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2019 SPRING CONFERENCE

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2019 Plains Nutrition Council

Pre-conference Symposium
and
Wednesday evening reception
The 2019 Plains Nutrition Council Spring Conference

**Thursday, April 11**
1:00 PM  **Welcome and Introductions** - Dr. Wade Nichols, President, Plains Nutrition Council, Merck Animal Health, Lubbock, TX
1:10  **Exploring a United States Without Livestock** - Dr. Mary Beth Hall, USDA-ARS, Madison, WI
2:00  **The Beef Industry: Upcycling Protein for Human Consumption** – Dr. Tryon Wickersham, Texas A&M University, College Station
2:45  **Break and Graduate Research Poster Presentations**
3:15  **Research Update** – Dr. Jhones Sarturi, Texas Tech Univ., Lubbock
3:45  **Feeding Cattle in All-Natural and Conventional Programs** - Dr. Zach Smith, South Dakota State Univ., Brookings
4:30  **The California Net Energy System 50th Anniversary Symposium** - Dr. Roberto Sainz, Univ. of California - Davis
5:15  **Legends of Feedlot Nutrition Recognition** – Dr. Ben Holland, Past President, Plains Nutrition Council, Cactus Feeders, Amarillo
5:30  **Research Poster Presentations and visit with presenters**
5:30–7:30  **Evening Reception**  *Sponsored by RAMP– Sweet Bran Cargill*

**Friday, April 12**
7–11:00 AM  **Research Poster Presentations and visit with presenters**

8:00  **PNC Business Meeting**
8:15  **Research Update** – Dr. Galen Erickson, Univ. of Nebraska, Lincoln
8:45  **Mineral and Vitamin Status in Cattle: Sampling and Diagnostics** – Dr. Dwayne Hamar, Colorado State Univ., Ft. Collins
9:30  **Dr. Kenneth & Caroline Eng (-K-) Trust Fund Graduate Student Recognition -**
Kurt Landis, 2nd VP Plains Nutrition Council, Cargill Animal Nutrition, Amarillo, Dr. Kenneth Eng, San Antonio
9:45  **Break and Graduate Research Poster Presentations**
10:15  **Mid-Late Feeding Mortalities in Finishing Cattle and Potential Causes** – Dr. Milt Thomas, Colorado State Univ., Ft. Collins
11:00  **Feed Ingredients: What is Contributing to Volatility in Supply and Costs?** – Dr. Kendall Karr, Cactus Feeders, Amarillo, TX
12:00PM  **Adjourn**
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Graduate Student Research Poster
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CHR HANSEN

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**Legends of Feedlot Nutrition - Class of 2019** | 150  |
Exploring a United States Without Livestock

Mary Beth Hall, PhD  
USDA- ARS, U.S. Dairy Forage Research Center, Madison, WI

Robin White, PhD  
Animal and Poultry Science, Virginia Tech University, Blacksburg

Our world is all about balance. Just enough of this, not too much of that. Keeping this balance is important for maintaining sustainability of systems, whether we’re talking about the environment, or our cows’ rations. As if maintaining this balance isn’t challenging enough, biological systems present the additional complication that changing one part of the system results in changes elsewhere. Such related changes may be unanticipated, or can be anticipated if you have enough information, like predicting the ripples when you toss a rock into a pond. In short, when we think about managing systems, we need to see the big picture response in addition to the small piece that we’re focused on.

We often think about the systems we manage -- the farm system, the rumen -- however, we rarely consider the systems we are a part of. People are a component of a food system with crop and animal agriculture. Like a food web in nature where plants grow with sunlight and water, mice eat the plants, hawks eat the mice, and their feces and carcasses fertilize the plants -- everything has to balance and supply the needs of each part, or the system won’t be sustainable. In society’s food web, resources, both products and “wastes” are traded among human society, crop agriculture, and animal agriculture. “Wastes” can be the resources made by one group that they can’t use, but that another group can. For example, animal manure fertilizes crops, and by-products from producing food, biofuel, and fiber for human society are feed for animals. Enormous amounts of products and wastes are traded among people, plants and livestock. These exchanges make for an integrated and complex system of supplies and demands (Figure 1).

It has been suggested that getting rid of livestock will save the planet. Livestock make greenhouse gases that increase climate change, they can pollute water, they can compete with people for food, people deforest land for grazing, and the list goes on. In addition to environmental challenges, livestock products have been criticized as unhealthy. So, why keep farm-raised cattle, sheep, goats, poultry, and fish? Remembering natural food webs and the need for balance, if you remove livestock from society’s food web, what happens?

When we evaluated what would happen if we removed livestock from U.S. agriculture (White and Hall, 2017), some key questions we had were:
1) What will you do with the land currently used for silage, hay, and tillable pasture?
2) How will the food supply change?
3) How well will you be able to feed people?
4) What happens to greenhouse gas emissions?
#1 The Land

If we got rid of farmed animals all 415 million acres of permanent pasture and rangeland would go out of food production. We can't be certain what will happen to the 56 million tillable acres used to grow forage, but we assumed it was largely converted to crops for people, except for 4.4 million acres that would be used to grow hay for the U.S.'s 10.2 million horses. Some have suggested that the tillable forage acreage could be let go to wildlife habitat, but we disagreed – short of a massive government program to take that land out of production, farmers would still need to earn a living from working the land. We did assume that tillable land was reallocated to grow crops for people based on current proportions of land use for 89 crops. That added 1.8 million acres of fruits, vegetables, and nuts. Why not add more fruits and vegetables? The U.S. currently imports 51% of the fruits and 39% of the vegetables that we consume. We assumed that if it was profitable to grow these high value crops, farmers would already be doing it. Climate, weather, soil quality, water availability, labor, markets, profitability, and risk all affect what crops can be grown in different areas. More than 70% of the fruits and vegetables grown in this country are irrigated (USDA, 2012). As concerns grow about the availability of water, do we have or would we be able to develop ways to grow more of the crops needed to feed people?

#2 Food Supply

With livestock gone and all crops not used for industrial products and seed available as food, the food supply tonnage would increase by 23% of what the current system with animals provides. That's over 66 million more tons of food available to feed people in the U.S. or to export. However, with only crop agriculture, the food supply would look a lot different. Grain would make up 58% of the food, up from 21%. 77% of those grains would be corn. Legumes would go from 1.4% in the present system, to 10% if animals were removed. 92% of the legumes would be soy and soy flour. The total amounts of essential nutrients available from foods generally increased with livestock gone. Some exceptions were fatty acids (long chain omega-3 fatty acids, arachidonic acid), calcium, and vitamins A, D, and B12; those nutrients are in greater supply in or are only gotten from foods from animals. With rendering products no longer available, foods would have to be diverted from use by people to provide 727 thousand tons of protein and 143 thousand tons of fat to feed our 70 million dogs, 74 million cats, and the rest of our pets.

#3 Feeding the Population

People don’t eat nutrients, they eat foods. And a general recommendation is that it’s better to get nutrients from foods than from supplements. We ran least cost diets intended to support the U.S. population based on the foods available in systems with or without animals. We assumed the U.S. food production system plus current imports needed to supply enough food to meet the population’s requirement for 36 essential nutrients including protein, energy, amino acids, fatty acids, vitamins, and minerals. Without supplements, the diets from the current (with animals) food supply was deficient
in vitamins D, E, K, and choline. However, without animals, diets were deficient in those nutrients as well as in calcium vitamins A and B12, and in fatty acids (long chain omega-3 fatty acids and arachidonic acids). These fatty acids are important for normal cognitive and visual development in children. Calcium and B12 are also crucial for our health. If you don’t eat foods from animals, you absolutely have to take B12 supplements. If we removed animal agriculture, we would have to find a way to provide the needed supplements to everyone. People would also have to eat more food in the plants-only system because plants are not very concentrated sources of essential nutrients. And because of the sheer amount of grain available, our diets would be 85% grain.

