</td>
<td>19.8</td>
</tr>
<tr>
<td>F:G4</td>
<td>6.27</td>
<td>5.48</td>
<td>5.75</td>
</tr>
</tbody>
</table>

1Dry-rolled corn (DRC) or steam-flaked corn (SFC) based diets containing 0% wet distiller’s grains plus solubles
derived from corn (WDGS).
2DRC or SFC based diets containing 35% WDGS.
3Corn = main effect of corn processing method (DRC vs. SFC); WDGS = main effect of WDGS inclusion; Int =
interaction of corn processing method and WDGS inclusion.
4Final BW calculated by hot carcass weight/0.63. ADG and F:G were calculated using Final BW calculated in
this manner.

WDGS inclusion interactions were found for any response variable ($P > 0.19$; Table 2).
Steers consuming SFC-based diets had lower DMI ($P < 0.01$), similar ADG ($P = 0.51$), and
decreased feed:gain ($P < 0.01$) than steers consuming DRC-based diets. Steers consuming
WDGS had decreased feed:gain compared to steers consuming diets without WDGS ($P =
0.03$). Using the replacement method to calculate energy concentrations of ingredients,
WDGS appears to have 110% the energy content of SFC and 125% the energy content of
These data suggest that WDGS inclusion of 25% decreases animal performance in both DRC and SFC diets when diets have been equilibrated for ether extract.

**Trial 3: Effects of roughage level in steam-flaked corn based finishing diets containing 25% sorghum wet distiller’s grain plus solubles.** J. C. MacDonald, K. H. Jenkins, and N. A. Cole.

Two hundred forty crossbred yearling steers (836 ± 41 lb) were blocked by weight and used in a randomized complete block design to determine effects of roughage level in SFC-based finishing diets containing 25% sorghum WDGS. Alfalfa hay was used as the roughage source and was included at 7.5, 10.0, and 12.5% of diet DM. A SFC control diet containing 10% alfalfa hay was included to determine effects of sorghum WDGS. The control diet with no WDGS was formulated to contain 13.5% CP. The WDGS replaced 19.22 percentage units of corn, 3.67 percentage units of cottonseed meal, 1.39 percentage units of yellow grease (diets were equilibrated for ether extract), 0.69 percentage units of urea, and 0.03 percentage units limestone. All diets contained 5% glycerin, and 0.70% Ca. Steers were implanted once with Revalor - S® and were on feed for an average of 154 d. Contrasts of interest were linear and quadratic affects of roughage level and SFC control vs. 25% WDGS with 10% alfalfa hay.

**Table 3.** Effects of alfalfa level in steam-flaked corn based finishing diets containing 25% wet distiller’s plus solubles derived from sorghum on performance of steers (Trial 3).

<table>
<thead>
<tr>
<th>Item</th>
<th>Cont³</th>
<th>Level of Alfalfa¹</th>
<th>P – Value²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.5</td>
<td>10.0</td>
<td>12.5</td>
</tr>
<tr>
<td>Initial BW, lb</td>
<td>834</td>
<td>839</td>
<td>838</td>
</tr>
<tr>
<td>Final BW, lb⁴</td>
<td>1461</td>
<td>1432</td>
<td>1434</td>
</tr>
<tr>
<td>ADG, lb⁴</td>
<td>4.14</td>
<td>3.93</td>
<td>3.96</td>
</tr>
<tr>
<td>DMI, lb/d</td>
<td>22.9</td>
<td>23.2</td>
<td>23.9</td>
</tr>
<tr>
<td>F:G³</td>
<td>5.54</td>
<td>5.89</td>
<td>6.04</td>
</tr>
</tbody>
</table>

¹Diets contained 25% wet distiller’s grains plus solubles (WDGS) with 7.5, 10.0, or 12.5% alfalfa hay
²Contrasts c = Cont diet vs. 25% WDGS with 10% alfalfa hay; lin = linear effect of alfalfa level within diets containing 25% WDGS; quad = quadratic effect of alfalfa level within diets containing 25% WDGS.
³Cont = steam-flaked corn based control diet containing 0% WDGS and 10% alfalfa hay.
⁴Final BW calculated by hot carcass weight/0.63. ADG and F:G were calculated using Final BW calculated in this manner.

There was no significant quadratic effect of roughage level on animal performance (P > 0.72). There was a slight tendency for increasing roughage level to linearly increase DMI (P = 0.16; Table 3) and linearly decrease feed efficiency (P = 0.13). Relative to the SFC control diet, 25% WDGS increased feed:gain (P = 0.04). Using the replacement method to calculate energy concentrations of ingredients, WDGS appears to have 73% the energy content of SFC. These data suggest that WDGS inclusion of 25% decreases animal performance in SFC diets when diets have been equilibrated for ether extract. However, if sorghum WDGS is priced favorable into the diet, reducing alfalfa to 7.5% of dietary DM may improve feed:gain.

Six ruminally and duodenally fistulated crossbred steers were used in a 6X6 latin square metabolism study to determine effects of corn processing method and WDGS inclusion and source on digestion characteristics. Experimental design was a 2X3 factorial with two corn processing methods (DRC and SFC) with 0% WDGS, 20% WDGS derived from corn, and 20% WDGS derived from sorghum. At the end of each period, the corn and WDGS was ruminally incubated for 48, 24, 16, 12, 8, 4, 2, or 0 hr. Extent of digestion was determined from the 48 hr incubation. Rate of digestion was determined by regressing the natural log of the percent of the potentially degradable fraction remaining on time. Inclusion of WDGS did not affect the rate or extent of digestion of either DRC or SFC ($P = 0.24$; Table 4). DRC and SFC had similar rates of digestion ($P = 0.55$), but SFC had a greater extent of digestion ($P < 0.01$). There was a tendency for and interaction of WDGS source and corn processing method on the rate of digestion of the WDGS ($P = 0.14$) where the rate of digestion of corn WDGS was greater in DRC diets compared to SFC diets and the rate of digestion of sorghum WDGS did not differ due to corn processing method. Additionally, the 48-hr extent of digestion was greater for corn WDGS compared to sorghum WDGS ($P < 0.01$) and there was a tendency for both corn and WDGS to have greater extents of digestion in DRC based diets compared to SFC based diets. These data may explain differences in observed performance of cattle consuming WDGS from corn or sorghum in DRC vs. SFC based finishing diets.
Table 4. Effects of 20% inclusion of wet distiller’s grains plus solubles (WDGS) derived from corn or sorghum in dry-rolled corn (DRC) or steam-flaked corn (SFC) based diets on rate and extent of ruminal DM digestion of processed corn and WDGS.

<table>
<thead>
<tr>
<th>Item</th>
<th>0% WDGS</th>
<th>20% Corn WDGS</th>
<th>20% Sorghum WDGS</th>
<th>SEM</th>
<th>P – Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DRC</td>
<td>SFC</td>
<td>DRC</td>
<td>SFC</td>
<td></td>
</tr>
<tr>
<td>Corn Kd, %/hr^5</td>
<td>5.21</td>
<td>5.10</td>
<td>4.29</td>
<td>4.64</td>
<td>0.60</td>
</tr>
<tr>
<td>Corn Extent, %^5</td>
<td>70.4</td>
<td>75.2</td>
<td>68.3</td>
<td>78.1</td>
<td>0.03</td>
</tr>
<tr>
<td>WDGS Kd, %/hr^6</td>
<td>--</td>
<td>--</td>
<td>5.97</td>
<td>4.20</td>
<td>0.76</td>
</tr>
<tr>
<td>WDGS Extent, %^6</td>
<td>--</td>
<td>--</td>
<td>74.5</td>
<td>73.6</td>
<td>1.9</td>
</tr>
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1Dry-rolled corn (DRC) or steam-flaked corn (SFC) based diets containing 0% WDGS.
2DRC or SFC based diets containing 20% WDGS derived from corn.
3DRC or SFC based diets containing 20% WDGS derived from sorghum.
4Corn = main effect of corn processing method (DRC vs. SFC); WDGS = main effect of WDGS inclusion; Int = interaction of corn processing method and WDGS inclusion.
5Effect of corn processing method and inclusion and source of WDGS on rate and extent of the corn.
6Effect of corn processing method and inclusion and source of WDGS on rate and extent of the WDGS.
In the feedlot nutrition area, research has been focused on grain milling byproduct utilization (distillers grains and corn gluten feed), grain utilization including research on rumen acidosis and starch utilization, environmental issues related to decreasing N losses and improving use of P, methods to decrease incidence of E. coli O157:H7, and growth promotion including work with feed additives and implants. For more complete information on our program efforts, the 2008 Nebraska Beef Report and previous years are available electronically at: [http://beef.unl.edu](http://beef.unl.edu) under ‘reports’ tab. There is also a 25 page research update on “Utilization of corn milling coproducts by beef cattle” and a storage manual for wet distillers grains under the ‘byproduct feeds’ tab.

**Level of distillers grains**

Feeding of distillers grains and corn gluten feed is common in Nebraska. Distillers grains plus solubles can be fed wet (WDGS), modified wet (MWDGS), or dry (DDGS). We recently completed a ‘meta-analysis’ approach to combine trials over the past 20 years. Bremer et al. (2008) suggested that the feeding value, expressed as a percentage of dry-rolled or high-moisture corn, changed as inclusion level changed. Both ADG and G:F increased as WDGS replaced dry-rolled or a dry-rolled:high-moisture blend of corn. Feeding values for WDGS were 145, 142, 137, 131, and 126% of corn at 10, 20, 30, 40, and 50% inclusions (DM basis). Feeding values for DDGS are 153, 123, 107, and 100% of corn at 10, 20, 30, and 40% inclusions (DM basis). Clearly, WDGS can be fed at greater inclusions and has a higher feed value at those higher inclusions. Numerous other experiments would support the concept that DDGS has a lower feeding value than WDGS. However, at 10% inclusion, little differences are evident between the two. MWDGS is partially dried during production. If drying decreases the feeding value, then will MWDGS feed more like WDGS or more like DDGS? To address this, Huls et al. (2008) fed 0, 10, 20, 30, 40, or 50% MWDGS. Two hundred eighty eight yearling steers (initial BW = 731 lb) were blocked by BW, stratified within block, and assigned randomly to pens (8 steers/pen; 6 pens/treatment). All diets included 7.5% alfalfa hay and 5% supplement with the remaining as a 1:1 ratio of dry rolled corn and high moisture corn. Final BW, ADG, and DMI responded quadratically (P < 0.01) as MWDGS inclusion increased from 0 to 50% of the diet, with 20% MWDGS having the greatest DMI and ADG. A linear increase (P < 0.01) was observed for G:F as MWDGS increased. HCW and calculated USDA Yield Grade responded quadratically (P < 0.05) with 20% MWDGS inclusion having the greatest HCW and USDA Yield Grade. Differences were not observed (P > 0.10) across MWDGS level for fat depth and marbling score. The calculated feeding value of MWDGS was 123, 127, 118, 109, and 111% the value of corn at 10, 20, 30, 40, and 50% inclusions (DM basis). Finishing diets may include MWDGS up to 50% of the diet DM; however, optimal performance is likely between 20 to 40% of the diet DM. This also suggests that the feeding value of MWDGS is intermediate to the feeding value of DDGS and WDGS.

Some exciting new work on feeding level of WDGS has been completed by Wilken et al. (2008; National ASAS abstract). Crossbred steers (n=288; weighing 823 lb) were used to
evaluate feedlot performance from feeding diets with no grain and different inclusions of wet distillers grains plus solubles (WDGS) and wet corn gluten feed (WCGF). Steers were assigned randomly to 36 pens with 8 steers/pen and 3 weight blocks. Six treatments were tested (6 pens/treatment) with all diets containing 7.5% alfalfa hay and 5% supplement. Diets tested included: 1) a corn, control diet of 82.5% dry rolled corn and 5.0% molasses (CON); 2) diet with 43.8% WDGS and 43.8% corn (WDGS); 3) a 32.8% WDGS, 32.8% WCGF, and 21.9% corn blend diet (CORN); 4) a similar blend of 32.8% WDGS, 32.8% WCGF, but with 21.9% soyhulls (HULLS); 5) a diet with a blend of 43.8% WDGS and 43.8% WCGF (BYPROD); and 6) a diet with mostly WDGS (65.6%) and 21.9% grass hay (HAY). Many of these diets contained no corn and all comprised the 87.5% of the diet energy portion. Steers fed 65.6% WDGS with grass hay had greater DMI (P < 0.05; 26.6 lb/d) than those fed 43.8% WDGS with corn (25.2 lbs/d) and 43.8% WDGS with 43.8% WCGF (24.8 lb/d). Cattle intakes for the blend of WDGS and WCGF (43.8% each) was the lowest (P < 0.05) overall. Comparing all diets, daily gain was greatest for steers fed 43.8% WDGS with corn (P < 0.05) at 4.47 lb/day and least for the diet containing 32.8% WDGS, 32.8% WCGF, and 21.9% soyhulls (P < 0.05) at 3.73 lb/day. Similarly, steers fed 43.8% WDGS with corn had lower (P < 0.05) feed:gain (i.e., better; 5.64) compared to all other diets. Steers fed 32.8% WDGS, 32.8% WCGF, and 21.9% soyhulls (6.92) had the poorest feed:gain and was poorer feed:gain (P = 0.06) compared to steers fed 65.6% WDGS with grass hay (6.60). Interestingly, steers fed 65.6% WDGS with grass hay and steers fed 43.8% WDGS with 43.8% WCGF had similar gains and F:G (P > 0.05) to steers fed the 82.5% corn, control diet. These results allow us to conclude it is possible to feed byproduct diets with no corn and not sacrifice feedlot performance. However, performance will likely be reduced with all byproduct diets compared to feeding 43.8% WDGS with corn, which is more typical today, at least in Nebraska, than feeding all corn diets.

### Table 1. Yearling steer finishing feedlot performance when fed different byproduct diets and inclusions.

<table>
<thead>
<tr>
<th>Item</th>
<th>CON</th>
<th>WDGS</th>
<th>CORN</th>
<th>HULLS</th>
<th>BYPROD</th>
<th>HAY</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, lb/d</td>
<td>26.0a</td>
<td>25.1b</td>
<td>26.0a</td>
<td>25.8abc</td>
<td>24.9c</td>
<td>26.6a</td>
<td>0.9</td>
</tr>
<tr>
<td>ADG, lb</td>
<td>4.03x</td>
<td>4.47w</td>
<td>4.16x</td>
<td>3.72y</td>
<td>3.96x</td>
<td>4.03x</td>
<td>0.20</td>
</tr>
<tr>
<td>G:F</td>
<td>0.155xy</td>
<td>0.177w</td>
<td>0.160x</td>
<td>0.145z</td>
<td>0.160x</td>
<td>0.151yz</td>
<td>0.003</td>
</tr>
</tbody>
</table>

a,b,cWithin a row, means without common superscript differ (P = 0.06). w,x,y,zWithin a row means without common superscript differ (P < 0.01).

### Composition of WDGS and MWDGS

There has always been a great deal of discussion on variability of distillers grains and that contributes to challenges at feeding. However, few data are available on variation in nutrient composition of WDGS. Dry matter, crude protein (CP), fat, phosphorus (P), and sulfur (S) were measured on 50 WDGS or MWDGS samples per ethanol plant (6 plants in NE) with 10 samples*d-1, 5 consecutive d, and repeated over 4 separate months (periods) throughout the year in a study by Buckner et al. (Midwest ASAS abstract). Multiple samples were taken from a semi-truck or the area of distillers grains that was loaded onto a truck, mixed, and sub-
sampled. Therefore, each sample represented a potential load that a livestock producer would receive. Samples were then shipped frozen and nutrients analyzed in duplicate. Because DM averages varied across ethanol plants, each plant’s average was indexed to 100%. Coefficients of variation (CV) for DM were higher for some plants than others, were consistent across periods, and variation appeared to be less within d than across d. Composition for these samples across the 6 plants averaged 31.0% CP, 11.9% fat, 0.83% P, and 0.77% S. Plant averages for fat within period for these samples ranged from 10.2 to 13.3%, with ranges of 2 to 5 percentage units for plants within period. Period did not seem to have an effect on CV for fat, but CV were not consistent across plants and variation within d was lower than the variation among all samples within a period for fat. The CV for S appeared less within d than across d, differed across plants, and appeared to decrease across periods. The CV for S was mostly 4 to 9% and averaged 7.4%, but the highest CV within a plant within period was 36%. The variation in CP and P were minimal as CV averaged 1.9 and 2.8%, respectively. These values serve as a database for nutrient composition of WDGS and MDGS for livestock producers and what variation they can expect. We recommend testing with the specific ethanol plant providing distillers grains to ensure DM, fat, and S are known by the end-user.

Interaction of roughage and byproduct feeding

Roughages are often included at low levels (<12% of diet DM) to control acidosis and maintain intake in feedlot cattle. Since byproducts reduce the occurrence of acidosis in feedlot cattle, then perhaps roughage levels may be reduced from conventional levels in diets containing byproducts. Farran et al., (2004) fed either 0 or 35% WCGF with either 0, 3.75, or 7.5% alfalfa hay at each level (i.e., treatments were factorialized with WCGF level and hay level). There was a significant interaction between WCGF and alfalfa level for feed conversion. With 0% WCGF, increasing alfalfa level increased ADG and DMI with no effect on feed conversion. With 35% WCGF, increasing alfalfa hay increased ADG and DMI, but hindered (increased) feed conversion linearly. It appears that roughage can be decreased in DRC-based diets that contain 35% or more WCGF. The ADG was reduced for the 0% hay, 35% WCGF treatment which has economic implications so a small amount of roughage would be recommended. Similar results have been observed with SFC-based diets where alfalfa can be reduced to 2% with at least 25% WCGF.

We wanted to test the roughage level and source (lower quality roughage) in diets containing WDGS. Benton et al., (2007) fed alfalfa hay, corn silage, or corn stalks fed as the roughage source in 30% WDGS (DM basis) diets. Each of the sources was included at a conventional level and one-half that level. The low level was equal to 4% alfalfa hay and the normal level was equal to 8% alfalfa hay. In general, normal roughage levels increased DMI, ADG, and profit. However, steers fed 3% corn stalks performed similarly to steers fed normal levels of roughage. When roughage was eliminated from the 30% WDGS diets, DMI, ADG, and profit were decreased compared with diets containing cornstalks or normal levels of alfalfa or corn silage. Therefore it is not beneficial to completely eliminate roughage sources from finishing diets containing 30% WDGS (DM basis). In more recent metabolism work (Benton et al., 2008; National ASAS abstract), we compared alfalfa and corn stalks at 3 levels (0, 4, and 8% for alfalfa, and 0, 3, and 6% for corn stalks). Six ruminally fistulated steers (764 lb) were used in a 6x6 Latin square with ruminal metabolism and nutrient digestibility measured. Diets were balanced to provide equal percentages of NDF from roughage at each level and contained
30% WDGS (DM basis). Periods included a 9-d adaptation and 5-d collection. Steers were fed once daily at 0730 h, and ruminal pH and DMI were continuously monitored during collection. There was not a source x level interaction for digestibility or rumen pH. There were no differences (P > 0.05) in DMI (9.4 kg/d) or CP digestibility (77.6%) across diets. No differences (P > 0.16) in DM and OM digestibility (DMD, OMD) were observed between cattle fed alfalfa or corn stalks. A linear increase (P < 0.01) was observed in DMD and OMD as roughage decreased with 81.7, 82.5, and 86.4% DMD for normal, low, or zero roughage levels, respectively. Cattle fed alfalfa had greater (P < 0.05) NDF digestibility (NDFd) compared to corn stalks (75.8 and 72.2%, respectively). A linear increase (P = 0.02) in NDFd was observed as roughage level decreased with 72.1, 72.9, and 76.9% NDFd for normal, low, or zero roughage levels, respectively. Average daily ruminal pH decreased linearly (P < 0.05) as roughage decreased and measured 5.70, 5.49, and 5.31 for normal, low, or zero roughage levels, respectively. Roughage source did not affect (P > 0.50) ruminal pH. In summary, these data indicate roughages can be exchanged on an equal NDF basis and that roughage levels can be decreased but not removed in feedlot diets containing 30% WDGS.

Wet byproducts allow the use of lower quality roughages because the byproducts contain considerable protein and because the moisture minimizes sorting of all ingredients, especially the lower quality roughages. The lower quality roughages have higher fiber contents so diets should be formulated on the basis of roughage fiber content. Small amounts of roughage, equal to 3 to 4% alfalfa hay, should be included in diets with wet byproducts to ensure good levels of intake and daily gain.

**Other work**

Several posters are presented here on distillers grains, and therefore will not be presented, but only the titles given. The only one that will be focused on is the interaction between grain processing and WDGS inclusion.

Effect of Rumensin® and Tylan® in feedlot diets containing wet distillers grains plus solubles fed to beef steers. N. F. Meyer*1, G. E. Erickson1, T. J. Klopfenstein1, J. R. Benton1, M. K. Luebbe1, and S. B. Laudert2, 1University of Nebraska, Lincoln, 2Elanco Animal Health, Greenfield, IN

Comparison of two grain adaptation systems, one with forage and another using wet corn gluten feed, on ruminal pH, feed intake, and digestibility of feedlot cattle. *Huls*, T. J., N. F. Meyer, G. E. Erickson, T. J. Klopfenstein.


Effect of varying corn price on the economics of two cattle production systems. W.A. Griffin, T.J. Klopfenstein, and G.E. Erickson.

Effect of the grains to solubles ratio in diets containing WDGS and effect of dry-rolled or steam-flaked corn in diets containing WDG. C.M. Godsey, M.K. Luebbe, J.R. Benton, G.E. Erickson, T.J. Klopfenstein.

Grain processing and Distillers Grains

Corn processing in diets containing WDGS appears to be somewhat different than diets containing WCGF or diets without byproducts. In diets containing WCGF, corn processing enhances performance and responds as expected with better feed efficiency for steam flaked corn (SFC) compared to dry-rolled corn (DRC). However, high-moisture corn (HMC) feeding results in even better feed efficiency relative to DRC in diets with WCGF compared to diets without WCGF. Vander Pol et al. (2006) fed diets containing 30% WDGS with either whole, DRC, HMC, a 50:50 blend of HMC and DRC (DM basis), or SFC to calf-feds for 168 days. Cattle fed DRC, HMC, or a combination of HMC and DRC gained more and were more efficient (lower feed conversion) than cattle fed whole corn (Table 2). Interestingly, cattle fed SFC were not as efficient. Corrigan et al. (2007b) investigated feeding DRC, HMC, or SFC in diets containing 0, 15, 27.5 or 40% WDGS. We found greater performance response to WDGS inclusion in diets based on DRC and HMC (Figure 1). Optimal ADG, and F:G were seen with 40% WDGS in DRC based diets, 27.5 to 40% WDGS in HMC based diets, and 15% WDGS in SFC based diets. In addition, when diets contained 40% WDGS with DRC, the cattle performed just as efficiently as cattle on the SFC diets. A greater performance response to WDGS inclusion in diets based on less intensely processed grain may render them an economically attractive alternative to diets based on more intensely processed grains. It is unclear why steam flaking did not improve performance when diets contained WDGS at inclusion levels similar to WCGF inclusion levels.

Table 2. Effect of corn processing when fed with 30% wet distillers grains included in all diets (Vander Pol et al., 2006).

<table>
<thead>
<tr>
<th>Processing method&lt;sup&gt;e&lt;/sup&gt;</th>
<th>Whole</th>
<th>DRC</th>
<th>DRC/HMC</th>
<th>HMC</th>
<th>SFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, lb/d</td>
<td>23.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>21.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21.0&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>20.4&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>ADG, lb</td>
<td>3.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.91&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.89&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.59&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>F:G</td>
<td>6.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.68&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>5.61&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>5.46&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.76&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a,b,c,d</sup> Means with different superscripts differ (P < 0.05).
<sup>e</sup> DRC = dry rolled corn, HMC = high moisture corn, SFC = steam flaked corn, whole = whole corn.
Figure 1. Feed:Gain of WDGS with different corn processing types$^{ab}$.

In a more recent metabolism study to evaluate this interaction, corn processing method (CPM) and wet distiller's grains with solubles (WDGS) level was tested using 7 ruminally-cannulated steers in a 6 period cross-over design to determine effects on digestibility and ruminal fermentation characteristics (Corrigan et al., 2008 PNC abstract). A 3 × 2 factorial arrangement of treatments was used. Diets were based on dry-rolled (DRC), high-moisture (HMC), or steam-flaked corn (SFC) and contained either 0 or 40% WDGS (DM basis). Steers fed 0% WDGS had decreased (P $\leq$ 0.02) intake of DM (18.3 vs. 22.2 lb), OM, NDF (1.08 vs. 2.25 kg), and ether extract (0.27 vs. 0.68 kg) compared to steers fed 40% WDGS. Digestibilities of DM (81.8 vs 77.5%) and OM (84.0 vs. 79.3%) were greater (P $\leq$ 0.08), and digestibility of ether extract (87.0 vs. 90.4%) tended (P = 0.11) to be decreased for steers fed 0% WDGS compared to steers fed 40% WDGS. Ruminal pH change (1.50 vs. 1.25), variance (0.140 vs. 0.087), and maximum (6.50 vs. 6.26) were greater (P $\leq$ 0.09) for steers fed 0% WDGS compared to steers fed 40% WDGS. Steers fed 0% WDGS also had decreased (P = 0.09) DMI per meal (0.91 vs. 1.09 kg) and greater (P = 0.09) acetate:propionate (1.59 vs. 1.23) compared to steers fed 40% WDGS. The observations of greater maximum rumen pH and acetate:propionate in steers fed 0% WDGS are interesting given that they consumed considerably less NDF than steers fed 40% WDGS. There were not clear explanations for the observed interactions we have observed for feedlot performance. We thought starch digestibility may explain the interaction, but it may be related to VFA profiles.

Environmental work

We have recently evaluated feeding WDGS on nutrient balance. Diets containing WDGS in place of corn tend to increase both dietary N (CP) and P. Therefore, we wanted to determine the impact on nutrient mass balance in open-lot pens. Luebbe et al. (2008) reported...
on two experiments conducted to evaluate effects of three dietary inclusions (0, 15, and 30%, DM basis) of WDGS on feedlot performance and nutrient mass balance in open feedlots. Replacing corn with WDGS increased ADG and HCW in both experiments as expected. Feeding WDGS balanced for metabolizable protein (15%) or in excess of requirements (30%) resulted in more OM in the manure but only more manure N in the winter experiment (Table 3). Percentage N loss was not different among WDGS level but the amount of N lost was increased when WDGS were fed due to greater N excretion compared with cattle fed the control diet. Increasing dietary P with WDGS resulted in more phosphorus in the manure (Table 4). Interestingly, this extra P in manure was once a detriment, and may still be a challenge to distribute. However, increasing fertilizer N and P prices has alleviated many nutrient management challenges related to manure. We have a model that adequately addresses this process of determining land area needs, costs of distribution, as well as net return from manure use as a fertilizer (Bremer et al., 2008) and is available on-line at: http://www.puyallup.wsu.edu/dairy/nutrient-management/software.asp under the FNMP$ tool.

Another idea that we have recently tested to decrease N losses was to evaluate the DCAD (dietary cation-anion difference) in finishing diets. A negative DCAD diet (or lower DCAD diets) results in mild metabolic acidosis and decreases urinary pH. The objective of this research was to test whether decreasing dietary DCAD would decrease manure pH (more acidic) and thereby trap more N in the ammonium (NH₄) form which is non-volatile and minimize the amount of NH₃ lost. This reaction normally favors conversion of NH₄ to NH₃ because the NH₃ is lost as it is produced. However, small changes in acidity can slow this reaction.