#4 Greenhouse Gases

Agriculture has accounted for about 9% of total U.S. greenhouse gas emissions, with animals accounting for approximately 50% of that. Without animals, national greenhouse gas emissions drop by 2.6%, or 28% of agricultural emissions. Why 28% rather than the 50% that animals produce? Greenhouse gases produced from industrially producing fertilizer to take the place of manure is part of the answer. Incinerating inedible byproducts is part. The change in crops grown with all of the emissions now credited to people is the other major part of the picture.

So, what happens when you remove animals from U.S. agriculture? Some good things, some not so good. It’s complex. More food, but more nutrient deficiencies unless we supplement everyone. Less greenhouse gases, but not a massive national decrease. Agriculture is essential for providing people with food, products, and livelihoods. When we look at how we will feed people and make the system work in the long term, we need to look at the entire system, not just one or two aspects that we want to change.

Literature cited

Figure 1. Society’s food web. People/Industry provides at least 47.6 million tons of byproduct feeds to Animal Agriculture. Crop Agriculture provides: 189.6 million tons of food and 141.1 million tons of non-food products to People/Industry, and 123.5 million tons of crops to Animal Agriculture. Animal Agriculture provides 132.3 million tons of food and 13.4 million tons of non-food products to People/Industry, and 4.4, 1.9, and 2.1 million tons of manure nitrogen, phosphorus, and potassium to Crop Agriculture. (White and Hall, 2017).
The Beef Industry: Upcycling Protein for Human Consumption

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Introduction

Utilization of ruminants as a source of protein, calories, and other essential nutrients predates agriculture. Domestication of ruminants allows societies to more effectively harness the ruminant's capacity to transform calories (energy) and amino acids (protein) locked in biomass (plants) inaccessible to the human gastrointestinal tract. Ruminant production systems convert solar energy, carbon dioxide, nitrogen, and water into high-quality nutrients for human growth and development. Upcycling of nutrients from unavailable biomass results in relatively poor feed efficiency and significant energy losses, including methane. Ultimately, this leaves consumers asking, "Are we as a society deriving value from beef production?" Beef producers, when asked: respond with a resounding "YES!" Often, these somewhat defensive responses by the beef industry lack quantitative support.

Developing methods of accurately accounting for beef's contribution to human nutrient supplies and for the costs associated with beef production is essential for addressing societal concerns. Thoughtfully developed methods of accounting can quantify the net benefit of alternate production systems, evaluate existing and emerging technologies, and improve the efficiency of beef production, all of which benefit both beef producers and consumers. Accurately describing the benefits and costs associated with beef production and using that knowledge to improve the sustainability of beef production systems while providing rational and defensible, rather than defensive, answers to concerned consumers is the goal.

Protein's Value

Beef production systems primarily bring value to society by providing a source of high-quality nutrients in a highly palatable form, beef. Cattle do this largely by consuming diets (forages and byproducts) whose nutritional value is limited to humans, pigs, and chickens. In effect, cattle (ruminants) are upcyclers of protein, transforming low-quality or human-inedible proteins into beef, a high-quality protein source. Human-consumable nutrients are fed to beef cattle to improve utilization of other nutrients and to significantly improve system efficiency. Some of the largest gains in sustainability of beef cattle production have been made by the delivery of energy-dense rations for a short period of time (e.g., during finishing).

Protein cost

Protein sources in livestock diets are divided into two categories: 1) sources that cannot be consumed by humans (grass, cottonseed meal, distillers' grains, etc.) and 2) sources
that can be consumed by humans (wheat, corn, soybeans, etc.). Protein consumed by humans is human-edible protein and the consumption of human-edible protein by livestock systems represents a cost. Accounting for this cost and describing the net benefit of this cost may alleviate consumer concerns and be useful in creating a positive talking point for modern beef production systems.

Upcycling

Beef cattle systems have two distinct advantages compared to other animal protein sources in the United States:

1) Ruminal microbes transform low-quality sources of protein into a more valuable source of indispensable amino acids.
2) Ruminants can utilize sources of biomass (e.g., forages and byproducts) that other meat-producing animals cannot.

Upcycling of low-value or inaccessible sources of protein into a high-quality source of human edible protein is truly remarkable, and an essential component of meeting the increasing demand for high-quality sources of human-edible protein.

Model description

Protein Quality
At first glance, directing human-edible protein to livestock feed may appear to be a completely negative action; however, in some cases (e.g., wheat, corn) ruminant transformation of the protein significantly improves the digestible indispensable amino acid score (DIAAS) of the protein consumed by humans. If soybean meal is fed to animals, the potential for improvement is low, because it already provides a relatively high-quality protein (high DIAAS). It is also important to note that for most humans, the desire to consume meat protein is greater than the desire to consume soy protein.

When human-edible protein is fed to livestock, minimizing the DIAAS score of the feedstuffs used provides the animal production system with a greater opportunity to improve protein quality. Improvement in protein quality is quantified as a protein quality ratio (Equation 1). The output DIAAS, in this case the protein quality score for beef, is fixed by biology; there is very little producers can do to change the amino acid profile of beef. The input DIAAS or the DIAAS of the feed used to produce beef is determined by taking a weighted average of the DIAAS score for the human-edible proteins fed to beef cattle. These values are calculated using published equations (FAO, 2011; Ertl et al. 2016). Sources of protein that are inedible by humans are not included in this calculation, instead, the weighted average DIAAS score of only the human edible portion is considered. Similar to Ertl et al. (2016), the reference protein used in our model is the human amino acid requirements published by FAO (2011) for children between the ages of 0.5 to 3 years.

If we fed a diet where the only source of human-edible protein (HeP) was corn, the protein quality ratio would be 3.04 (Equation 1.1) indicating a more than doubling of
protein quality. This would be the calculated result if corn were 50% of the diet or 100% of the diet, as it represents the only HeP fed. In contrast, if the human-edible portion of the steer’s diet contained 25% soybean meal and 75% corn the protein quality ratio would be decreased (2.17; Equation 1.2) as a result of adding the high-quality soybean protein to the diet.

Equation 1: \[
\text{protein quality ratio} = \frac{\text{output DIAAS}}{\text{input DIAAS}} = \frac{\text{beef DIAAS}}{\text{cattle feed DIAAS}}
\]

Equation 1.1: \[
\text{protein quality ratio} = \frac{112.0}{36.8} = 3.04
\]

Equation 1.2: \[
\text{protein quality ratio} = \frac{112.0}{(36.8 \times 75\%) + (96.6 \times 25\%)} = 2.17
\]

Human-edible Protein Conversion
Feed conversion is a concept familiar to most livestock producers and represents how effectively the animal converted the diet into gain. A similar concept in the discussion of protein is human-edible protein conversion efficiency (HePCE; Equation 2); a descriptor of how effectively the HeP in the animal’s diet was converted into HeP in the product. There are two values required for this comparison: the amount of human-edible protein found in the product (82.3 g of protein/kg of carcass) and the amount of human-edible protein required to produce the kg of meat. Similar to the DIAAS value, the amount of protein in a kg of meat is relatively fixed; but increasing the amount of fat in proportion to lean decreases this number. In contrast, the amount of human-edible protein fed to produce that beef begins at zero and increases depending on the diet offered. For example, feeding 83.5 g of dietary human-edible protein to produce 1 kg of meat (82.3 g of protein/kg of carcass) results in a conversion efficiency of 0.99 (Equation 2.1). Which means for every pound of human edible protein put into the system 0.99 pounds of human edible protein is produced. This conversion is simply the ratio of inputs to outputs and does not account for any improvement in protein-quality.