Fifteen lambs were used in five 3x3 latin squares and eight Holstein steers were used in two 4x4 latin squares to determine the influence of dietary cation-anion difference (DCAD) on urinary and fecal pH, and DMI in high concentrate diets (Luebbe et al., 2008). Urine and fecal samples were collected three times daily for 3 d in both experiments. Lambs were fed a basal concentrate diet (DCAD=8 mEq) with levels of DCAD adjusted using ammonium chloride, ammonium sulfate, calcium chloride, sodium bicarbonate, and potassium carbonate to DCAD levels of 40, 32, 24, 16, 0, -8, -16, -24, and -45 mEq with the basal diet included in every square. Urinary pH decreased for lambs (P = 0.03) from 7.36 to 7.18 throughout the 12 h sampling day. Urinary pH increased linearly with DCAD level (P < 0.01) in all squares for the lambs. Combined DMI from all lamb squares increased linearly (P = 0.02) from 1.04 kg to 1.54 kg with DCAD level for lambs. Basal diets in the two squares for steers were either a corn based diet (DCAD = 8 mEq) or a diet with 20% (DM basis) wet distillers grains (WDG; DCAD= -2 mEq). Calcium chloride and sodium bicarbonate were used to adjust DCAD for steers to -12, -22, -32 mEq in the WDG square, and -2, -12, -22 mEq in the concentrate square. Urinary pH decreased (P < 0.01) for steers throughout the 12 h sampling day from 6.45 to 6.24. Urinary pH increased linearly (P < 0.01) with DCAD level for the steers in both squares. Dry matter intake decreased linearly with DCAD level (P = 0.01) for the steers fed corn but was not different (P = 0.54) in the WDG square. Fecal pH was not different (P = 0.15) among DCAD levels in the steer experiments. Lowering DCAD in high concentrate diets with or without WDGS decreased urinary pH.
Table 3. Effect of feeding 0, 15, or 30% WDGS on nitrogen mass balance during either WINTER or SUMMER feeding periods.a

<table>
<thead>
<tr>
<th>Dietary Treatment b:</th>
<th>0</th>
<th>15</th>
<th>30</th>
<th>SEM</th>
<th>P-value c</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WINTER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N intake d</td>
<td>69.4</td>
<td>79.8</td>
<td>98.4</td>
<td>1.6</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>N excretion d,e</td>
<td>57.1</td>
<td>67.1</td>
<td>85.3</td>
<td>1.6</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Manure N d,f</td>
<td>25.2</td>
<td>24.0</td>
<td>38.1</td>
<td>5.2</td>
<td>0.04</td>
</tr>
<tr>
<td>N Run-off</td>
<td>1.03</td>
<td>1.18</td>
<td>1.72</td>
<td>0.36</td>
<td>0.18</td>
</tr>
<tr>
<td>N lost d</td>
<td>30.9</td>
<td>42.0</td>
<td>45.5</td>
<td>4.6</td>
<td>0.03</td>
</tr>
<tr>
<td>N loss, % g</td>
<td>55.1</td>
<td>63.8</td>
<td>55.0</td>
<td>6.8</td>
<td>0.37</td>
</tr>
<tr>
<td>DM removed</td>
<td>1691</td>
<td>1877</td>
<td>2033</td>
<td>231</td>
<td>0.37</td>
</tr>
<tr>
<td>OM removed d</td>
<td>350</td>
<td>447</td>
<td>480</td>
<td>58</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>SUMMER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N intake d</td>
<td>63.8</td>
<td>78.2</td>
<td>94.6</td>
<td>1.2</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>N excretion d,e</td>
<td>53.6</td>
<td>67.3</td>
<td>83.9</td>
<td>1.1</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Manure N f</td>
<td>19.8</td>
<td>21.3</td>
<td>22.1</td>
<td>5.0</td>
<td>0.89</td>
</tr>
<tr>
<td>N Run-off</td>
<td>2.6</td>
<td>1.9</td>
<td>3.4</td>
<td>1.2</td>
<td>0.53</td>
</tr>
<tr>
<td>N lost d</td>
<td>31.2</td>
<td>44.1</td>
<td>58.4</td>
<td>5.1</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>N loss, % g</td>
<td>58.1</td>
<td>65.6</td>
<td>69.6</td>
<td>7.2</td>
<td>0.15</td>
</tr>
<tr>
<td>DM removed</td>
<td>1140</td>
<td>1167</td>
<td>2208</td>
<td>354</td>
<td>0.02</td>
</tr>
<tr>
<td>OM removed d</td>
<td>216</td>
<td>237</td>
<td>343</td>
<td>45</td>
<td>0.04</td>
</tr>
</tbody>
</table>

a Values are expressed as lb/steer over entire feeding period (167 d for WINTER and 133 d for SUMMER).
b Dietary treatments: 0 = Control corn-based diet with no WDGS, 15 = 15% WDGS (DM basis), 30 = 30% WDGS (DM basis).
c F-test statistic for dietary treatment.
d Linear (P < 0.05) effect of WDGS level.
e Calculated as N intake - N retention.
f Manure N with correction for soil N.
g Calculated as N lost divided by N excretion.

A winter feedlot trial (Midwest ASAS abstract; Luebbe et al., 2008) and summer feedlot trial (National ASAS abstract; Luebbe et al., 2008) were conducted to evaluate the impact of dietary cation-anion difference on performance and N mass balance. Ninety-six steer calves (winter) or 96 yearlings (summer) were used in each experiment and assigned randomly to 12 pens (6 pens/treatment) for each season. Calves were fed for 196 d from November to May and yearlings fed from June to October (145 d). Basal diets consisted of high-moisture and dry-rolled corn, fed at a constant 1:1 ratio (DM basis), 20% wet distillers grains, 7.5% alfalfa, and 5% supplement in both sets of experiments. Calcium chloride and sodium bicarbonate were included in the supplement to adjust dietary cation-anion difference (DCAD) to 20 mEq for the positive (POS) diet and -16 mEq for the negative (NEG) diet. Mass balance for N was conducted similar to many previous experiments.
Table 4. Effect of feeding 0, 15, or 30% WDGS on phosphorus mass balance during either WINTER or SUMMER feeding periods.\(^a\)

<table>
<thead>
<tr>
<th>Dietary Treatment(^b):</th>
<th>0</th>
<th>15</th>
<th>30</th>
<th>SEM</th>
<th>P-value(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WINTER</strong> P intake(^d)</td>
<td>11.5(^i)</td>
<td>14.4(^j)</td>
<td>17.2(^k)</td>
<td>0.3</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Manure P(^d)</td>
<td>6.1(^i)</td>
<td>8.4(^i,j)</td>
<td>9.9(^j)</td>
<td>1.1</td>
<td>0.02</td>
</tr>
<tr>
<td>Run-off P</td>
<td>0.5</td>
<td>0.3</td>
<td>0.4</td>
<td>0.1</td>
<td>0.66</td>
</tr>
<tr>
<td>N:P ratio(^e)</td>
<td>3.06</td>
<td>2.81</td>
<td>2.65</td>
<td>0.36</td>
<td>0.53</td>
</tr>
<tr>
<td><strong>SUMMER</strong> P intake(^d)</td>
<td>11.4(^i)</td>
<td>13.5(^j)</td>
<td>16.0(^k)</td>
<td>0.2</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Manure P(^d)</td>
<td>4.5(^i)</td>
<td>5.7(^i)</td>
<td>9.5(^j)</td>
<td>1.2</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Run-off P</td>
<td>1.0</td>
<td>0.7</td>
<td>0.7</td>
<td>0.4</td>
<td>0.79</td>
</tr>
<tr>
<td>N:P ratio(^d,e)</td>
<td>3.06</td>
<td>4.03</td>
<td>3.95</td>
<td>1.26</td>
<td>0.70</td>
</tr>
</tbody>
</table>

\(^a\) Values are expressed as lb/steer over entire feeding period (167 d for WINTER and 133 d for SUMMER).
\(^b\) Dietary treatments: 0 = Control corn-based diet with no WDGS, 15 = 15% WDGS (DM basis), 30 = 30% WDGS (DM basis).
\(^c\) F-test statistic for dietary treatment.
\(^d\) Linear (\(P < 0.05\)) effect of WDGS level.
\(^e\) Nitrogen to Phosphorus ratio.
\(i,j,k\) Within a row, means without a common superscript letter differ (\(P < 0.05\)).

For the winter trial, DMI was not different (\(P = 0.12\)) among treatments, and ADG was not different among treatments (3.44 and 3.37 lb for NEG and POS, respectively). Gain efficiency was greater (\(P = 0.05\)) for NEG compared with POS (0.179, and 0.167, respectively). Carcass characteristics were not different (\(P > 0.10\)) among treatments. Intake, retention, and excretion of N were not different (\(P > 0.20\)) among treatments. Manure N was not different (\(P = 0.73\)) among treatments (39.0 and 41.4 lb for POS and NEG, respectively). Amount of N lost was similar (\(P = 0.59\)) among treatments (30.8 and 28.4 lb for POS and NEG, respectively). Manure pH was greater (\(P<0.01\)) for POS than NEG (8.80 and 8.52, respectively). Pen surface soil core pH change (initial and final) was greater (\(P < 0.01\)) for POS than NEG (0.31 and -0.005, respectively). Amount of DM and OM removed from pens was similar (\(P > 0.20\)) among treatments.

For the summer trial, DMI was not different (\(P=0.17\)), ADG was not different (\(P=0.82\)) among treatments and was 4.05 and 4.03 lb for NEG and POS, respectively. Gain efficiency was not different (\(P=0.11\)) among treatments and was 0.166 and 0.160 for NEG and POS, respectively. Intake, retention, and excretion of N were not different (\(P>0.10\)) among treatments. Manure N was not different (\(P=0.67\)) among treatments (24.4 and 25.8 lb for POS and NEG, respectively). Percent N lost was not different among treatments (64.6 and 61.3% for POS and NEG, respectively). Manure pH was greater (\(P<0.01\)) for POS than NEG (8.12 and 8.52, respectively). Pen surface soil core pH was not different (\(P=0.29\)) among treatments (8.01 and 8.07 for POS and NEG, respectively). Amount of DM and OM removed from pens was similar (\(P>0.50\)) among treatments. Altering DCAD in diets with wet distillers grains does not change manure and pen surface pH enough to improve N mass balance in open dirt feedlot.
pens. It is likely that the soil has buffering capacity making it difficult to dramatically lower manure pH.

The last area of recent research in the nutrient management area is a comparison of stockpiling manure versus composting. Stockpiling would be the most prevalent manure storage method, but has not been compared to composting in terms of nutrient changes over time (during storage). With fertilizer prices, we wanted to evaluate which method was best at conserving N. Two years of data have been collected comparing these two manure handling methods. During year 1 (Midwest ASAS abstract; Luebbe et al., 2008), the two manure management and storage methods, manure stockpiled anaerobically or composted aerobically, were evaluated during a 104 d storage period. In July, manure from 30 pens was scraped, sampled, and weighed before constructing two anaerobic stockpiles and six aerobic windrows. Windrows were turned on days 14, 42, 59, 69, and 83 while stockpiles were not disturbed. Manure core samples and temperature were collected on d 42, 69, 83, and 104. Nutrient recoveries were calculated using total ash as an internal marker. Ammonium N was measured on samples as-is and after drying for 24 h in a 100°C oven. Total N recoveries were greater (P < 0.01) for stockpiles than compost after 42 d (87.5, and 78.5%, respectively at d 42) and remained that way throughout the experiment (85.7, and 56.4%, respectively at d 104). Organic N was greater (P < 0.01) for compost than stockpiles on d 69, 83, and 104. Ammonium N (% of total N) for fresh samples was greater (P < 0.01) for stockpiles than compost on d 69, 83, and 104 (19.0% and 4.2%, respectively at d 104). Total N recoveries calculated using oven dried samples remained greater (P < 0.01) for stockpiled manure compared with compost after 104 d (73.3% and 60.0%, respectively). Organic matter and organic C recoveries were greater for the stockpile than compost. Recovery of P2O5 was not different (P = 0.83) among storage methods. The N:P ratio was greater (P < 0.01) for stockpiled manure compared with compost on d 69, 83, and 104 due to greater N in manure.

During year 2 (National ASAS abstract, Luebbe et al., 2008), the same treatments were evaluated for a 111 d storage period. In July, manure from 11 open pens was scraped, sampled, and weighed before constructing three anaerobic stockpiles and four aerobic windrows. Windrows were turned on d 14, 35, 61, and 90 while stockpiles were not disturbed. Manure core samples and temperature were collected on d 0, 36, 62, and 111. Dry matter and OM recovery was not different (P>0.70) on d 111. Total N concentration was greater (P<0.01) on d 111 for stockpiled manure than compost (6.0 and 5.0 g/kg DM, respectively). Total N recovery was greater (P<0.01) for stockpiled manure than compost on d 111 (75.8 and 65.6%, respectively). Organic N (% of total N) was greater (P<0.01) for compost than stockpiled manure on d 36, 62, and 111. Ammonium N (% of total N) for fresh samples was greater (P<0.01) for stockpiled manure than compost on d 36, 62, and 111. Nitrate N was greater (P<0.01) for compost than stockpiled manure on d 62 and 111. Total N recoveries calculated using oven dried samples tended to be greater (P=0.10) for stockpiled manure than compost on d 111 (70.5 and 65.0%, respectively). Recovery of P2O5 was not different (P=0.81) for composted and stockpiled manure at d 111 (97.0 and 95.8%, respectively). Concentration of P2O5 was similar (P=0.40) for stockpiled manure and compost on d 111 (9.0 and 8.7 g/kg DM, respectively). The N:P ratio was greater (P=0.01) for stockpiled manure than compost on d 111 (1.54 and 1.32, respectively). For both years combined, when manure samples were dried down completely to simulate hot, dry conditions during field application, the amount of ammonia N lost from stockpiled manure was not great enough to offset the total N recovery advantage of
this method. When evaluated on a nutrient basis, stockpiled manure has greater value as a fertilizer compared with composted manure.

**Literature Cited**


Graduate Student Research Presentations


Cattle are commonly sorted at weaning into different production systems. Our objective was to determine if sorting cattle by BW decreases variation in HCW and decreases overweight carcasses (950 lbs). In both years, steers (n=288/yr) were purchased weaned calves in the fall. All the cattle were assigned randomly into sorted or unsorted groups (n=144/yr). The unsorted group was then assigned randomly to one of three feeding times: calf-fed, summer yearling or fall yearling. The calf-feds were fed from November to May. The summer and fall yearlings grazed cornstalks together through the winter until spring and then grazed cool season grass until May. The summer yearlings entered the feedlot in May and were fed until October. The fall yearlings grazed pasture until September when they entered the feedlot and were fed until January. In the sorted group, the heaviest 1/3 were fed as calf-feds. When the cattle were brought off of grass in May, the heaviest 1/2 of the remaining sorted group were fed as summer yearlings, while the lightest 1/2 went to pasture and then were fed until January. When entering the feedlot, the cattle were assigned randomly to six pens per group per feeding time and pen was experimental unit. Design was a 2 X 3 factorial. There were interactions (P<0.05) for initial feedlot BW and HCW (by design), and for DMI and F:G and percent of carcasses > 950 lbs. Sorted cattle had heavier initial feedlot BW and HCW as calf-feds but lighter as fall yearlings compared to controls. Sorted cattle had fewer overweight carcasses as fall yearlings (9.52% vs. 35.42%) and summer yearlings (2.08% vs. 10.42%), but there were few overweight carcasses among either sorted or control as calf-feds. Unsorted calf-feds had lower F:G than sorted with no differences due to sorting within summer or fall yearlings. Sorting decreased variation of HCW (SD=55 vs. 73 lbs) and number of overweight carcasses without affecting fat thickness or quality grade. When considering time of year the cattle were fed, animals that gained weight on forages before entering the feedlot had a higher initial feedlot BW. As the initial feedlot BW increased, the F:G also increased which resulted in a lower efficiency.


Rising feed costs have forced beef stocker operators to evaluate alternative feeding practices which may reduce their costs of gain. Limit-feeding prior to a period of grazing may provide an opportunity for cost reduction. Highly stressed, crossbred beef steers (n = 329; BW = 191 kg) were fed a high energy diet (NE\textsubscript{G} = 1.12 Mcal/kg) in a drylot at DMI at 2.50% BW, 2.25% BW, 2.00% BW or ad-libitum. Steers were weighed at 14 day intervals and intakes of restricted treatments were adjusted accordingly. ADG for ad-libitum steers was higher (P < 0.05) than all other treatments. Feed:Gain was improved (P < 0.05) by 6% for steers whose intakes were restricted to 2.50% or 2.25% BW. After 45 days of restricted feeding in a drylot and conclusion of the grazing phase, all treatments were fed a common diet at 2.00% of BW for 5 days to reduce the variances in gut-fill. Steers were randomly allotted by weight and treatment and placed on native tallgrass pastures with equal stocking densities for 90 days. Compared to ad-libitum steers, ADG was higher (P < 0.05) during the first 45 days on pasture.
for all drylot-restricted treatments. Off-pasture BW for ad-libitum, 2.50%, and 2.25%
treatments were similar (P > 0.05). The 2.00% restricted treatment weighed significantly less
(P < 0.01) than all other treatments. Restricted feeding practices reduced ADG but improved
feed efficiency during the drylot phase. This research suggests that restricting steers’ DMI to
2.5% or 2.25% BW in a drylot will allow steers to compensate in terms of weight gain during
early intensive grazing.

Zilpaterol-HCl feeding reduces myosin heavy chain mRNA abundance in skeletal muscle
of finishing steers. T. J. Baxa, J. P. Hutcheson, M. F. Miller, W. T. Nichols, M. N.
Streeter, D. A. Yates, and B. J. Johnson. Kansas State University, Manhattan, Intervet Inc.,
Millsboro, DE, and Texas Tech University, Lubbock.

This experiment investigated the effects of zilpaterol-HCl with and without the steroidal
implant Revalor-S (Rev-S) on feedlot performance and mRNA expression of β-adrenergic
receptors (β-AR), insulin-like growth factor I (IGF-I), and myosin heavy chain (MHC)
isoforms I, IIa, and IIx. A total of 2279 (940 lbs) feedlot steers were administered Rev-S (0 vs.
120 mg trenbolone acetate and 24 mg estradiol-17β) on day 0, and fed zilpaterol (0 vs. 7.56
g/ton on a dry matter basis) on day 58. The zilpaterol was fed during the last 30 days with a 3
day withdrawal. The total length of the study was 91 days. Treatments were randomly assigned
to 24 pens. At the completion of the trial, cattle were transported and harvested at a commercial
abattoir. Within 10 minutes of slaughter, semimembranosus muscle tissue was excised from
four randomly selected carcasses per pen. Samples were snap-frozen in liquid nitrogen and
shipped to Kansas State University, where total RNA was isolated. Pen was the experimental
unit. Zilpaterol administration increased (P < 0.01) ADG, G:F, HCW, and REA; decreased (P <
0.01) 12th rib fat depth, and marbling; and improved (P < 0.01) yield grade. There was no
effect (P > 0.10) for zilpaterol feeding on the expression of β1-AR mRNA concentrations;
however there was a tendency (P = 0.09) for Rev-S administration to decrease β1-AR mRNA
levels in skeletal muscle at the end of the feeding period. Treatments did not affect (P > 0.10)
β2-AR mRNA. Administration of Rev-S decreased (P = 0.03) β3-AR mRNA, and zilpaterol
feeding had a tendency (P = 0.07) to decrease β3-AR mRNA. There was no effect (P > 0.10) on
the expression of IGF-I mRNA for any of the treatments. For MHC-I mRNA, there was a
tendency (P = 0.09) for zilpaterol by implant interaction, with zilpaterol decreasing (P = 0.03)
MHC-I mRNA levels. We also observed a zilpaterol by Rev-S interaction (P = 0.05) for MHC-
IIx abundance. Zilpaterol administration decreased (P = 0.01) MHC-IIa, and numerically
decreased MHC-IIx. These data indicate the combined use of zilpaterol and Rev-S additively
contributes to total lean tissue accumulation in finishing feedlot steers. In addition, zilpaterol
feeding reduces the abundance of myosin heavy chain mRNA in skeletal muscle which could
be a consequence of altered protein synthesis and degradation.

Comparable results in performance, carcass merit, and meat quality with the addition of
dry rolled corn or distiller’s grains to flaked corn diets. P.L. Black, G.L. Parsons, M.K.
Shelor, and J.S. Drouillard; Kansas State University, Manhattan.

Crossbred heifers (n=689, 667 ± 71 lb initial BW) were used to evaluate finishing
performance of cattle fed combinations of steam-flaked corn (SFC), dry-rolled corn (DRC), and
dried corn distiller's grains with solubles (DDG). The study was conducted as a randomized
complete block using a 2 x 2 factorial arrangement of treatments. All diets contained SFC, and
factors consisted of the levels (DM basis) of DDG (0 or 25%) and DRC (0 or 25%). Heifers
were individually weighed and blocked into heavy and light groups. Within block, heifers were assigned randomly to pens containing 25 animals each. A total of 7 pens were fed for each treatment. Heifers were fed once daily *ad libitum* for 137 to 157 d. Average daily gain, dry matter intake and feed efficiency were not different among treatment groups (P > 0.05). There were no differences among treatments with respect to HCW, quality grade, yield grade, 12th rib fat thickness, KPH, ribeye area, incidence of liver abscesses, or total carcass value. Heifers fed DRC had greater dressing percentages than their counterparts fed diets without DRC (P < 0.05). Feeding DDG also increased dressing percentage (P < 0.05). To evaluate meat quality, four heifers were randomly selected from 24 pens (3 pens per treatment at each of two harvest points), and the wholesale rib sections were removed from one side of each carcass following a 24-h chill. Steaks (1 in. thick) were evaluated for color shelf life during a 7-day retail display period and lipid oxidation (TBARS). Sensory traits of initial tenderness, juiciness, chewiness, beef flavor, residual connective tissue, mealy texture, fiber awareness, bloody/serumy flavors, metallic flavors, and rancidity were evaluated by a 5-member professional profile panel using a 15-point scale. Steaks from cattle fed the different diets did not differ in color display attributes or TBARS values (P > 0.20). Dry-rolled corn or dried distiller’s grains can replace portions of steam-flaked corn and yield similar feedlot performance, carcass characteristics, and meat sensory attributes.

**Optaflexx impacts protein degradation in the rumen.** C. E. Walker and J. S. Drouillard. *Kansas State University, Manhattan.*

The effects of ractopamine (Optaflexx™, Elanco Animal Health) supplementation on ruminal concentrations of ammonia and free amino acids were evaluated in a completely randomized complete block experiment utilizing a 2 X 2 X 2 factorial arrangement of treatments. Factors consisted of grain processing method (steam-flaked or dry–rolled corn; SFC or DRC); level of dried distiller’s grain with solubles (0% DG or 25% DG, dry basis); and level of Optaflexx (0 or 200 mg/d). Sixteen ruminally fistulated Holstein steers were randomly assigned to the 8 treatment combinations and adapted to their respective diets for 21 d prior to sampling ruminal fluid. Ruminal fluid was collected during a 3-d sampling period; d 1 at 0, 6, 12, 18 h; d 2 at 2, 8, 14, 20 h; d 3 at 4, 10, 16, 22 h. Ruminal fluid was strained through 4 layers of cheesecloth, mixed in a 4:1 ratio with 25% metaphosphoric acid solution, and frozen. Prior to analysis, samples were thawed, thoroughly homogenized, and then centrifuged at 21,000 x g to remove particulate matter. Concentrations of ammonia and amino acids in the supernatant were measured colorimetrically using an autoanalyzer (Technicon III Auto Analyzer). Ruminal NH₃ concentrations were lower when Optaflexx was fed in combination with DRC, but not when fed in conjunction with SFC (Grain processing x Optaflexx, P < 0.01). Addition of Optaflexx, SFC, and DG all resulted in lower ruminal ammonia concentrations (main effects, P < 0.01). Amino acid concentrations were decreased when Optaflexx was added to diets without DG, but were unchanged in diets with DG added (interaction, P < 0.05). Changes in ruminal NH₃ and amino acid concentration with Optaflexx supplementation are dependent on processing method of the grain and the addition of distiller’s grains to finishing diets. The results of this experiment suggest that Optaflexx may influence ruminal degradation of dietary protein, which could have important implications for diet formulation.

Previously we have reported an interaction of corn processing method and wet distiller’s grains with solubles (WDGS) level on G:F in finishing steer diets. Therefore, 7 ruminally-fistulated steers were used in a 6 period cross-over design to determine effects of WDGS inclusion level and corn processing method on digestibility and ruminal fermentation characteristics. A 3 × 2 factorial arrangement of treatments was used. Diets were based on dry-rolled (DRC), high-moisture (HMC), or steam-flaked corn (SFC) and contained either 0 or 40% WDGS (diet DM). No corn processing method × WDGS level interaction was observed in this study (P > 0.10). Steers fed 0% WDGS had lower (P ≤ 0.02) intake of DM (18.4 vs. 22.3 lb), NDF (2.39 vs. 4.97 lb), and ether extract (0.6 vs. 1.5 lb) compared to steers fed 40% WDGS. Digestibilities of DM (81.8 vs 77.5%) and OM (84.0 vs. 79.3%) were greater (P ≤ 0.08), and digestibility of ether extract (87.0 vs. 90.4%) tended (P = 0.11) to be lower for steers fed 0% WDGS compared to steers fed 40% WDGS. Ruminal pH change (1.50 vs. 1.25), variance (0.140 vs. 0.087), and maximum (6.50 vs. 6.26) were greater (P ≤ 0.09) for steers fed 0% WDGS compared to steers fed 40% WDGS. Steers fed 0% WDGS also had decreased (P = 0.09) DMI per meal (0.91 vs. 1.09 kg) and greater (P = 0.09) acetate:propionate (1.59 vs. 1.23) compared to steers fed 40% WDGS. The observations of greater maximum ruminal pH and acetate:propionate in steers fed 0% WDGS are interesting given that they consumed considerably less NDF than steers fed 40% WDGS. Starch digestibility was greater (P = 0.04) for steers fed SFC (99.1%) than for steers fed DRC (95.5%) or HMC (96.5%), and digestibility of ether extract was greater (P = 0.02) for steers fed SFC (88.7%) or HMC (90.8%) than for steers fed DRC (86.5%). Processing also affected ruminal pH with SFC fed steers having greater (P ≤ 0.05) ruminal pH change (1.56) and variance (0.161) compared to steers fed DRC (1.21 and 0.070, respectively) and HMC (1.34 and 0.109, respectively). Maximum ruminal pH was also greater (P ≤ 0.07) for steers fed SFC (6.50) and HMC (6.41) compared to steers fed DRC (6.22). A corn processing method × WDGS level interaction that was approaching significance (P = 0.1044) was observed for rumen propionate concentrations where concentrations were greatest in SFC fed cattle in diets containing 0% WDGS, but concentrations were equal among all corn processing method in diets containing 40% WDGS.


Five hundred-four crossbred heifers (422 ± 34 kg) were utilized to investigate the impact of feeding ractopamine-hydrochloride (RAC; 200 mg·hd⁻¹·d⁻¹) for the last 0, 14, 28, or 42 d prior to slaughter on growth performance and carcass characteristics. Heifers were sorted into one of seven treatment groups (9 hd/pen) by in weight, breed, and body condition scores. Data were analyzed by using a two by three factorial arrangement. Fixed effects included were RAC treatment, time period RAC was fed (TIME; 14, 28, or 42 d), RAC *TIME, day (DAY; -7, 0, 7, 14, 21, 28, 35 or 42), DAY*RAC, DAY*TIME, and DAY*RAC*TIME. Live weight and weight gain as compared to baseline treatments was greater (P < 0.0001) for heifers fed RAC and for control fed heifers. Thirty-six days of RAC supplementation were needed to achieve maximum live weight response. Average daily gain was greater (P < 0.001) for heifers fed RAC as compared to controls (1.32 versus 0.96, kg·hd daily). Interactions between RAC
and TIME were not significant for initial weight, final weight, total gain, and average daily gain. Daily dry matter intake for RAC heifers versus control heifers tended ($P > 0.12$) to be slightly greater (7.80 vs. 7.57 kg). Gain to feed ratio was improved ($P < 0.01$) by 39% by feeding RAC. Feeding RAC 14, 28, or 42 days improved HCW by $2.86$ ($P < 0.23$), $3.64$ ($P < 0.13$), or $8.64$ kg ($P < 0.01$), respectively. Hot carcass weight increased ($P < 0.0001$) as the DOF increased in control and RAC supplemented heifers. Overall heifers receiving RAC had heavier HCW ($P < 0.01$). Fat depth ($P > 0.11$) and yield grade ($P > 0.41$) was similar for RAC and control heifers at days 14, 28 and 42. Marbling score was similar for all treatments ($P > 0.78$). The likelihood of an individual carcass grading Choice or Prime ($P > 0.70$), Select ($P > 0.90$), or sub-Select ($P > 0.10$) was similar for all treatments. These data suggest that RAC increases growth performance and HCW in feedlot heifers.

**Effects of feeding a polyclonal antibody preparation against *Escherichia coli* O157:H7 on performance, carcass characteristics and *E. coli* O157:H7 fecal shedding of feedlot steers.**

Oral doses of avian-derived polyclonal antibody preparations (PAP) against *Streptococcus bovis* or *Fusobacterium necrophorum* were effective at reducing ruminal counts of target bacteria, and improving feed efficiency of feedlot steers. The objective of this study was to determine the effects of feeding a PAP against *E. coli* O157:H7 (PAP-Ec) on performance, carcass characteristics and *E. coli* O157:H7 fecal shedding of feedlot steers. Eighty four Angus and Angus crossbred steers (258 kg initial BW ± 22) were randomly allocated to one of two treatments: PAP-Ec or CTL. Steers received a basal diet (1.39 Mcal NE/kg DM, 12.5% CP, 0.7% Ca, and 0.35% P) comprised of high-moisture corn and dry ground corn (50:50 mix, DM basis), corn silage, and a supplement containing laidlomycin propionate and were supplemented (PAP-Ec) or not (CTL) with 2.5 mL PAP-Ec/d. Individual fecal samples were collected every 28 d for *E. coli* O157:H7 analysis. Steers receiving PAP-Ec tended ($P = 0.06$) to have greater feed efficiency (live basis). Carcass-adjusted feed efficiency did not differ ($P = 0.10$) between treatments. Steers receiving PAP-Ec had greater ($P < 0.05$) fat thickness than CTL. No differences ($P > 0.10$) were observed in *E. coli* O157:H7 fecal shedding at 0, 28, 84 and 165 d on feed. After 56 d on feed, a greater ($P < 0.05$) prevalence of *E. coli* O157:H7 was observed in steers fed PAP-Ec. Steers fed PAP-Ec had a lower ($P < 0.05$) prevalence of *E. coli* O157:H7 after 112 d on feed and tended ($P = 0.06$) to have reduced *E. coli* O157:H7 prevalence after 140 d on feed. The use of an avian-derived polyclonal antibody preparation against *E. coli* O157:H7 in feedlot diets may be a valid intervention to enhance cattle performance and reduce *E. coli* O157:H7 fecal shedding.