To determine the human-edible protein consumed, feedstuffs with nutrient compositions presented in NASEM (2016) are classified as edible, partially edible, or inedible using information from Ertl (2016), Wilkinson (2011), and other available literature. For partially edible feedstuffs (i.e. corn silage), a fraction of the feedstuff is estimated as edible. Multiplying the total amount of protein fed by the proportion of the feed protein that is human-edible yields human-edible protein fed (HePf). To predict human-edible protein contained in each animal, human-edible protein in the carcass is estimated from NASEM (2016) using empty body weight adjusted for non-edible products using data from Terry et al., 1990 and Apple et al., 1999. Subtracting the amount of human-edible protein in an animal when it enters a production system from the amount of human-edible protein in an animal when it leaves the production system results in human-edible protein gain (HePg). Human-edible protein conversion efficiency is calculated by dividing HePg by HePf.
Equation 2: \( \text{HePCE} = \frac{\text{HePg Output}}{\text{HePf Input}} \)

Equation 2.1: \( \text{HePCE} = \frac{82.3 \text{ g HeP in 1 kg of carcass}}{83.5 \text{ g HeP fed to produce 1 kg of carcass}} = 0.99 \)

**Net Protein Contribution**

Multiplying the human-edible protein conversion by the protein quality ratio adjusts both the input and the output for DIAAS content, and this is termed net protein contribution (Equation 3). Net protein contribution provides a complete picture of how much a specified livestock production system contributes to our ability to meet human protein demand. Feeding diets that allow the animal to make greater improvements to protein quality (i.e. a high protein quality ratio) or feeding diets that contain less human-edible protein (lower HePf, increased HePCE) creates a livestock production system that makes a greater contribution to addressing human protein requirements (Equations 3.1 and 3.2). A value greater than one for NPC indicates the production system is yielding more indispensable amino acids than it consumed, whereas a value of less than one indicates the production system is competing with humans for human-edible indispensable amino acids. It is important to keep in mind that sustainability is a multi-faceted concept involving economic, environmental, and societal aspects all of which must be balanced. When evaluating the beef value chain’s NPC, other indicators of sustainability should be factored in as maximizing NPC may negatively affect profitability or the environment. To demonstrate this concept we calculated total enteric methane production relative to kg HePg.

Equation 3: \( \text{Net Protein Contribution} = \text{Protein Quality Ratio} \times \text{HePCE} \)

Equation 3.1: \( \text{Net Protein Contribution} = 3.04 \times 0.99 = 3.01 \)

Equation 3.2: \( \text{Net Protein Contribution} = 2.17 \times 0.99 = 2.15 \)

**Cow-calf sector**

Cow-calf production primarily involves grazing pasture and rangelands (non-human-edible feeds) with little to no human-edible protein supplementation. Weaned calves as well as cull cows and cull bulls are sold each year which is the HeP produced from this sector. Compared to stocker and feedlot sectors, the cow-calf sector consumes the least amount of HeP (less than 0.01% of total HeP fed in the value chain; table 1) and produces the greatest amount of HeP (56% of total HeP produced in in the value chain). Because of this the cow-calf sector also has the greatest conversion efficiency of HeP and the greatest NPC compared to the other two sectors, but the cow-calf sector also produces the most enteric methane (81% of enteric methane produced). Additionally, protein quality of beef produced is roughly 3 times greater than the quality of protein consumed. Improvement in protein quality represents the ability of beef cattle to upcycle protein, and this is evident in each sector of the beef value chain.

Intensification of the cow-calf sector by limit feeding grain lowers methane production by approximately 50% when compared to conventional cow-calf production while still
positively contributing to meeting humanity’s protein requirement (NPC > 1). Intensified cow-calf management strategies can be incorporated into a sustainable beef value chain, while maintaining the ability of the value chain to be a net contributor to human protein requirements.

There is an evident trade-off between NPC and enteric methane production, meaning NPC cannot be maximized while minimizing enteric methane production. Additionally, intensified strategies can help decrease the environmental footprint of the value chain and may confer some advantages to economic sustainability.

**Stocker sector**

Oftentimes, stocker cattle graze native pasture or winter pastures; neither of which are sources of human-edible protein. However, these cattle are often supplemented with protein (i.e. distillers’ grains or cottonseed meal) and energy (i.e. corn) for optimal performance. Protein upcycling or improvement in protein quality is similar to cow-calf and feedlot sectors. Consumption of HeP is greater in this sector (approximately 2% of total HeP fed) compared to cow-calf production, but lower than the feedlot sector. The lowest proportion of HeP production occurs in this sector (10% of total HeP produced by the beef value chain). Both HePCE and NPC for the stocker sector are intermediate to the cow-calf and feedlot sectors.

**Feedlot Sector**

Beef cattle typically spend less time in the feedlot phase than the cow-calf phase; however, the majority of cereal grain consumed in beef production is in the feedlot phase (approximately 96% of total HeP fed). Human-edible protein gains (beef) during the feeding period do not make up for the HeP fed which results in an HePCE of approximately 0.34. Because the quality of HeP fed is upcycled to HeP in beef (PQR of 3.15), the feedlot sector has an NPC above one as well. Enteric methane production (kg/kg of HeP produced) is lowest for the feedlot sector (0.94) compared to the other sectors of the beef value chain.

**Detailed Feedlot Evaluation**

To evaluate NPC in commercial feedlot settings and determine which factors in feedlot production systems affect NPC, we modeled NPC of 8 commercial feedlots (Kansas = 2; Texas panhandle = 6) from 2006 through 2017. Annual production variables and weighted yearly starter and finisher diets were incorporated into the previously described model. Regression equations were developed for each feedlot and feedlots were categorized as increasing NPC (INC) or constant NPC (CON) then differences in feedlot attributes dependent upon feedlot type (INC or CON) were determined.

Since 2006, 4 of the 8 feedlots increased NPC while the remaining 4 feedlots had a constant NPC. Net protein contribution increased 0.03 units each year for INC feedlots reaching a NPC of 0.94 in 2017.
Ethanol production in the United States is a major source of corn milling byproducts domestically and worldwide with up to 25% of corn byproducts exported annually (Makkar, 2012). Rapid increases of corn milling byproducts in the mid-2000s (Hoffman and Baker, 2010) created new feed ingredient opportunities for feedlots. Byproduct inclusion in both INC and CON feedlots increased over time and across the industry as corn milling byproducts became more readily available (Vasconcelos and Galyean, 2007; Samuelson et al. 2016). Feedlots with improving NPC (INC) were closer to corn milling byproducts sources and were able to substitute cereal grains (primary source of HeP in feedlot diets) with human-inedible feed ingredients (byproducts) to a greater degree than CON.

Corn milling byproducts are initially included in feedlot diets to replace protein sources and non-protein nitrogen sources; i.e., the substitution is driven by the value of dietary protein. Once protein targets are met, corn milling byproducts begin replacing the primary energy source (i.e. corn; Makkar, 2012) when the unit cost of energy is competitive. The feedlot type × year interaction observed for cereal grain was indicative of cereal grain replacement with byproducts. Decreased amounts of cereal grain (% of DM) were observed for both feedlot types over the time period analyzed, but INC reduced cereal grain inclusion to a greater extent than CON feedlots.

Ingredient inclusion in feedlot diets is based on least cost formulation; therefore, inclusion level of an ingredient changes when price changes relative to comparable ingredients. Corn, the main HeP ingredient used in feedlots, has a DIAAS of 36.8 which is similar to intercepts estimated for DIAAS for CON and INC, 37.2 and 36.9, respectively. In 2013, 6 of the 8 feedlots substituted flaked corn for flaked wheat (DIAAS of 43.1), resulting in greater DIAAS and lower PQR and lower NPC compared to years when corn was fed.

There has been a trend over time to increase placement weight finished weight in US feedlots (LMIC, 2018), and this was evident in the feedlots evaluated in our study. Finished weights increased from 560 to 612 kg from 2003 to 2017 (USDA-ERS, 2018). Feedlots for which NPC increased over time typically placed 19 kg lighter cattle and harvested cattle at 14 kg lighter weights compared to CON feedlots. In spite of lighter placement and harvest weights, INC feedlots generated 5 kg more BW gain during production resulting from more time on feed.

Despite increased days on feed for INC feedlots, HePf was lower for INC than CON feedlots, suggesting that lower diet HeP concentration influenced HePf more than days on feed. Over the period analyzed, INC feedlots reduced HePf by 14%, and INC and CON feedlots increased HeP9 by 6.3 and 5.7%, respectively, resulting in the feedlot type × year effect observed for HePCE. Human-edible protein conversion efficiency increased 43% from 2006 to 2017 for INC feedlots and 10% for CON feedlots during the same period, but only increases observed for INC were significant from zero. Despite relatively less efficient conversions of HeP in the feedlot compared to other sectors in the value chain, this sector remains more efficient than nonruminant systems.
Beef Value Chain

Beef production is more complex than other animal protein systems with multiple segments contributing to NPC of the beef value chain. Supporting cow-calf and stocker segments primarily graze forage and utilize other human-inedible feeds as supplements. The majority (66%) of HeP gained in beef production occurs in these two sectors both of which have NPC greater than 1 (8,036 and 15.9 for cow-calf and stocker, respectively; Baber et al., 2018). Although feedlots are often in competition with humans for HeP (estimates of NPC ranging from 0.41 to 1.15), this is outweighed by the stocker and cow-calf sectors’ ability to positively contribute to the human food supply by using less HeP and improving protein quality.

Combining the aforementioned estimates of NPC for the cow-calf and stocker segments with estimates of NPC for feedlots in 2017, results in a NPC of 3.5 for INC and 2.8 for CON. Additionally, when analyzed using the best and worst case scenarios of feedlot NPC observed (1.15 and 0.41), NPC of the beef value chain was 4.60 and 1.51, respectfully. Across the range of feedlot NPC observed, the NPC for beef production remained greater than 1 indicating that these production systems positively contribute to addressing human protein requirements.

Compared to swine and poultry production systems in Austria (NPC of 0.64 and 0.76, respectively), the US beef value chain has a greater NPC and ability to positively contribute to meeting humanity’s protein requirements.

Perspective

Feeding 770 lb of corn produces 385 lb of beef. If we eliminated beef production, 770 lb of corn would meet the lysine (protein) requirements of 3 children for a year. However, by feeding corn to cattle, we are able to meet the lysine (protein) requirements of 17 children.
Literature Cited


Table 1. Net protein contribution and key variables for each sector and the beef value chain

<table>
<thead>
<tr>
<th>Sector</th>
<th>Cow-calf</th>
<th>Stocker</th>
<th>Feedlot</th>
<th>Beef value chain</th>
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<tr>
<td>PQR</td>
<td>3.04</td>
<td>3.04</td>
<td>3.15</td>
<td>3.15</td>
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<tr>
<td>HePₗ, lb</td>
<td>0.02</td>
<td>2.2</td>
<td>117.0</td>
<td>119.2</td>
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<td>HePᵡ, lb</td>
<td>66.1</td>
<td>11.7</td>
<td>39.8</td>
<td>117.7</td>
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<td>HePCE</td>
<td>2,640.8</td>
<td>5.22</td>
<td>0.34</td>
<td>0.99</td>
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<td>NPC</td>
<td>8,036.0</td>
<td>15.88</td>
<td>1.07</td>
<td>3.11</td>
</tr>
<tr>
<td>CH₄/kg HePᵩ</td>
<td>10.0</td>
<td>4.2</td>
<td>2.1</td>
<td>6.6</td>
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Adapted from Baber et al., 2018

Table 2. Estimated intercepts and year coefficients for each feedlot type

<table>
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<tr>
<th></th>
<th>β₀</th>
<th>β₁</th>
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<th>β₁</th>
<th>P-value</th>
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<tr>
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<td>β₀</td>
<td>β₁</td>
<td></td>
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<tr>
<td>NPC</td>
<td></td>
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<tr>
<td>CON</td>
<td>0.64 ± 0.04</td>
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<tr>
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<td>Byproduct, % DM of diet</td>
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<td></td>
<td></td>
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<td>CON</td>
<td>5.8 ± 1.6</td>
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<td>&lt;0.01</td>
<td></td>
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<tr>
<td>Cereal grain, % DM of diet</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>CON</td>
<td>76.0 ± 1.3</td>
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<td>HePᵩ, kg/animal for total feeding period</td>
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<td></td>
<td></td>
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<td>CON</td>
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<td>HePCE</td>
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<td></td>
</tr>
<tr>
<td>CON</td>
<td>0.21 ± 0.01</td>
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<td>INC</td>
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</tbody>
</table>

¹ Superscript denotes year coefficient is statistically different from zero (P < 0.05)
**Figure 1.** Time series of NPC for individual feedlots from 2006 through 2017

**Figure 2.** Impact of beef production

**Impact of beef production**

- 770 lb corn
- Fed to cattle
- Fed to children
- Protein upcycling

Meets yearly AA requirements of:
Better trace minerals, better value
A Product of MicroNutrients
Bond
®
Lhoist North America

Lhoist Group
Feeding Cattle in All-Natural and Conventional Programs

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Introduction

Beef cattle producers must choose the best production system for their situation. Conventional production systems use steroidal implants with anabolic activity, ionophores, and beta-adrenergic agonists to improve animal productivity; feed grade and injectable antimicrobials are also used to control, treat or prevent disease and improve animal health. Conventional systems also may feed animal by-products, which may not be allowed in some natural programs and are never allowed in organic cattle feeding systems. Some consumers have expressed a preference for beef produced without these technologies. Since the European Union fully banned the use of growth promoting compounds in animals intended for human consumption in the late 1980’s, the natural-fed segment of the U.S. beef market has grown. The definition of “natural” within the context of beef production channels is much more ambiguous than the definition of “organic” or non-hormone treated cattle (NHTC). According to the U.S. Department of Agriculture - Food Safety Inspection Service (USDA-FSIS), all fresh beef qualifies to carry a “natural” label, in the sense that fresh beef is only minimally processed, and contains no artificial ingredients, or chemical preservatives. Thus, understanding what is meant in reference to “natural” requires some clarification. The Agricultural Marketing Service of the USDA (USDA-AMS) has an organic certification that requires cattle be managed under a prescribed protocol from the last third of gestation throughout the entire life of the animal, and require the use of certified organic feeds (USDA-AMS, 2019). Additionally, the USDA-NHTC program has clearly defined management practices and is verified through USDA audits.

Unlike the USDA-Organic and NHTC programs, “All-Natural” beef programs are not USDA certified. These “All-Natural” programs are primarily managed by branded beef marketing groups and involve a third-party audit of participating entities. Thus, for cattle fed in “All-Natural” programs the conditions of each individual marketing program dictate the types of feed, feed additives, and other pharmaceutical technologies that can be used during production. Throughout this paper, anything that is not conventionally produced will be referred to as “All-Natural”. Premiums for “All-Natural” cattle are enticing but the true differences in the cost of production between the “All-Natural” and conventional cattle are hard to estimate. The improvements in average daily gain (ADG), out weight, feed to gain (F:G), and hot carcass weight (HCW) of cattle fed in conventional feeding systems compared to “All-Natural” production systems are substantial. The differences in production efficiencies between each type of non-conventional production systems must be re-captured in added premiums when cattle are marketed and sold.

Other economic factors are more difficult to quantify. One cannot ignore the potential fallout rate of animals that are placed in an “All-Natural” program. Plus, factors such as
the premium paid for the feeder calf, decreased growth performance coupled with a lower out weight, and salvage value of the fallout animals that must be considered. These factors can be used to estimate the dollar value that needs be returned to the cattle feeder when participating in an “All-Natural” program. The objective of this paper is to outline production efficiency differences and other thought processes required to decide if feeding cattle intended for marketing programs that forbid the use of conventional technologies is a sound business decision.