**Branched-chain amino acid supplementation in endotoxin-challenged steers.**

Newly received feedlot calves under stress from transportation, processing, and compiling are susceptible to infectious agents. This exposure may activate a calf’s immune system altering metabolism and nutrient requirements. Our previous research demonstrated that calves exposed to a bacterial lipopolysaccharide (LPS) have greater requirements for dietary protein, likely due to increased need for AA to support synthesis of immune system proteins. The objective of this study was to evaluate effects of LPS and branched-chain AA (BCAA) on N balance and blood metabolites of 20 ruminally canulated Angus steers (177 ± 4.2 kg BW).
Treatments were a 2 x 2 factorial of LPS (0 vs ≥1.0 µg/kg BW; -LPS vs +LPS) and BCAA (0 vs 35 g/d; -BCAA vs +BCAA) in a randomized block design, with 14 d for adaptation to metabolism stalls and diet (DM fed = 1.5% BW), and 6 d for collection. The LPS was dissolved in sterile saline (100 mL) and infused (1 mL/min) via an i.v. catheter on d 15. The BCAA were dissolved in an essential AA solution (900 mL) and infused post-ruminally 3 times daily beginning on d 7. Rectal temperatures and blood samples were collected on d 15 at h 0, 2, 4, 8, 12, and 24 after LPS infusion. Feces and urine were collected from d 16 to 20. Rectal temperatures increased from 2 to 4 h, then decreased at 8 h, and were not different at 12 and 24 h after LPS infusion for +LPS vs -LPS steers (LPS x h, *P* < 0.01). Serum cortisol increased 2 h after LPS infusion, peaked at h 4, and was greater for +LPS than -LPS steers at 8, 12, and 24 h thereafter (LPS x h, *P* < 0.01). Serum insulin tended to be greater in +LPS than -LPS steers (LPS, *P* = 0.06). Plasma Ile, Leu, and Val were lower, and His was greater in +LPS vs -LPS steers (LPS, *P* < 0.05). Plasma Met, Lys, Thr and Trp decreased at h 4 and remained lower at 8, 12, and 24 h after LPS infusion for +LPS vs -LPS steers (LPS x h, *P* < 0.05). Steers infused with +BCAA had greater plasma concentrations of Ile, Leu, and Val, and lower plasma concentrations of Met, Thr, His, Phe, and Trp than -BCAA steers at 0 h and 24 h after LPS infusion (BCAA x h, *P* < 0.05). No LPS x BCAA interactions (*P* > 0.24) were observed for N balance (Table 1). Intake, fecal, digested, and retained N were lower (LPS, *P* < 0.05) for +LPS than -LPS steers. Steers receiving +BCAA had greater intake, fecal, and digested N (BCAA, *P* < 0.05), and tended to have greater N retention (BCAA, *P* = 0.11) than -BCAA steers. These findings imply that BCAA may limit tissue deposition of growing steers. However, BCAA supplementation does not alleviate the negative effects of an endotoxin.

### Table 1. Effects of lipopolysaccharide (LPS) and branched-chain AA (BCAA) supplementation on N retention of steers

<table>
<thead>
<tr>
<th>Nitrogen, g/d</th>
<th>-LPS -BCAA</th>
<th>+LPS +BCAA</th>
<th>SEM</th>
<th>LxB*</th>
<th>LPS</th>
<th>BCAA</th>
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<tr>
<td>Intake</td>
<td>64.4</td>
<td>71.2</td>
<td>47.4</td>
<td>63.5</td>
<td>4.58</td>
<td>0.30</td>
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<td>Feces</td>
<td>15.7</td>
<td>18.0</td>
<td>10.2</td>
<td>14.5</td>
<td>1.50</td>
<td>0.49</td>
</tr>
<tr>
<td>Urine</td>
<td>29.7</td>
<td>29.0</td>
<td>30.4</td>
<td>33.5</td>
<td>1.31</td>
<td>0.24</td>
</tr>
<tr>
<td>Digested</td>
<td>48.7</td>
<td>53.1</td>
<td>37.2</td>
<td>49.0</td>
<td>3.30</td>
<td>0.29</td>
</tr>
<tr>
<td>Retained</td>
<td>18.9</td>
<td>24.0</td>
<td>6.5</td>
<td>15.6</td>
<td>3.56</td>
<td>0.64</td>
</tr>
</tbody>
</table>

*Lx*B = Interaction of LPS and BCAA.

### Effect of the grains to solubles ratio in diets containing WDGS and effect of dry-rolled or steam-flaked corn in diets containing WDG.

**C.M. Godsey, M.K. Luebbe, J.R. Benton, G.E. Erickson, T.J. Klopfenstein. University of Nebraska, Lincoln.**

Two experiments were conducted to determine variables affecting cattle performance and carcass characteristics of the by-product, wet distillers grains (WDG) without solubles. WDG utilized in the studies contained 33.6% CP, 10.0% EE, and solubles contain 25.5% CP and 16.1% EE. In Exp.1, diets were designed as a 2 X 3 + 1 factorial arrangement of treatments. Dietary treatments were formulated to contain two WDG (±S) levels (20, or 40%) and three distillers grains to distillers solubles ratios (100:0, 85:15, or 70:30), and one corn control. This equated to solubles replacing 0, 15, or 30% of WDG. WDG (±S) replaced a 50:50 blend of dry-rolled (DRC) and high-moisture (HMC) corn, and all diets contained 7.5% alfalfa and 5% supplement. Three hundred thirty-six crossbred yearling steers (856 ± 31 lbs) were
allocated to one of forty-two pens, with pens assigned randomly to treatment (6 pens/treatment). In Exp. 2, diets were designed as a 2 X 3 + 2 factorial arrangement of treatments. Diets were formulated to contain 0, 20 or 40% WDG (no solubles), replacing either DRC or steam-flaked (SFC) corn. Two additional diets containing SFC and 40% WDG were formulated to contain 11.25 or 15 % alfalfa to see if roughage level would impact cattle performance. One hundred twenty, individually fed, crossbred yearling steers (857 ± 55 lbs) were weighed on 3 consecutive days and allocated to one of eight treatments (15 steers/treatment). In Exp. 1, no WDG level by solubles ratio interaction was observed (P > 0.10). Additionally, there was no main effect of solubles ratio (P>0.05) on cattle performance. However, ADG increased (P=0.02) and F:G decreased (P<0.01) linearly as WDG increased from 0 to 40% diet. In Exp. 2, an interaction between corn processing method and WDG inclusion was observed for ADG (P = 0.09) and F:G (P = 0.02), but not DMI (P = 0.26). In diets containing DRC, ADG responded quadratically (P = 0.02), while there was no effect of WDG inclusion on ADG for diets containing SFC (P > 0.20). Feed conversion also responded quadratically for both diets containing DRC or SFC (P = 0.03). DMI tended to increase as roughage level increased in diets containing 40% byproduct and SFC (P = 0.07). Additionally, F:G tended to increase linearly (P = 0.09) with increasing roughage level. These studies suggest that the solubles ratio inclusion in WDG(±S) does not affect cattle performance. However, corn processing method does interact with distillers grains inclusion in terms of cattle performance, with an observed optimal inclusion of 20% WDG for SFC diets whereas 40% WDG can be fed in DRC based diets. Also, F:G is not enhanced when roughage levels are increased in diets containing WDG and SFC.

Effect of varying corn price on the economics of two cattle production systems.
W.A. Griffin, T.J. Klopfenstein, and G.E. Erickson. University of Nebraska, Lincoln.

Data from the University of Nebraska calf-feeding and long yearling production systems were used to determine the effect of varying corn price on production cost and profitability of each system. The assumption that calf-feeding is a breakeven opportunity was used to determine steer purchase price at corn prices of $2.50, $3.50, and $4.50/bu. Steers entering the calf-feeding system were heavier than steer calves entering the yearling production system (642 vs. 526 lb; P < 0.01). Because calf-feds were heavier at receiving initial steer cost was always higher for calf-feds (P < 0.01). Because of increased length of ownership interest for yearlings was $31.10 (P < 0.01), $28.22 (P < 0.01), and $25.27 (P < 0.01) higher when compared to calf-feds, at corn prices of $2.50, $3.50, and $4.50/bu, respectively. Feed cost increased with increasing corn price and was $45.73 (P < 0.01), $61.31 (P < 0.01), and $76.88 (P < 0.01) higher for calf-feds compared to yearlings at $2.50, $3.50, and $4.50/bu, respectively. Total costs were $29.10 (P < 0.01), $27.04 (P = 0.03), and $26.71 (P = 0.06) higher for yearlings compared to calf-feds when corn price was $2.50, $3.50, and $4.50/bu, respectively. Cost of gain for the entire production system was lower for yearlings compared to calf-feds (P < 0.05) in all corn price scenarios. Profitability was calculated using $90.00/cwt live price. Final value of yearlings was $73.64 (P = 0.02) greater than calf-feds because of greater final BW for yearlings compared to calf-feds (1365 vs. 1265 lb; P < 0.01). Profitability was $43.66 (P = 0.05), $46.53 (P = 0.04), and $47.41/steer (P = 0.02) greater for yearlings compared with calf-feds at corn prices of $2.50, $3.50, and $4.50/bu, respectively. In conclusion, as corn price increases steer cost decreases. Additionally, interest costs decrease and feed costs increase. In all corn price scenarios yearlings were more profitable than calf-

One hundred twenty-eight beef steers (initial BW = 835 lb) were used in a 2 x 2 factorial to evaluate 2 bulk densities of steam-flaked corn (SFC; 26 or 30 lb/bu) and 2 roughage concentrations (6 or 10% coarsely ground alfalfa hay; DM basis) on finishing performance and carcass characteristics. Cattle were blocked by BW and sorted to 32 concrete, partially slotted floor pens (4 steers/pen). Treatments were assigned randomly to pens within 8 blocks, resulting in a total of 8 pens (32 steers)/treatment. The 4 treatment combinations consisted of: (1) 26 lb/bu SFC with 6% roughage (26-6); (2) 26 lb/bu SFC with 10% roughage (26-10); (3) 30 lb/bu SFC with 6% roughage (30-6); and (4) 30 lb/bu SFC with 10% roughage (30-10). Performance and carcass data were analyzed with pen as the experimental unit in a randomized complete block design using the Mixed procedure of SAS. No interactions were observed between bulk density and roughage concentration ($P \geq 0.33$), except for percentage of carcasses grading USDA Choice or greater ($P = 0.07$). Initial BW did not differ ($P \geq 0.21$), final live BW ($P = 0.30$), and carcass-adjusted final BW ($P = 0.51$) did not differ 26 and 30 lb/bu SFC or 6 and 10% roughage. As a result, no differences were observed for ADG between and the 2 bulk densities and the 2 roughage concentrations. From d 0 to 105 ($P < 0.01$) and d 0 to end ($P = 0.04$), cattle fed the 26 lb/bu SFC had greater G:F than those fed 30 lb/bu SFC, with tendencies for improved G:F with the lower flake weight also evident from d 0 to 35 ($P = 0.09$) and d 0 to 70 ($P = 0.10$). Dry matter intake was less by cattle fed 6 vs. 10% roughage concentration from d 0 to 35 ($P = 0.03$) and d 0 to 70 ($P = 0.05$). Hot carcass weight ($P \geq 0.23$), longissimus muscle area ($P \geq 0.78$), 12th rib fat ($P \geq 0.43$), yield grade ($P \geq 0.77$), marbling score ($P \geq 0.48$), and liver abscesses ($P \geq 0.68$) did not differ between the 2 bulk density and 2 roughage concentration treatments; however, cattle fed 10% roughage had a higher dressing percent ($P = 0.01$) and lower KPH ($P < 0.01$) than those fed 6% roughage. Our findings indicate that cattle fed 26 lb/bu SFC were more efficient than those fed 30 lb/bu SFC, and that feeding 6% ground alfalfa as the roughage source tended improve efficiency compared with 10% alfalfa hay. Thus, with the ranges of bulk density and roughage concentration we evaluated, it should be possible to lower cost of gain by feeding 26 lb/bu SFC in conjunction with 6% (DM basis) ground alfalfa hay.


The objective was to evaluate the effects of an extended withdrawal period after feeding the $\beta$-adrenergic agonist zilpaterol HCl for 20 d at the end of the feeding period. Three hundred eighty-four crossbred beef steers were blocked by weight and randomly allocated into 64 pens (6 steers/pen). Pens were assigned to treatments in a 2 x 4 factorial arrangement in a randomized complete block design. Main effects were the addition of 0 (control) or 7.6 g/ton zilpaterol HCl (DM basis; Zilmax) to the finishing diet for 20 d before estimated average slaughter date and
paired withdrawal periods of 3, 10, 17, or 24 d prior to slaughter. Individual BW was measured initially, 1 d prior to Zilmax feeding, and 1 d prior to slaughter. The Zilmax feeding period was initiated so that control cattle in the 3-d withdrawal group would be expected to average 65% USDA Choice quality grade and 0.5 in of fat over the thirteenth rib. Carcass data was collected in a commercial abattoir and sides from the two steers with the median BW from each pen were returned to the laboratory for fabrication and shear force measurements. The Zilmax×withdrawal d interaction was not significant (P≥0.10) for the majority of variables. There was no difference (P≥0.12) due to Zilmax feeding for final BW, carcass adjusted BW, or ADG. As withdrawal d increased, there was an increase (P≤0.008) in final BW and carcass adjusted BW, but a tendency (P=0.07) for decreased ADG over the finishing period and decreased (P=0.03) ADG over the Zilmax plus withdrawal period. When measured for the entire feeding period or the Zilmax plus withdrawal period only, Zilmax steers were more (P≤0.04) efficient than controls. There was a tendency (P=0.09) for a Zilmax×withdrawal d interaction for HCW. Overall, HCW was 837 and 814 lb for Zilmax and control steers, respectively (P<0.001). However, the difference between Zilmax and control was 32, 38, 9, and 14 lb with 3, 7, 10, and 24 d withdrawal, respectively. Feeding Zilmax increased dressing percentage (65.8 vs 64.6%; P<0.001) and LM area (14.7 vs 13.9 in²; P<0.001), but decreased calculated yield grade (2.69 vs 2.91; P=0.03) and percentage of cattle grading USDA choice (34.91 vs 48.21%; P=0.03) compared with controls. The percentage of lean from the chuck (P=0.03), loin (P<0.01), and round (P<0.01) was greater for Zilmax vs control steers. In addition, overall percentage lean (51.48 vs 50.03%; P<0.001) was greater for Zilmax. Warner-Bratzler shear force values were greater (P<0.01) for Zilmax than control across 7, 14, and 21 d aging times. Withdrawal time had no impact on beef tenderness, but tended (P=0.06) to improve at 10 d of withdrawal. In this experiment, the improvements in animal performance and carcass weight due to feeding Zilmax were generally maintained when withdrawal was extended through 24 d.

**Evaluation of the acute phase response in the neonate bovine model following vaccination against Bovine Respiratory Disease Complex.** W. J. Horne*, K. S. Barling†, J. A. Carroll‡, A. D. Herring*, G. A. Holub* and J. E. Sawyer*. Texas A&M University, College Station*, Novartis Animal Health US, Inc, Larchwood, IA†, and USDA-ARS, Lubbock, TX‡.