**Pharmaceutical Compounds**

Steroidal implants and beta-adrenergic agonists are two technologies that can increase production efficiencies by enhancing animal growth. Feed grade and injectable antimicrobials are used for controlling, treating and preventing disease. These technologies are proven to be safe and routinely provide a great return on investment to the producer. To opt out of using technology in a cattle feeding enterprise or at least in certain pens of cattle within a yard (more on this topic later), it is necessary to have an idea of what might potentially be given up in animal growth performance. For more than 60 years, beef cattle producers have safely used various types of growth-enhancing technologies (GETs) to improve carcass leanness, increase ADG, improve F:G, and alter DMI. When a producer chooses to utilize a GET, improvements in treated cattle over non-treated cattle are typically in the range of 10 to 30% for ADG and 5 to 20% for F:G (Johnson and Beckett, 2014).

Any new GET marketed in the U.S. is required to pass a thorough, multi-step scientific review by the U.S. Food and Drug Administration to ensure animal well-being and safety to the human food supply. Use of these compounds must continually be proven safe for human consumption via random testing for residues in edible tissue and potential environmental impacts by way of many independently conducted post-approval environmental impact studies.

The use of steroidal implants and ionophores can alter observed dietary NE values by increasing feed consumption above that required for maintenance and/or lessening the caloric content of growth. Therefore, one can assess differences in cost of production and observed dietary NE values due to differences in gain that were attributed to the pharmaceutical technologies. In the implant study by Smith et al. (2018) steers were administered no implant, a Revalor-XS (200 mg trenbolone acetate and 40 mg E2) 213 d prior to harvest, or a Revalor-200 (200 mg trenbolone acetate and 20 mg E2) 143 d prior to harvest (Table 1). Monensin sodium and tylosin phosphate were included in the basal diet. Results from these implant regimens provide insight to what might be expected when cattle are administered no steroidal implant, are given an implant that may be administered for this production window, and an implant administered to steers who became disqualified for an “All-Natural” feeding program approximately 70 d into the 200 d feeding period. The use of implants decreased \( P \leq 0.05 \) the cost of 1 Mcal of dietary NEm by 3.6% compared to non-implanted controls. In this same study, the use of implants decreased \( P \leq 0.05 \) the cost of 1 Mcal of dietary NEg by 4.7% compared to non-implanted controls.
A study was identified in the literature to provide insight to what may be expected in regard to cattle managed in an “All-Natural” program compared to cattle in conventional management systems (Maxwell et al., 2015). Two conventional management approaches were used with one including the feeding of zilpaterol HCl and both were compared to the “All-Natural” feeding program. In the “All-Natural” vs. conventional systems comparison, cattle fed monensin sodium, tylosin phosphate, and administered a steroidal implant decreased the cost of 1 Mcal of NEm and NEg by 12.1 and 17.2%, respectively, compared to controls (Table 2). In the same study, when zilpaterol HCl was fed to another group of conventionally managed steers, there was a 15.6 and 21.7% decrease in the cost of 1 Mcal of NEm and NEg, respectively, compared to controls. These data indicate that the influence of a beta-adrenergic agonist are less than the influence of an implant, ionophore, and feed grade antimicrobial combined.

Using raw data from Thompson et al. (2016) the cost of NEm and NEg was calculated. In this work, cattle were fed no ionophore or feed grade antimicrobial, fed laidlomycin propionate and chlortetracycline for 151 d, fed laidlomycin propionate and chlortetracycline for 119 d and offered ractopamine HCl [300 mg/head (hd)/d] for the final 32 of the 151 d feeding period, or fed monensin sodium and tylosin phosphate throughout the 151 d study and ractopamine HCl (300 mg/hd/d) was fed for the final 32 d (Table 3). All steers in the study were implanted with a 100 mg TBA and 14 mg estradiol benzoate implant at study initiation. Feeding laidlomycin propionate and chlortetracycline decreased ($P \leq 0.05$) the cost of energy by 3.8 and 5.0%/Mcal for NEm and NEg, respectively. In the same study, feeding laidlomycin propionate and chlortetracycline for 119 d and ractopamine HCl the final 32 d, decreased ($P \leq 0.05$) the cost of energy by 2.9 and 3.9%/Mcal for NEm and NEg, respectively. Feeding monensin sodium and tylosin phosphate throughout the study and ractopamine HCl the final 32 d, decreased ($P \leq 0.05$) the cost of energy by 4.2 and 5.5%, for NEm and NEg respectively. These examples used a dry diet cost of $250.00/ton, and are only intended as a reference as to what can be expected in regards to technologies that alter observed dietary NE values. The cost of NE might differ if feed additive cost was included in the actual diet cost used in these calculations. The use of pharmaceutical technologies can decrease the cost of each unit of energy that is used during production.

From 1992 to 2012 approximately 31 million acres of U.S. farmland were lost to urbanization (Theobald et al., 2018). From this 31 million acres of lost farmland, it was estimated that approximately 11 million of the lost acres were farmland with the most ideal soil conditions, growing seasons, and water availability; allowing for the most intensive production with the smallest environmental impact (Theobald et al., 2018). Therefore, corn acre usage should also be considered when calculating the overall impact of pharmaceutical technologies. For example, it would require 27 million hd of 1250 lb cattle (non-implanted) to match the beef output of 25 million hd of 1350 lb cattle (implanted). Assuming an equal initial body weight (BW) of 750 lb, 167 days on feed, and that an implant increases ADG by 20%, the resulting ADG would be 3.0 and 3.6 lb/d; with DMI of 20 and 21 lb (2% of median feeding BW). The F:G would be 6.67 and 5.83 for the non-implanted and implanted animals, respectively. With an estimated DM
inclusion of 65% corn in the finishing diet, assuming the DM of field corn is 85%, and 167 days on feed, the resulting corn intake would be 2,554 lb and 2,681 lb/hd for the non-implanted and implanted animal, respectively. Total corn consumption for 27 million hd of non-implanted animals would be 68.96 billion lb and for 25 million hd of implanted cattle would be 67.05 billion lb, resulting in 1.92 billion lb greater corn consumption by 2 million more hd of non-implanted cattle. Assuming that the bushel weight of corn is 56 lb, and an average yield of 176 bu/acre for field corn, the increased acres of corn cropland required to maintain similar levels of beef production without steroidal implants would be 194,358 acres/yr.

Pharmaceutical technologies are critical tools to U.S. beef production and consistently offer a great return on investment. The USDA-FSIS monitors levels of various residues in tissues such as muscle and liver, and the risk for residues in meat from animals treated with pharmaceutical compounds according to label instructions in negligible. Pharmaceutical technologies used by beef producers increases the efficiency of use of available resources. Pharmaceutical technologies used in conventional production systems can decrease the cost of each Mcal of NEm and NEg. A rough estimate in the increased field corn acres required to support current levels of beef production without the use of steroidal implants is approximately 194 thousand acres of corn crop land each year.

**Cattle Type**

In a conventional production setting, cattle in feedlots have three potential outcomes, the first is shipment to the primary market, the second is realization to a secondary market (commonly referred to as a “railer” market), and the final outcome is death (Holland and Word, 2018). For cattle fed in an “All-Natural” program, the additional outcome of a “fallout” due to antimicrobial treatment is a possibility. Fallout cattle are typically treated, then fed, and marketed as conventional cattle. In an “All-Natural” program the potential for fallout cattle in calf-feds is considerably higher than for yearling cattle, just because calves tend to have higher rates of morbidity and treatment. Fallout rate can be as high as 20 to 50% with calves and 5 to 10% with yearling placements in an “All-Natural” program (T. Milton, personal communication). As transit time and distance increases, animal performance decreases and morbidity increases (Camp et al., 1981), even with single-source, ranch raised cattle. Typically, feeder cattle that are eligible for “All-Natural” programs, whether calves or yearlings, are more expensive than commodity cattle. The additional premium for “All-Natural” feeder cattle can be roughly estimated as approximately $2.00 to 5.00/cwt live when purchased. Coupled with this premium, the large differences in fallout rate between the two classes of cattle favors purchase of yearlings for natural programs. On the other hand, placing only yearling cattle into “All-Natural” programs, limits the marketing opportunities at different times of the year.