A study using 7-d old Holstein calves was conducted to determine the effects of viral vaccination on febrile and pro-inflammatory cytokine responses in the neonate. Calves were treated with a multi-valent modified live virus vaccine (Arsenal 4.1®, n = 3; ML) or a multi-valent killed virus vaccine (ViraShield 6®, n = 3; KV) within a week of birth at label dosage. Blood samples and rectal temperatures (RT) were collected 1 h before, hourly for 12 h, at 18, 24, 30, 36, 48, 60, and 72 h after vaccines were administered. Serum was analyzed for tumor necrosis factor-α (TNF-a), interferon-γ (IFN-g), interleukin 1-β (IL-1), interleukin 2 (IL-2), interleukin 4 (IL-4), and interleukin 6 (IL-6). Responses were evaluated as difference from baseline within calf. Data were analyzed as repeated measures with calf as the subject. Time influenced (P < 0.1) all responses except serum IL-4 (P = 0.18). Peak increases in TNF-a, IL-6, and IFN-g occurred at 24 h, with IFN-g falling below baseline at 48 h; IL-6 remained elevated through 60 h. Increased IL-2 was observed at 0, 30, 36, 60, and 72 h after vaccination. Treatment by time interactions occurred for RT (P = 0.04) and IL-1 (P = 0.05). After 6 h, all calves had elevated RT, but the magnitude of increase was greater for calves receiving ML than those receiving KV. Increase in IL-1 was of greater magnitude in the first 12 h for calves
receiving KV, but returned to baseline after 24 h. For those receiving ML, IL-1 increased at 5 and 6 h, returned to baseline, then increased after 30 h. Animals receiving ML had greater increases ($P = 0.07$) in serum IL-4 concentrations than those receiving KV. However, KV inspired greater ($P = 0.02$) increases in IL-6. Both vaccines stimulated cytokine production. The febrile response does not appear to be well correlated with the release of any specific cytokine. Vaccines have differential effects on the magnitude and timing of release of various cytokines. Understanding these differences and immunological sequelae to cytokine release may enhance development of vaccination strategies.

**Comparison of two grain adaptation systems, one with forage and another using wet corn gluten feed, on ruminal pH, feed intake, and digestibility of feedlot cattle. T.J. Huls, N. F. Meyer, G. E. Erickson, and T. J. Klopfenstein. University of Nebraska, Lincoln.**

A metabolism trial was conducted using 8 ruminally fistulated steers (641 ± 42 lbs) to compare decreasing the level of wet corn gluten feed (WCGF; Sweet Bran®, Cargill) for grain adaptation with a traditional grain adaptation system using forages (CON). Steers (4/treatment) were adapted to finishing diets across 5 periods consisting of 5, 7, 7, 7, and 7 d with the last 7d on the finishing diet. The CON adaptation contained supplement and molasses at 5% each with decreasing alfalfa from 45 to 7.5% and increasing corn (DM basis). The WCGF adaptation had supplement and alfalfa hay at 5 and 7.5% of the diet, respectively, with WCGF decreasing from 87.5 to 35% while corn increased (DM basis). Continuous pH and intakes were recorded 4 of 7 d while steers were placed in stanchions. Dacron bags (50 µm pore size) containing both adaptation diets (8/steer) were incubated 24 h in each steer during each period to determine DM digestibility. One steer (on CON treatment) was removed due to acidosis after the third adaptation diet. No period by adaptation diet interactions occurred ($P > 0.60$). Ruminal pH was decreased ($P < 0.05$) and time and area below pH 5.6 was increased ($P < 0.05$) for WCGF compared to CON adaptation systems. However, steers adapted using WCGF had greater DMI than CON ($P < 0.01$). As cattle were adapted to finishing diets, DMI increased ($P = 0.01$) and ruminal pH decreased while time and area below pH 5.6 increased ($P < 0.05$). Ruminal pH for CON steers decreased as corn replaced alfalfa hay from 6.59 to 6.12 while pH decreased from 6.0 to 5.79 for WCGF steers. In Situ DM digestibility had no treatment by incubation diet interactions ($P > 0.18$) for adaptation period 1 and 2 although period 3, 4, and Finisher did ($P < 0.01$). Steers adapted using WCGF had greater in situ digestion than steers adapted using CON. Diets containing WCGF were more digestible than diets containing forage whether inserted in either CON or WCGF fed steers. Decreasing WCGF inclusion instead of forage is a viable method for adapting feedlot cattle to high-concentrate diets based on greater DMI, despite lower pH.

**Relationships between residual feed intake and nutrient digestibilities in growing calves. W.K. Krueger1, G.E. Carstens1, P.A. Lancaster1, L.J. Slay1, J.C. Miller1 and T.D.A. Forbes2. 1Texas A&M University, College Station and 2Texas AgriLife Research, Uvalde.**

The objective of this study was to determine if animal variation in residual feed intake (RFI) in growing calves was associated with variation in apparent nutrient digestibilities and estimates of methane production. A three-year study was conducted with Brangus heifers (N = 114-116/yr) from the Camp Cooley Ranch with initial ages and BW of 232 ± 13 d and 273 ± 27 kg. Heifers were fed a high-roughage diet (ME = 2.1 Mcal/kg DM), and individual DMI and
BW measured for 70 d following a 28-d adaptation period. RFI was calculated as the residual from the linear regression of DMI on mid-test BW^{0.75} and ADG. Within year, heifers were ranked by RFI and those with the lowest (n = 18-20) and the highest (n = 18-20) RFI selected to measure nutrient digestibilities. Daily fecal and ort samples were collected for 7 d and acid insoluble ash used as an internal marker to estimate diet DM (DMD), CP (dCP), NDF (dNDF), and phosphorus (dP) digestibility. Overall mean (± SD) ADG, DMI, and RFI were 0.99 ± 0.18, 9.61 ± 1.62, and 0.04 ± 1.08 kg/d, respectively. RFI was not correlated with ADG or BW but was positively correlated (P < 0.001) with DMI (0.66), and feed:gain ratio (0.66). Heifers with low RFI phenotypes (n = 58) consumed 18% less DMI and had 17% lower feed:gain ratios than heifers with high RFI (n = 57). Heifers with low RFI had higher (P < 0.05) DMD (731 vs. 705 ± 12 g/kg DM), dCP (691 vs. 657 ± 13 g/kg DM), dNDF (670 vs. 642 ± 14 g/kg DM) and tended (P = 0.10) to have higher dP (534 vs 495 ± 16 g/kg DM) than heifers with high RFI. Heifers with low RFI had 25% lower (P < 0.001) fecal DM and N excretions and tended to have lower (P < 0.20) fecal P excretions than heifers with high RFI. Heifers with low RFI had lower (P < 0.001) estimates of methane production (5.8 vs. 6.1 ± 0.06 Mcal CH4, %GE) and less methane per unit of gain (190 vs. 227 ± 7 g CH4/ADG). Results from this study suggest that inter-animal variation in apparent nutrients digestibility and estimates of methane production contribute to observed phenotypic inter-animal variation in RFI. Selection to improve RFI in cattle would be an effective strategy to reduce feed cost and mitigate the environmental impact of beef production systems through reductions in fecal nutrient excretion and methane production.


With the recent approvals of β-adrenergic agonists for beef cattle in the United States, producers now have other options to enhance growth in cattle. Increased knowledge of the magnitude of change in expression of key skeletal muscle genes would allow for more accurate recommendations for use of β-adrenergic agonists in calf-fed Holstein steers. Two experiments were conducted to examine changes on gene expression of calf-fed Holstein steers fed ractopamine-HCl (RAC; Optaflexx; Elanco Animal Health) and zilpaterol-HCl (ZIL; Zilmax; Intervet, Inc.). In experiment 1, 320 calf-fed Holstein steers were fed diets supplemented with 75 mg ZIL per head per d for the durations of 0 d (n = 80), 20 d (n = 80), 25 d (n = 80), and 30 d (n = 80) with a 3 d withdrawal. There were 10 replicates for each treatment (8 cattle per replicate); all treatments were randomly assigned to pens. At harvest, a sample from the semimembranosus muscle was taken from 2 randomly selected steers from 5 randomly selected pens per treatment for a total of 40 samples over a 2 d sampling period. The samples were snap-frozen in liquid nitrogen and then used for mRNA analysis. The expression of calpastatin (CAL) mRNA and three muscle fiber types: myosin I (I), myosin IIA (Iia), and myosin IIX (IIx) mRNA in the ZIL fed steers were compared to the control steers. Results showed that ZIL fed for 20 d, 25 d, or 30 d had no effect (P > 0.05) on the expression of CAL, I, Iia, or IIx in calf-fed Holstein steers compared to control steers. In experiment 2, calf-fed Holstein steers (n = 620; initial bodyweight = 287 lbs) were implanted with Synovex-S (SYN-S; Intervet, Inc.). Steers were then randomly assigned a treatment group of control (n = 290), RAC (200 mg RAC
per steer daily; n = 128), or ZIL (75 mg ZIL per steer daily; n = 290). RAC was fed for 30 d and ZIL was fed for 20 d with a 3 d withdrawal. At harvest, random samples were removed from the semimembranosus muscle of 20 steers from each treatment and snap-frozen in liquid nitrogen. Samples were analyzed for mRNA expression of CAL, I, Iia, IIX, \( \beta \)-adrenergic receptors (\( \beta AR \)): \( \beta \)-adrenergic receptor 1 (\( \beta AR1 \)), \( \beta \)-adrenergic receptor 2 (\( \beta AR2 \)), and insulin-like growth factor-I (IGF-I). Neither RAC nor ZIL had an effect (\( P > 0.05 \)) on the expression of CAL, I, Iia, IIX, \( \beta AR1 \), \( \beta AR2 \), or IGF-I. However, there was a tendency (\( P = 0.09 \)) for ZIL to decrease I. We concluded from these data that RAC or ZIL fed to Holstein steers had no impact on myosin fiber types, CAL, \( \beta AR \) type or IGF-I mRNA expression. These results contradict data from our laboratory obtained from beef-type steers. In several experiments with beef-type steers, administration of ZIL significantly decreased mRNA concentrations for all three myosin isoforms.


A metabolism study was conducted to determine digestibility characteristics for Holstein steers (n = 16, 773 lb BW) with ruminal cannulae fed 0 or 25% (dry basis) dried corn distiller’s grains with solubles (DDG) with dry-rolled corn (DRC) or steam-flaked corn (SFC). Vegetable oil was added to diets without DDG to balance ether extract. The study was a randomized incomplete block design using a 2 x 2 factorial arrangement of treatments in two periods (8 steers/treatment). Periods included a 14-d adaptation followed by a 3-d collection phase. Chromic oxide was intraruminally dosed before feeding for the final 7 days of each period and used to determine total fecal output. Ruminal digesta and feces were collected at 2-h intervals post-feeding. There were no interactions (\( P > 0.10 \)) between grain source and DDG level in terms of differences in digestibility or ruminal VFA concentrations. Compared to DRC, feeding SFC decreased DMI, ruminal pH, and ruminal concentrations of ammonia, acetate, butyrate, isobutyrate, and isovalerate, but increased concentrations of lactate and propionate and increased digestion of organic matter, starch, NDF, and ether extract (\( P < 0.01 \)). Feeding DDG decreased apparent total tract digestion of ether extract (\( P <0.01 \)) and tended to decrease OM digestion (\( P <0.10 \)). Ruminal ammonia concentrations were lower for cattle fed diets with DDG (\( P < 0.05 \)) compared to those without DDG. In general, effects of DDG addition to finishing diets were not markedly influenced by grain processing.

| Table 1. Apparent total tract digestibility for steers fed SFC or DRC with DDG |
|---------------------------------|--------|--------|--------|--------|--------|--------|--------|
| Item                           | DRC    |        | SFC    |        | P-Values |        |        |
|                                | 0% DDG | 25% DDG | 0% DDG | 25% DDG | SEM     | Grain | DDG  | Grain* DDG |
| DM                             | 78.84  | 77.71   | 85.30  | 82.88   | 1.49    | <0.01 | 0.11  | 0.56     |
| OM                             | 79.80  | 78.88   | 86.88  | 84.20   | 1.44    | <0.01 | 0.10  | 0.43     |
| Starch                         | 88.99  | 89.60   | 98.56  | 98.84   | 1.57    | <0.01 | 0.94  | 0.65     |
| NDF                            | 17.09  | 29.14   | 47.10  | 46.42   | 6.25    | <0.01 | 0.22  | 0.20     |
| Ether Extract                  | 92.27  | 88.44   | 93.58  | 91.60   | 0.82    | <0.01 | <0.01 | 0.20     |

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Ruminal parameters and quantitative detection of bacterial genomes following intraruminal dosing of cattle with a placebo or live cultures of *Megasphaera elsdenii* strain NCIMB 41125. Reid McDaniel¹, Jessie Heidenreich¹, Pieter Henning², and Jim Drouillard¹. ¹Kansas State University, Manhattan and Kemira ²GrowHow, Centurion, South Africa.

A metabolism study was conducted to evaluate ruminal parameters in cattle intraruminally dosed with 0, 1.62x10⁹, 1.62x10¹⁰, or 1.62x10¹¹ colony forming units (CFU) of *Megasphaera elsdenii* strain NCIMB 41125 following an abrupt change from an all-forage diet to a concentrate diet. Angus steers (n=20; average BW=558 lbs) fitted with ruminal fistulas were blocked by BW and assigned randomly to treatments. Cattle were allowed free access to alfalfa hay and water, which were removed for 24 hours prior to administering treatments. *Megasphaera* treatments were dosed via the rumen cannula as a liquid suspension containing 10⁹ viable cells/mL of *M. elsdenii* strain NCIMB 41125. The placebo consisted of 100 mL of autoclaved culture. On the morning of the diet change, cattle were administered their treatments and then allowed free access to a diet consisting of 34% alfalfa hay and 66% steam flaked corn-based concentrate. Ruminal pH and concentrations of lactate and VFAs were monitored following introduction of the concentrate diet. Ruminal samples were collected at 0, 2, 4, 6, 8, and 24 h after feeding for quantitative rt-PCR detection of total population of *M. elsdenii*, as well as total bacterial genomes. Capacity for metabolism of lactic acid was evaluated by inoculating 0.2 mL of strained ruminal fluid into anaerobic culture tubes containing 15 mL of semi-defined lactate media. Tubes were incubated at 102.2°F, and turbidity changes were determined by measuring absorbance at 2-h intervals for 12 h. Ruminal lactate concentrations increased in response to the diet change (P<0.05), but concentrations were lower for cattle that received *M. elsdenii* compared to the placebo group (P<0.05). Compared to the placebo group, cattle administered *M. elsdenii* maintained higher ruminal pH 24 h after feeding the concentrate diet (P<0.05). Total number of bacterial genomes 24 h after inoculation was unaffected by intraruminal dosing of *M. elsdenii* strain NCIMB 41125 (P > 0.05). Populations of total *M. elsdenii* in the cattle that received live cultures increased by 24 h after inoculation (P < 0.05). Turbidity of cultures containing lactate media increased in response to *M. elsdenii* administration (P < 0.05), suggesting a greater capacity for lactate utilization in inoculated cattle compared to the placebo group. Inoculating cattle with *M. elsdenii* before introduction of a concentrate diet is effective in bolstering populations of ruminal lactate utilizers, and may reduce the risk of acidosis by preventing accumulation of lactic acid and avoiding severe depressions in ruminal pH.