What are the economic losses associated with fallout cattle? Because of the premium paid at purchase and the anticipated premium at harvest, feeders may be reluctant to treat morbid cattle in a natural program. If so, they must decide how long they will allow
the animal to suffer prior to treating the animal with an antimicrobial. Most of us would not just give our child an aspirin for pink eye. With delayed treatment, an animal will likely be in poor condition by the time the decision is made to treat, and the implant and antimicrobial may only make the animal have performance that is par with the animal who remained in the “All-Natural” program at the very best.

Even if implants and other conventional management technologies are used in cattle that fallout of an “All-Natural” program after antimicrobial treatment, the feeder premium is lost. Fallout rate is not everything and salvage value of the fallout animal is critical to determining what must be returned to the feeder in premiums at harvest. As fallout rate increases, the salvage value of the fallout animal likely remains greater and as fallout rate decreases, salvage value of the fallout animal becomes less (primarily driven by salvage out weight). If treatment is delayed, will a steroidal implant and an antimicrobial allow this animal to be par with the cattle that remained in the program, or will it have been a lost cause by the time it was treated and salvage value will be reduced because of a lower out weight? To understand what is at stake requires the calculation of a breakeven. Important factors that drive a selling breakeven are ADG, F:G, and out weight; most can agree that the biggest driver is out weight, and not using a steroidal implant is certainly going to decrease out weight.

When foregoing use of implants during the finishing phase, a producer gives up 10 to 30% responses in ADG but performance lost is not equal across gender groups. Differences in ADG responses to implants between steers and heifers do exist. Herschler et al. (1995) indicated that steers and intact heifers administered an implant that contained 200 mg of TBA and 28 mg of estradiol benzoate had improved ADG by 20.9 and 10.5% compared to non-implanted controls for steers and intact heifers, respectively. Pritchard and Rust (1997) summarized six studies representing 1,468 heifers in total (Nygard and Embry, 1966; Yamamoto et al., 1978; Rush and Reece, 1981; Rupp et al., 1982; Garber et al., 1990; Main, 1990). In their pooled analysis, steroidal implants increased ADG by 10.5 and 15.7% compared to non-implanted controls for intact and ovariectomized heifers, respectively. Differing responses between steers, intact heifers, and ovariectomized heifers when steroidal implants are used is most likely due to differences in endogenous estradiol-17β production between steers, intact heifers, and ovariectomized heifers. Within a sex or class of cattle, responses to implants are typically of similar magnitude. Even though, a non-implanted steer has better performance than a non-implanted heifer. Sex differences in ADG responses to a steroidal implant, makes for a strong case that heifers might be better suited for feeding in “All-Natural” programs where the use of steroidal hormones are forbidden.

A critical management step in order to effectively produce cattle destined for an “All-Natural” program is the procurement of genetically and immunologically superior cattle. To illustrate this, closeout summaries from two yards that are customers of the Midwest-PMS organization (Table 4; data courtesy of Dr. P. Anderson) were obtained. These two yards typically place cattle of equal genetic merit into their “All-Natural”/NHTC programs and their conventional feeding program. The differences in ADG between cattle in the differing programs was 24.61 and 11.70% for steers and heifers across both feedyards,
respectively. Often, cattle being fed in “All-Natural”, NHTC, and USDA-Organic programs are cattle that represent the best genetics available to producers. It is not uncommon for these “All-Natural” cattle to have a similar ADG to conventionally raised animals that have been administered anabolic implants and given antimicrobials when needed. Initially, one might be pleased with the performance of their “All-Natural” cattle compared to their conventional cattle if ADG is similar between both groups; however, this is not a fair comparison. If an implanted steer gains 3.6 lb/d, he would likely only gain 3.0 lb/d without the steroidal implant (i.e. a 20% response in ADG due to the steroidal implant). Likewise, an “All-Natural” steer that gains 3.5 lb/d without the use of a steroidal implant might easily have gained 4.2 lb/d (i.e. a 20% increase in ADG) if administered a steroidal implant. Does feeding in an “All-Natural” or NHTC program, limit the return on investment for the animal with the best genetics available? Perhaps when all things are considered (i.e. fallout rate and salvage weight of the fallout animal) economic performance might have been better using the technology on the valuable calf as compared to managing the animal under the guidelines of an “All-Natural” or similar program.

The question of genetic capability is significant because of substantial differences inherent in the feeder cattle population. Data in Table 5 and Table 6 from the Midwest-PMS organization (data courtesy of Dr. P. Anderson) show the range in value for closed lots of 675 lb heifers and 675 lb steers. These data were obtained from a random subpopulation of all closeouts in recent years for the Midwest-PMS organization, based upon sex (heifers and steers) and placement weight (initial BW of 650 to 699.9 lb). The value for each lot was calculated using a standardized feed and sale price. Out weight was used along with the standard sale price to calculate revenue. After revenue was calculated, cost of production (i.e. feed consumed, medicine and processing costs, and other miscellaneous costs) was subtracted in order to calculate a breakeven purchase value of the entire lot as feeders. This value was then divided by number of hd placed to calculate a per hd value (PHV). The PHV is the total amount that could have been paid at placement in order to breakeven. The data are indexed in 50.00 $/PHV increments to generate the rows of mean data presented in Table 5 and Table 6.

Given the assumptions, the average value of all 675 lb feeder heifers was $941.45/hd and a $139.47/cwt purchase breakeven (Table 5). The two lowest value 675 lb heifer lots had PHV of $558.66/hd and $85.42/cwt purchase breakeven as feeders. The two low value lots (550 PHV) had mean ADG of 1.34 lb/d, F:G of 14.39, and 28.81% mortality and were worth $382.79/hd less as feeders than the average. Alternatively, there were three very exceptional lots (1150 PHV) that had a PHV of $1138.82/hd and a purchase breakeven of $166.49/cwt as feeders. These three exceptional lots of heifers had mean ADG of 3.45 lb/d, F:G of 4.95, and no mortality. These three 1150 PHV lots of heifers were worth $197.37/hd more than the average as feeders and $580.16/hd more as feeders than the lowest PHV index lots. It is the same story for 675 lb feeder steers (Table 6) except the range in value is even greater at $639.90/hd more as feeders between the lowest and greatest PHV groups. Cattle who have exceptional gain, finish heavy, and have minimal mortality also have outstanding F:G. These higher quality cattle have a higher purchase breakeven as feeders. According to these close
out summaries, valuable cattle are cattle that justify a premium at purchase. They stay alive, eat, and get very large, they also convert feed to gain very efficiently, and this means that a conventional feeder has an opportunity to attempt to purchase these cattle away from the "All-Natural" feeder without having to be concerned with fallout cattle from the primary market.

**Feed and Diet**

Cattle fed in the USDA-Organic program are strictly limited to organic feedstuffs and no constituents of the diet may be obtained from another animal. Other “All-Natural” programs are not typically required to be fed organic feedstuffs and some allow the use of animal by-products in feed. If a feedlot chooses to feed some pens in a feedyard under conventional management and other pens in the same feedyard under management practices that forbid the use of feed grade antimicrobials, ionophores, or beta adrenergic agonists using the same feeding equipment, might easily become out of compliance. The analytical assays used to check for drug compliance during auditing are conducted under high pressure liquid chromatography. This analytical procedure is very sensitive and can detect traces of drugs in the ppm (mg/kg) to ppb (μg/kg) range. Minimizing cross contamination can become impossible when using the same equipment if there is a “zero-tolerance” policy. Even if there is not a “zero-tolerance” policy, flushing and feed management can become very difficult with the level of surveillance capable using the employed analytical techniques. If the same system cannot be used to feed conventional and “All-Natural” cattle, what does the true cost of the “All-Natural” feeding program become to the feedyard? One opportunity is to only exclusively feed “All-Natural” cattle at a designated facility in the organization, however, this will not work for every operation. This practice would minimize the risk of being out of compliance during a routine audit procedure, however, a major issue with a dedicated facility for “All-Natural” production is the transportation of fallout cattle to their new home.

Cattle fed in an “All-Natural” program will likely have lighter final BW, they will also consume lesser DM, as intake per unit BW remains unchanged. For a custom cattle feeder, these cattle will consume less of the feed that is for sale. If a pen of NHTC are expected to consume 6% less cumulative DM, it might be wise to consider an appropriate mark-up to the ration in order to normalize income across the yard.

The type of diet that is fed to cattle in various marketing programs should be considered. Although it will take more days to reach an acceptable level of finish, cattle in an “All-Natural” program that forbids the use of an ionophore and steroidal implants, may be better suited for a 58 Mcal/cwt NEg top-diet. Two reasons as to why this strategy of a lower NEg top-diet might be better suited for the “All-Natural” beef animal are: 1) without the use of a steroidal implant, frame can be grown in this individual by using a lower energy top-diet as compared to a 67 Mcal/cwt NEg diet in order to generate more BW at harvest. The latter option produces lighter weight, fatter cattle and 2) when feeding a top-diet with a higher roughage inclusion, the ionophore might not be as important compared to feeding a low roughage inclusion, 67 Mcal/cwt NEg top-diet.
The type of diet fed to “All-Natural” destined cattle should commensurate with the available feedstuffs and the management skills of the cattle feeder when pharmaceutical technologies are forbidden. If one chooses the higher roughage, home-grown feed route when finishing “All-Natural” cattle, examining F:G might be a cause for concern, however, more out weight is generated, albeit less efficiently. If you are not growing your own feed, the feed cost of gain might be alarming, so this would not be a recommendation for every operation.

What is the technical savvy of the cattle feeder and cattle feeding enterprise? Feeding operations in the Midwest and Texas panhandle can prove to be profitable for two very different reasons. Corporate yards in the Texas panhandle have better pen conditions, greater feed costs and a larger one time capacity than Midwestern cattle feeders. Operations in the Texas panhandle also have to transport the higher quality (no bos indicus influence) Northern cattle in that might be better suited for an “All-Natural” program, while the Midwestern feeder is considerably closer to the source of quality cattle. Being closer to the source of quality cattle can allow for lower morbidity and possibly lower the risk for fallout cattle, as there is a shorter transit distance from point of origin to the feedyard. Corporate yards in the Panhandle of Texas often have the technical and individual animal management capabilities to better manage risk when opting to feed cattle that can qualify for an “All-Natural” program. Alternatively, the small Midwestern farmer feeder may have the available profit center in home-grown feedstuffs, is closer to the cattle supply, and can in turn also produce cattle destined for “All-Natural” programs.

**Pen Size**

Pen size is another topic worth discussion. In an ideal situation, cattle destined for an “All-Natural” program would never be co-mingled with cattle from other sources in order to fill a pen at placement. What is the ideal pen size for feeding cattle in an “All-Natural” program? What is the average pen size at large capacity yards in the Texas panhandle or for the smaller total capacity farmer-feeder in Eastern South Dakota? They are probably both over 200 hd. Why is this the case? Is it really that hard to put more posts in the ground to make smaller pens? Is accounting and record keeping easier on larger hd number pens compared to smaller hd number pens? The answer to both questions is a resounding no! It is important to keep in mind the amount of cattle that can be procured at one time from a single source in order to fill an entire pen. For larger pen sizes, this might be easier said than done.

The average cow herd size in the U.S. is approximately 40 hd. There are larger operations; however, the absolute number of these larger operations (greater than 100 hd) account for approximately 18% of all cattle operations and pale in comparison, to the smaller cattle herds that have fewer than 100 hd, and make up nearly 82% of all cattle operations. Big pens (i.e. greater than 150 hd) may not allow the flexibility required to keep cattle from different sources separated. Keeping cattle sorted by sex and source will minimize morbidity and are critical to effectively producing cattle destined for an “All-Natural” program. Smaller capacity pens could prove valuable to the
“All-Natural” cattle feeder allowing for greater flexibility in acquiring single and known source cattle.

Summary

Technologies used in conventional production are critical tools to U.S. beef production. The differences in cost of production and purchase price for “All-Natural”, NHTC, and USDA-Organic cattle are going to need to be re-captured in premiums when the cattle are marketed. What this premium will need to be is dependent upon fallout rate and salvage animal weight. A higher fallout rate might allow for greater salvage out weight and a lower fallout rate might mean you have limited salvage weight by attempting to keep defective cattle in the program. The management practices used by successful “All-Natural” feeding programs must not be ignored. There may very well come a time, where the “tools” we use as beef producers may not be available. At that time, the cattle feeding enterprise that understands cattle nutritional management and growth biology better than others, might be in the best position to last in the long run.

Literature Cited


Main, D. G. 1990. The effects of ovarioectomy, growth promotants and pubertal status on perfromance of growing and finishing beef heifers M.S. Thesis, Michigan State University


Table 1. Cost of NEm and NEg ($/Mcal) in steers fed for 213 d.¹

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment²</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NI</td>
<td>Revalor-XS</td>
<td>Revalor-200</td>
</tr>
<tr>
<td>Observed NE, Mcal/lb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
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<td>0.92ᵃ</td>
<td>0.92ᵃ</td>
<td>0.010</td>
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<td>0.62ᵃ</td>
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</tr>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>0.92ᵇ</td>
<td>0.95ᵃ</td>
<td>0.95ᵃ</td>
<td>0.010</td>
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<tr>
<td>Gain</td>
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<td>NEg, $/Mcal</td>
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<td>$250.00, DM ton</td>
<td>0.2117ᵃ</td>
<td>0.2019ᵇ</td>
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</table>

¹ Adapted from (Smith et al., 2018).
² Treatments included: no implant (NI), 200 mg TBA and 40 mg E₂ administered at trial initiation (Revalor-XS) or 200 mg TBA and 20 mg E₂ administered on d 70 (Revalor-200).
ᵃᵇ Means without a common superscript differ (P < 0.05).
Table 2. Cost of NEm and NEg ($/Mcal) for steers fed for an average of 136 d.1

<table>
<thead>
<tr>
<th>Item, $/Mcal</th>
<th>Treatment2</th>
<th>NAT</th>
<th>CONV</th>
<th>CONV-Z</th>
<th>SEM</th>
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<td>Maintenance</td>
<td></td>
<td></td>
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<td></td>
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<td>NEm, Mcal/lb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain</td>
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<td>0.59b</td>
<td>0.61a</td>
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<tr>
<td></td>
<td>$250.00, DM ton</td>
<td>0.1602</td>
<td>0.1428</td>
<td>0.1385</td>
<td>-</td>
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<tr>
<td>NEg, $/Mcal</td>
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<td></td>
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<td>$250.00, DM ton</td>
<td></td>
<td>0.2505</td>
<td>0.2137</td>
<td>0.2057</td>
<td>-</td>
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</tbody>
</table>

1 Adapted from (Maxwell et al., 2015).
2 Treatments included: all natural (NAT), fed monensin sodium, tylosin phosphate, and administered an anabolic implant under conventional management (CONV), and conventional management + zilpaterol HCl (CONV-Z).