Effect of Rumensin® and Tylan® in feedlot diets containing wet distillers grains plus solubles fed to beef steers. N. F. Meyer¹, G. E. Erickson¹, T. J. Klopfenstein¹, J. R. Benton¹, M. K. Luebbe¹, and S. B. Laudert², ¹University of Nebraska, Lincoln and ²Elanco Animal Health, Greenfield, IN.

The objective of this study was to evaluate the effects of Rumensin and Tylan in feedlot diets containing wet distillers grains plus solubles. Eight hundred beef steers (725 ± 55 lb) were blocked by initial BW and randomly assigned to one of five treatments (20 steers per pen, 8 pens per treatment). Treatments consisted of a corn-based diet with Rumensin and Tylan (CORN+RT) and four treatments with 25% wet distillers grains plus solubles (DG) and either
33.3 g/ton (R) or 44.4 g/ton (HIR) of Rumensin and Tylan (T) at 90 mg•hd⁻¹•d⁻¹. Compared to CORN+RT, steers fed DG+RT gained more, were more efficient (P<0.05), and had similar DMI (23.5 vs. 23.4 lb). Feeding Rumensin increased G:F by 3.1% and Rumensin plus Tylan increased G:F by 4.9% when compared to DG alone (P<0.05). With the exception of dressing percentage, there were no differences in performance or carcass characteristics when Rumensin was fed at 33.3 compared to 44.4 g/ton. Total liver abscesses were significantly greater for DG (42.4%) and DG+R (40.8%), compared to treatments containing Tylan, CORN+RT (17.0%), DG+RT (8.3%), and DG+HIRT (8.9%). Severe liver abscesses were also less for diets containing Tylan (P<0.05). This study indicates that steers fed Rumensin and Tylan in diets containing wet distillers grains plus solubles results in improved feed efficiency and decreased liver abscesses compared to similar diets without these feed additives.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Statistics</th>
</tr>
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<tbody>
<tr>
<td>CORN+ RT</td>
<td>DG</td>
</tr>
<tr>
<td>Final BW, lb¹</td>
<td>1294ᵃ</td>
</tr>
<tr>
<td>DMI, lb</td>
<td>23.5ᵃᵇᶜ</td>
</tr>
<tr>
<td>ADG, lb¹</td>
<td>3.72ᵃ</td>
</tr>
<tr>
<td>G:F</td>
<td>0.159ᵃ</td>
</tr>
<tr>
<td>F:G²</td>
<td>6.31</td>
</tr>
</tbody>
</table>

Liver Abscesses

| Total, %            | 17.0ᵃ                   | 42.4ᵇ                   | 40.8ᵇ                   | 8.3ᵃ                   | 8.9ᵃ     | 3.0   | <0.01  |
| A+, %               | 4.4ᵃ                   | 16.5ᵇ                   | 19.1ᵇ                   | 3.8ᵃ                   | 7.0ᵃ     | 2.2   | <0.01  |

ᵃᵇᶜWithin a row means without a common superscript letter differ (P < 0.05).
¹Calculated from carcass weight, adjusted to a common 63% dressing percentage.
²Statistical analysis reported for G:F only.


This research was conducted to determine the effect fall stocking rate (SR) of small grain pastures has on animal performance during the fall and subsequent spring for 3 establishment methods including: 1) no-till (NT) seeding into undisturbed stubble, 2) reduced-till (RT) - disking once followed by broadcast seeding, and 3) conventional-till (CT) – drilling into a prepared seedbed. Soft-red winter wheat was sown in the first week of September at a rate of 136kg/ha. Goals for residue cover were 85%, 50%, and < 15% for NT, RT, and CT, respectively. During the fall, 60 steers (BW = 255 ± 4.0 kg) were stocked at 1.85, 2.47, and 3.70 steers/ha (n = 2 pastures/SR and establishment method) and grazed from 31 October until 2 or 14 February (depending on forage availability). During the spring, 180 steers (BW = 237 ± 2.9 kg) were placed on all pastures at 7.4 steers/ha and grazed from 28 February until 4 or 10 April (depending on forage availability). Grazing was initiated in the fall when forage reached 20 cm and terminated when forage allowance dropped below 1,000 kg/ha. Data were analyzed using the mixed procedure of SAS. Forage availability (kg DM/ha) was affected (P < 0.01) by
tillage treatment and a tillage treatment by SR interaction in October and December. In October, pastures established by NT produced more \((P < 0.01)\) forage DM in pastures stocked at 3.70 and 2.47 steers/ha, but forage DM availability was not different \((P \geq 0.13)\) among tillage treatments in pastures stocked at 1.85 steers/ha. In December, NT pastures stocked at 3.70 steers/ha produced 473 kg more \((P \leq 0.02)\) forage DM than pastures established by CT and RT, while at the 2.47 steers/ha SR there was no difference \((P \geq 0.23)\) forage DM availability among tillage treatments. Pastures established by CT at the 1.85 steers/ha SR had 454 kg/ha greater \((P = 0.01)\) forage DM available than RT. In January, pastures established by NT contained 544 kg/ha more \((P < 0.01)\) available forage DM than CT, and pastures stocked at 3.70 steers/ha contained less \((P < 0.01)\) available forage DM than pastures stocked with 2.47 or 1.85 steers/ha. Tillage treatment did not affect \((P \geq 0.27)\) available forage DM during spring grazing. Fall BW gain and ADG were not affected \((P \geq 0.17)\) by establishment method or the establishment method x SR interaction, but as SR increased from 1.85 to 3.70 steers/ha there were linear \((P < 0.01)\) decreases in BW gain (144, 121, and 103 \(\pm 4.8\) kg, respectively) and quadratic \((P = 0.05)\) decreases in ADG (1.35, 1.15, and 1.18 \(\pm 0.05\) kg, respectively). During the spring, there was an interaction \((P = 0.04)\) between SR in the fall and establishment method for BW gain and ADG. At the 3.70 steers/ha SR, BW gain and ADG during the spring grazing period for NT (42 and 1.03 kg, respectively) and CT (37 and 0.90 kg) were greater \((P \leq 0.04)\) than RT (25 and 0.66 kg), but at the 1.85 and 2.47 steers/ha SR, establishment method had no effect \((P \geq 0.07)\) on BW gain or ADG. Gain/ha was not affected \((P \geq 0.09)\) by SR, establishment method, or the interaction. But BW gain/ha tended to increase \((\text{quadratic}, P = 0.09)\) with SR (607, 564, and 647 kg/ha, respectively). Based on this data, pastures established by NT or CT can be stocked at 3.70 steers/ha in the fall with no effect on animal performance during the spring. The most economically efficient tillage system and SR would thus be based on cost of production and value of BW gain.

### Effect of estradiol-17β, trenbolone acetate or the combination on adipogenic gene expression in finishing steers.

**S.L. Parr, K.Y. Chung, T. J. Baxa, L.D. Luque, and B.J. Johnson. Kansas State University, Manhattan.**

Crossbred steers \((n = 20; BW = 926 \text{ lb})\) were used to determine the effect of estradiol-17β \((E_2)\), trenbolone acetate \((TBA)\) or the combination on adipogenic gene expression in the longissimus thoracis muscle. Steers were stratified by BW and split into 5 groups based on BW. Within each group, steers were randomly assigned to treatment. Treatments were 1) no implant; 2) Compudose \((25.7 \text{ mg} \ E_2)\); 3) Finaplex-H \((\text{four pellet were removed; 120 mg TBA})\); and 4) Revalor-S \((24 \text{ mg} \ E_2 \text{ and 120 mg TBA})\). Initiation of experiment occurred upon implanting \((d \ 0)\) and BW were measured on \(d \ 0, 7, 14 \text{ and } 28\). A tissue sample from the longissimus thoracis muscle was collected on respective weigh days for analysis of CCAAT/enhancer binding protein \(\beta \) \((C/EBP\beta)\), peroxisome proliferators-activated receptor \(\gamma \) \((PPAR\gamma)\), and stearoyl CoA \((SCD)\) mRNA concentrations. Steers were housed in individual pens and DMI was measured for each steer. Diet \((\text{NEm} = 94.8; \text{NEg} = 64.6 \text{ Mcal/lb})\) was common among all treatments. During the 28 day period ADG \((\text{mean} = 3.4 \text{ lb})\), DMI \((\text{mean} = 18.8 \text{ lb})\), and feed to gain \((\text{mean} = 5.9 \text{ lb/lb})\) did not differ \((P > 0.10)\) among treatment. Since the number of steers per treatment was limited and performance was measured for only 28 days, the influence of implants on feedlot performance could not be effectively demonstrated. However, the effect of implants on adipogenic gene expression can be demonstrated at the cellular level. Total C/EBP\(\beta\), PPAR\(\gamma\), and SCD mRNA concentrations were greater \((P < 0.05)\)
at d 28 compared to d 0. Steers implanted with Revalor-S had lower \((P < 0.06)\) PPAR\(\gamma\), C/EBP\(\beta\), and SCD mRNA compared to control steers. Concentrations of C/EBP\(\beta\) and SCD mRNA did not differ \((P > 0.10)\) among steers implanted with Compudose, Finaplex or non-implanted steers. Adipogenic gene expression in the longissimus thoracis muscle as indicated by C/EBP\(\beta\), PPAR\(\gamma\), and SCD mRNA abundance increased with increasing days on feed. The combination of E\(_2\) and TBA in steers inhibited adipogenic gene expression compared to non-implanted steers or E\(_2\) only treated steers.

**Glycerin improves performance of feedlot heifers when fed at low levels.**  
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The objectives of this study were to determine the effects of glycerin on performance and carcass traits, and to establish optimal feeding levels in finishing heifers. Crossbred heifers \((n=373; \text{929 lbs } \pm \text{63}.9)\) were fed finishing diets containing 0, 2, 4, 8, 12, or 16\% crude glycerin (DM basis). Diets consisted of steam-flaked corn with 6\% alfalfa hay and 1.2\% urea, and provided 300 mg monensin, 90 mg tylosin, and 0.5 mg melengestrol acetate per animal daily. Cattle were stratified by body weight and allocated randomly, within strata, to concrete-surfaced feedlot pens containing 6 to 7 heifers each with 9 pens per dietary treatment. Cattle were transitioned from the control diet to diets containing increasing proportions of glycerin over a period of 10 days. Cattle had \textit{ad libitum} access to feed, and diets were delivered once daily throughout the 85-d trial period. DMI decreased linearly as the level of glycerin increased \((P < 0.01)\). ADG were 2.63, 2.95, 2.85, 2.76, 2.58, and 2.26 lbs/d for heifers fed 0, 2, 4, 8, 12, and 16\% glycerin, respectively \((\text{Lin, } P < 0.01; \text{Quad, } P < 0.01)\). Feeding glycerin had a quadratic effect on efficiency of gain, and was optimal when fed at the 2\% of the diet \((\text{Quad; } P < 0.01)\). Glycerin increased final body weights by 27.9, 17.8, and 11.7 lbs when fed at 2, 4, and 8\% of the diet, respectively, but reduced final body weights by 4.3 and 31.5 lbs when included at 12 and 16\% of the diet \((\text{Lin, } P < 0.01; \text{Quad, } P < 0.01)\). Similarly, HCW increased by 17.8, 11.3, and 7.3 lbs when glycerin was added at 2, 4, and 8\% of the diet respectively, but were 2.7 and 20.0 lbs less than controls when glycerin was fed at 12 and 16\%, respectively \((\text{Lin, } P < 0.01; \text{Quad, } P < 0.01)\). Longissimus muscle area decreased linearly as glycerin levels increased \((P < 0.05)\). Feeding glycerin resulted in linear decreases in subcutaneous fat over the 12\textsuperscript{th} rib and marbling scores \((P < 0.01)\). Glycerin tended to decrease the percentage of cattle grading USDA Choice \((P < 0.10)\) and increased the percentage of cattle grading USDA Select. Adding glycerin to cattle finishing diets improved weight gain and efficiency, particularly when added at levels of 8\% or less of the diet dry matter.

**A revised analysis to estimate total internal fat in beef cattle using live animal and carcass measurements.**  
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The objective of this study was to revise a system that was developed to assess total internal fat (IFAT) based on a technique that measures kidney, pelvic and heart fat depth using real-time ultrasound (\textit{uKFd}) or a linear measurement on the carcass (\textit{cKFd}). Data for this study were obtained from 92 animals (16 bulls, 16 heifers and 60 steers) from 3 trials. Ultrasound measurements were taken 7 d prior to slaughter and measurements consisted of 12 to 13\textsuperscript{th} rib fat thickness and uKFd. The uKFd was measured in a cross-sectional image collected between the first lumbar vertebra and the 13\textsuperscript{th} rib. An equation to estimate IFAT was developed with the PROC REG procedure of SAS with a stepwise selection using KPH weight, cKFd,
carcass back fat (cBF), uKFd and ultrasound back fat (uBF). The selected equation had KPH weight, cKFd, and cBF with an $r^2$ of 0.93 and root mean square error (RMSE) of 2.58 kg. The relationship between cKFd and uKFd had an $r^2$ of 0.72, and a RMSE of 1.5 cm. A linear regression between iFat and uKFd and uBF (IFAT = -7.07197 + 21.57037×uBF + 1.09083×uKFd) yielded an $r^2$ of 0.75 and RMSE of 4.75 kg. Similarly, we used the PROC MIXED procedure to perform a meta-analyzes to estimate IFAT using uKFd and uBF. The fixed effect factors equation was IFAT = -11.0148 + 1.6115×uKFd + 17.0046×uBF. This equation explained 78 % of the variation and had a RMSE of 4.22 kg. This result shows that cKFd can be predicted with ultrasound and that IFAT can be estimated using uKFd in bulls, heifers and steers. This technique might improve our ability to estimate total body fat in beef cattle and could be used to better formulate feedlot ration, improve animal sorting, and assist in genetic selection programs.

Effects of on-arrival versus delayed clostridial or modified-live respiratory vaccinations on health, performance, bovine viral diarrhea type I titers, and physiological and immunological measures in high-risk, newly received beef calves. J. T. Richeson1, E. B. Kegley1, M. S. Gadberry2, P. A. Beck3, J. G. Powell1, and C. Jones4, 1University of Arkansas, Fayetteville, 2University of Arkansas, Little Rock, 3University of Arkansas, Hope, and 4Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO.

Stress commonly associated with weaning, marketing, and shipment of feeder cattle can compromise immune function, and vaccine administration during immunosuppression may reduce vaccine efficacy and calf growth. Four treatments were compared in a 2 × 2 factorial arrangement to evaluate the effect of on-arrival (d 0) vs. delayed (d 14) administration of 7-way clostridial (Alpha® 7, Boehringer-Ingelheim Vetmedica, Inc. [BIVI]; CLOS) and modified live viral respiratory (Express® 5, BIVI; RESP) vaccines. Crossbred calves (n = 263) were weighed (238 ± 1.2 kg), stratified by gender, and assigned randomly to vaccination treatment: 1) arrival CLOS, arrival RESP (ACAR), 2) arrival CLOS, delayed RESP (ACDR), 3) delayed CLOS, arrival RESP (DCAR), and 4) delayed CLOS, delayed RESP (DCDR). Gain did not differ ($P = 0.74$) averaging 0.98, 0.93, 0.95, and 0.91 kg/d for ACAR, ACDR, DCAR and DCDR, respectively for the entire 56-d trial. Vaccination timing did not affect morbidity ($P = 0.49$); however, there tended to be CLOS ($P = 0.07$) and RESP timing effects ($P = 0.09$) on d to initial bovine respiratory disease (BRD) treatment episode. Average d to initial BRD treatment were less for ACAR (6 ± 0.8 d) compared to DCDR (8 ± 0.8 d; $P = 0.01$). Serum cortisol concentrations were greater ($P \leq 0.01$) on d 0 than 14 or 28 but no treatment × day interaction ($P = 0.21$) was observed. RESP timing affected ($P = 0.001$) serum BVD titer levels, with greater ($P < 0.01$) levels in calves administered RESP vaccine on arrival. Delaying CLOS or RESP vaccination did not affect gain or morbidity in high risk, newly received stocker calves. Calves administered RESP vaccine on d 0 developed antibody titers to BVD earlier than delayed RESP treatments.
A comparison of a single vaccination to vaccination and revaccination with a modified live IBRV-BVDV (type 1 and 2)-PI3V-BRSV vaccine in the prevention of bovine respiratory disease. L. O. Burciaga-Robles\textsuperscript{1}, D.L. Step\textsuperscript{1}, C. R. Krehbiel\textsuperscript{1}, B. P. Holland\textsuperscript{1}, R. W. Fulton\textsuperscript{1}, A. W. Confer\textsuperscript{1}, D. T. Bechtol\textsuperscript{2}, D. Brister\textsuperscript{3}, J. P. Hutcheson\textsuperscript{3}, H. Newcomb\textsuperscript{3}. \textsuperscript{1}Oklahoma State University, Stillwater, \textsuperscript{2}Palo Duro Consultation, Research, and Feedlot, Canyon, TX, and \textsuperscript{3}Intervet, Millsboro, DE.

The objective was to evaluate the effect of a modified live viral vaccine (MLV; Vista 5\textsuperscript{®}, Intervet) with or without revaccination on d 11 on health and performance of calves. Six-hundred twelve crossbred male calves (483±52 lb) were stratified by BW and assigned to one of two treatments in a randomized complete block design (n=12 pens/treatment). Treatments were: 1) VAC: calves received a MLV on arrival; and 2) REVAC: calves that were vaccinated received a second dose of the same vaccine on d 11. After the completion of the preconditioning phase, 8 pens (4 pens/treatment) were shipped to a feedlot for finishing. On arrival, steers from each preconditioning treatment were assigned to: 1) vaccination with Vista 5\textsuperscript{®}; and 2) no MLV vaccination. This resulted in a 2×2 factorial arrangement of treatments during the finishing phase. Steers were fed in pens containing the GrowSafe System (Airdrie, AB, Canada). In addition, a PI BVDV steer was placed into each pen. There was no difference (P>0.10) in ADG, DMI, or F:G during the preconditioning period. BRD morbidity was greater (P=0.04) for REVAC compared with VAC; however, days on feed at first BRD treatment were not different (P=0.46). In addition, no differences in treatment success rate (P=0.67) or mortality (P=0.64) were detected. No differences (P>0.10) in BW, ADG, or DMI among treatments were observed during the finishing phase. REVAC steers had improved (P=0.02) F:G regardless of vaccination protocol in the finishing phase. Results suggest that a single vaccination was as efficacious as vaccination followed by revaccination with a MLV vaccine in high-risk calves, although feed efficiency was improved in the revaccinated group during the finishing period.

Impact of gastrointestinal parasites on antibody titer responses to vaccination and IBR challenge. J. Schutz\textsuperscript{1}, E. Sharman\textsuperscript{1}, N. Davis\textsuperscript{1}, T. Engle\textsuperscript{1}, T. Shelton\textsuperscript{2}, S. Nordstrom\textsuperscript{2} and J. Hutcheson\textsuperscript{2}. \textsuperscript{1}Colorado State University, Fort Collins, and \textsuperscript{2}Intervet Inc., Millsboro, DE.

Thirty-three colostrum deprived Holstein bull calves (initial BW of 131.34 kg ± 4.24) were utilized to determine the impact of timing of anthelmintic administration relative to vaccination on antibody titer response to vaccine components and subsequent rectal temperature and antibody response to an IBR challenge. Bull calves came from a single local dairy upon birth and serum titer counts were analyzed to ensure they were colostrum deprived. When all bull calves were at least three months of age they were randomly sorted into individual pens and placed into one of three treatment groups. Treatments consisted of: 1) dewormed 2 weeks prior to vaccination (DPV); 2) dewormed at the time of vaccination (DV); and 3) Control – not dewormed (CONT). All treatments were inoculated with infective larvae of brown stomach worms (Ostertagia ostertagi) and intestinal worms (Cooperia spp.) on d 1, 7, 10, 14, and 18 for a total dose of 235,710 infective larvae per calf. The DPV group was dewormed with a 10% fenbendazole suspension at 5 mg/kg BW two weeks prior to vaccination. On d 35, all treatments were vaccinated and DV calves were dewormed at the time of vaccination. Weekly fecal egg counts, blood, and rectal temperatures were collected throughout the experiment and intake and health status were recorded daily. Blood samples were obtained weekly for serum neutralizing antibody titers to IBR, BVDV 1, BVDV 2, and
PI-3. By design control animals had greater (P < 0.0001) fecal egg counts during the experiment. All treatment groups had elevated titers for IBR, BVDV 1, BVDV 2, and PI-3 by d 15 post vaccination. Animals dewormed at the time of vaccination had higher (P < 0.001) titers to BVD 1. On day 88 all calves were challenged with IBR (4 ml of 1.8 x 10^7 CCID) and blood samples were obtained on d 0, 1, 3, 4, 6, 8, 10, and 12 post inoculation. Post IBR inoculation all groups showed increased rectal temperatures. The CONT group had greater (P < 0.05) rectal temperatures than DPV and DV on d 88, 89, and 97. All groups had elevated titers for IBR, BVD 1, and BVD 2 during the challenge. Additionally, all treatment groups had increased rectal temperatures during the final 7 days of the IBR challenge. Therefore, it can be concluded that deworming prior to or at vaccination reduced parasite burden and decreased rectal temperature elevation following an IBR challenge in animals.


Two hundred and sixteen Angus crossbred steers purchased from sale barns (230 kg ± 3.6) were utilized to determine the impact of cobalt concentration on performance, carcass characteristics, blood and tissue metabolites, and lipid metabolism in steers. Steers were stratified by body weight and housed in 9-head pens. Pens were then randomly assigned to trace mineral treatments. Treatments during the finishing trial consisted of: 1) Control (no supplemental Co); 2) 0.10 mg Co/kg DM from cobalt glucoheptonate; 3) 1.0 mg Co/kg DM from cobalt glucoheptonate. On d 0, 56, 112, 168, 196, and 197 of the finishing phase, steers were individually weighed. On d 0, 56, and 196 of the finishing phase, steers were also bled for the determination of methylmalonic acid, serum vitamin B12, and glucose concentrations. Standard carcass data was collected on d 197 and a longissimus muscle sample was obtained from each steer post harvest for fatty acid analysis and a liver sample was obtained for the determination of methylmalonyl-CoA mutase activity. During the finishing phase, initial and final body weight, DMI, and feed efficiency were similar across Co treatments. Overall ADG tended (P < 0.06) to be higher for steers receiving 1.0 mg Co/kg DM (1.65, 1.62, 1.71 kg ± 0.03 for control, 0.10 mg Co/kg DM, 1.0 mg Co/kg DM treatments, respectively). Hot carcass weight, DP, marbling score, LM area, and fatty acid composition were similar across treatments. Steers receiving 1.0 mg Co/kg DM had higher YG (P < 0.04; 2.53, 2.29, 2.73 ± 0.11 for control, 0.10 mg Co/kg DM, 1.0 mg Co/kg DM treatments, respectively) and back fat thickness (P < 0.04; 1.54, 1.39, 1.71 cm ± 0.08 for control, 0.10 mg Co/kg DM, 1.0 mg Co/kg DM treatments, respectively) than steers receiving 0.10 mg Co/kg DM. Serum, liver, and longissimus muscle B12 concentrations increased (P < 0.04) as dietary Co concentration increased; however plasma glucose concentration, methylmalonyl-CoA concentration, and methylmalonyl-CoA mutase activity were similar across treatments.


Three hundred and fifty heifer calves were purchased and comiled in western Kentucky, and then delivered to the Oklahoma State University Willard Sparks Beef Research Center. Prior to being delivered, calves were dosed with a remote monitoring rumen

Ruminal pH is typically lower in cattle fed flaked grain diets compared to cattle fed rolled grain diets. It is plausible that low ruminal pH may influence digestibility of distiller’s grains when added to flaked grain diets. In vivo and in vitro studies were conducted to evaluate this hypothesis. In trial 1, ruminal fermentation characteristics and diet digestibility were examined in cannulated Holstein steers (n = 12; BW 487 ± 18 kg) fed flaked corn finishing diets with or without corn dried distiller’s grains with solubles (DDG), using alfalfa hay (AH) or corn silage (CS) as roughage sources. The study was a randomized incomplete block design with a 2 × 2 factorial arrangement of treatments. Factors were DDG level (0 or 25% DM) and roughage source (6% AH or 10% CS, DM basis). The study was conducted in two periods, each consisting of a 17-d adaptation phase and 3-d collection phase, with 3 cattle assigned to each treatment in each period. Ruminal digesta samples were collected at 2-h intervals after feeding, and were used to determine ruminal pH and ruminal concentrations of ammonia, VFAs, and lactate. Fecal samples were taken at each sampling point, pooled within animal and period, and used to determine total fecal output and apparent total tract digestibility. An in vitro study was conducted to investigate effects of pH on fermentative activity of ruminal contents from cattle adapted to a finishing diet containing 25% DDG (DM basis). The study was a randomized complete block design with a 3 x 4 factorial treatment arrangement. Factors were pH level (5, 5.5, or 6) and incubation time (6, 12, and 24 h), and sampling day served as a block. A 50:50 mixture of DDG and dry-rolled corn was used as substrate. Fermentations consisting of a 2:1 mixture of McDougall’s buffer and ruminal fluid were adjusted to target pH using citric acid. Fermentations were duplicated on each of 3 d (6 observations/treatment).
Concentrations of VFA and in vitro disappearance of DM (IVDMD) were measured. In study 1, ruminal pH for all treatments was below 5.8 for 14 h after feeding. Cattle fed DDG had consistently lower pH throughout the 24-h period when fed AH, but had higher pH from 12 to 22 h after feeding when fed CS (interaction, P < 0.05). Steers fed DDG had lower A/P ratio (P < 0.05) but higher ruminal lactate concentration (P < 0.05) than cattle fed no DDG. NDF digestion was similar for cattle fed diets with and without DDG (P > 0.10). Feeding DDG resulted in 6% lower digestion of DM and OM compared to feeding no DDG (P = 0.01). Most of this decrease was attributable to a depression in digestion of CP (P = 0.02) and, to a lesser degree, a reduction in starch digestion (P = 0.01). Ruminal ammonia concentrations were lower (P < 0.05) in steers fed diets containing DDG compared to those fed no DDG for 18 h after feeding. In study 2, there was an interaction (P < 0.01) between pH level and incubation time with respect to concentrations of acetate, propionate, total VFA, and A:P ratio. VFA concentrations were higher for pH 5.5 and 6.0 fermentations after 6 and 12 h, but were higher for pH 5.0 fermentations after 24 h. IVDMD increased with increasing pH (Linear, P < 0.01; Quadratic, P < 0.01) and incubation time. Feeding strategies aimed at increasing ruminal pH and ruminally degradable protein may be a viable method for improving digestion of dried distiller’s grains by cattle fed flaked grain diets.

The costs associated with reimplanting. J.O. Wallace1, C.D. Reinhardt1, W.T. Nichols2, J.P. Hutcheson2, B.J. Johnson1 and J.S. Drouillard1. 1Kansas State University, Manhattan, and 2Intervet Inc., Millsboro, DE.

A study was conducted to determine the costs incurred when reimplanting cattle which involved commercial feedyards and farmer-feeder operations throughout Kansas, Nebraska, Iowa, and Texas (n = 20). Reimplant events were monitored to measure the number of employees involved and time taken to reimplant pens of cattle (n = 68 pens and 8,945 cattle reimplanted). Together, these data were used to calculate labor costs associated with reimplanting. Ancillary costs were calculated from estimates provided by feedlot managers, and included time for personnel involved in planning reimplant events, longevity and cost of processing facilities, and the number of cattle injured during reimplant. Managers also provided DM intakes for pens of cattle (n = 321 pens; 47,141 cattle) for 10 d prior to and 10 d following reimplant events, making it possible to estimate changes in intake associated with reimplanting. Cattle were away from their pen an average of 102 min (range = 42 – 153 min). The average chute charge assessed to cattle owners was $0.65 per animal reimplanted, and the average labor, planning, and equipment costs incurred by feedlots were $0.62 per animal. Cattle consumed an average of 0.44 lb•hd⁻¹•d⁻¹ less DM for the 10 d following reimplanting compared to the 10 d preceding reimplanting (P < 0.01), and 61% of pens had lower and 39% of pens had similar or higher DMI following reimplant. Assuming an incremental conversion rate of 4 lb of DM per 1 lb of gain, the decreased intake would result in a loss of 1.10 lb of live weight. At a live weight price of $93/cwt, this is equivalent to a loss of $1.02. One animal was seriously injured for every 8,136 cattle reimplanted (average of manager estimates). Assuming a 900-lb feeder steer with a value of $96/cwt, this would be equivalent to an additional loss of $0.11 for each animal reimplanted. In summary, the total cost of reimplanting for a cattle owner is $1.78 per hd, which includes chute charges, cost of reduced performance, and physical injuries to cattle. The total cost to feedyards is approximately $1.75 per animal, which includes labor, planning, and equipment costs, reduced feed intake, and the cost of serious animal injuries. Direct and indirect costs of reimplanting cattle are real and measurable, but low stress.
animal handling and proper management of the reimplant event observed in this study help ensure that these costs do not overcome the net value of reimplanting.