a,b Means without a common superscript differ (P < 0.05).
Table 3. Cost of NEm and NEg ($/Mcal) for steers fed for 151 d.¹

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment²</th>
<th>CON</th>
<th>LP</th>
<th>LPRH</th>
<th>MT</th>
<th>SEM</th>
</tr>
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<tbody>
<tr>
<td>Observed NE, Mcal/lb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>0.93ᵇ</td>
<td>0.97ᵃ</td>
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<td>Gain</td>
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<td>0.66ᵃ</td>
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<tr>
<td>Observed/expected NE</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
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<td>0.99ᵃ</td>
<td>0.98ᵃ</td>
<td>0.99ᵃ</td>
<td>0.007</td>
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<tr>
<td>Gain</td>
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<td>0.99ᵃ</td>
<td>0.98ᵃ</td>
<td>0.99ᵃ</td>
<td>0.010</td>
<td></td>
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<tr>
<td>NEm, $/Mcal</td>
<td>$250.00, DM ton</td>
<td>0.134₁ᵃ</td>
<td>0.129₁ᵇ</td>
<td>0.130₂ᵇ</td>
<td>0.128₆ᵇ</td>
<td>0.0010¹</td>
</tr>
<tr>
<td>NEg, $/Mcal</td>
<td>$250.00, DM ton</td>
<td>0.198₀ᵃ</td>
<td>0.188₅ᵇ</td>
<td>0.190₅ᵇ</td>
<td>0.187₆ᵇ</td>
<td>0.0019₀</td>
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</tbody>
</table>

¹ Adapted from (Thompson et al., 2016).
² Treatments included: no ionophore or antimicrobial (CON), fed laidlomycin propionate (12.1 mg/kg DM) and chlortetracycline (350 mg/hd/d) for 151 d (LP), fed laidlomycin propionate (12.1 mg/kg DM) and chlortetracycline (350 mg/hd/d) for 119 d and ractopamine HCl (300 mg/hd/d) for the final 32 d (LPRH), and fed monensin sodium (36.4 mg/kg DM) and tylosin phosphate (12.1 mg/kg DM) for 119 d and ractopamine HCl (300 mg/hd/d) was also included for final 32 d (MT).

ᵃᵇ Means without a common superscript differ (P < 0.05).
Table 4. Summary of performance from two Midwest PMS customers who place cattle of equal genetic merit into their “All-Natural” and conventional feeding programs (data courtesy of Dr. P. Anderson).

<table>
<thead>
<tr>
<th>Item</th>
<th>Steers, Yard A</th>
<th>Heifers, Yard A</th>
<th>Steers, Yard B</th>
<th>Heifers, Yard B</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Natural  Conv.</td>
<td>Natural  Conv.</td>
<td>Natural  Conv.</td>
<td>Natural  Conv.</td>
</tr>
<tr>
<td>Initial BW, lbs</td>
<td>849  809</td>
<td>793  792</td>
<td>817  809</td>
<td>772  723</td>
</tr>
<tr>
<td>Out BW, lbs</td>
<td>1259 1409</td>
<td>1268 1321</td>
<td>1343 1519</td>
<td>1260 1310</td>
</tr>
<tr>
<td>Days on feed</td>
<td>133  152</td>
<td>150  160</td>
<td>173  202</td>
<td>163  184</td>
</tr>
<tr>
<td>ADG, lbs</td>
<td>2.74  3.67</td>
<td>2.65  3.13</td>
<td>2.88  3.32</td>
<td>2.84  2.99</td>
</tr>
<tr>
<td>DMI, lbs</td>
<td>21.25 21.73</td>
<td>20.83 20.61</td>
<td>22.41 21.05</td>
<td>21.79 19.43</td>
</tr>
<tr>
<td>F:G</td>
<td>7.75  5.93</td>
<td>7.86  6.58</td>
<td>7.79  6.34</td>
<td>7.69  6.50</td>
</tr>
<tr>
<td>Death loss, %</td>
<td>2.63  1.92</td>
<td>4.75  1.75</td>
<td>1.71  1.75</td>
<td>7.76  2.35</td>
</tr>
</tbody>
</table>

1 Conv. = Conventional management.
Table 5. Range in value of 675 lb feeder heifers in a closeout summary from Midwest PMS.

Table 6. Range in value of 675 lb feeder steers in a closeout summary from Midwest PMS.
The 50th Anniversary of the California Net Energy System (CNES) Symposium was held at the University of California, Davis (UCD), from September 12 to September 14, 2018. This symposium built on the pioneering work of Professors Glen Lofgreen and Bill Garrett who published their system in the Journal of Animal Science in 1968 (A system for expressing net energy requirements and feed values for growing and finishing cattle, vol. 27, pp. 793-806). Their paper became the basis for how growing cattle are fed worldwide today and was the most cited paper in animal science journals for more than 25 years. The symposium focus was on cattle energetics, and how the CNES has been used since 1968 to improve our understanding of animal growth and nutrition through the presentation of fundamental and applied research by national and international speakers. The organizing committee consisted of two UC scientists Jim Oltjen and Bob Sainz, a nutritional consultant Carl Old who was a graduate student of Professor Garrett, and Michael Galyean, Texas Tech University Professor and Provost and beef cattle nutrition expert. The program was designed to encompass key issues in animal nutrition ranging from energy utilization at the animal level to energy interactions at the cellular and subcellular levels. Twenty nine internationally recognized speakers in a number of key areas were invited to give “state-of-the-science” presentations in each program session. There were eight sessions: 1) History of the California Net Energy System; 2) The California Net Energy System in Practice; 3) The California Net Energy System for Breeding Animals; 4) The California Net Energy System for the Tropics; 5) Modelling and the California Net Energy System; 6) Nutrient Interactions; 7) The California Net Energy System and Individual Efficiency; 8) The Future of the California Net Energy System; titles and speakers are given in Appendix 1. This presentation will attempt to share some highlights from each session. Some of the authors have submitted their conference papers to the journal Translational Animal Science, and these are now in press. In those cases, material from the papers has been used to enhance this presentation. Common abbreviations used throughout the text are given in Appendix 2.

**Session 1: History of the California Net Energy System**

Following introductory remarks by UCD dignitaries, Bob Sainz presented a brief history and overview of nutritional energetics, since Cal Ferrell was unable to attend. This included concepts such as the laws of thermodynamics, and partition of energy into digestible, metabolizable, and net energy components. Richard Zinn then gave a personal account of his relationships with Bill Garrett and Glen Lofgreen, for whom he worked as a youth and eventually succeeded at the Imperial Valley Field Station (now the UC Desert Research & Extension Center) in El Centro, CA. From its beginning, the California Net Energy System (CNES) was driven by the feedlot industry, and the unsatisfactory results obtained with the TDN system that existed in the 1950s. The comparative slaughter studies involving incremental replacement of a standard
reference feed (rolled barley) progressively led to development of the CNES. Lofgreen (1963) first presented the CNES to the industry, including separate NE values for maintenance and gain, and the maintenance coefficient (NE\textsubscript{m}) of 0.077 Mcal/kg\textsuperscript{0.75}. The actual paper (Lofgreen, G. P, and W. N. Garrett (1968) A system for expressing net energy requirements and feed values for growing and finishing cattle. J. Anim. Sci. 27:793-806) was rejected twice by the journal before being accepted! The rest, as they say, is history.

**Session 2: The California Net Energy System in Practice**

Fred Owens examined the use of live animal data to determine feed NE values, and gave examples in which comparison of reported gains with those projected by the CNES aided in spotting errors in data handling, experimental problems, and even data falsification. Drawing parallels between the CNES, a spouse’s automobile, and the institution of marriage, he concluded that “if it ain’t broke, don’t fix it”.

Robbi Pritchard discussed real world applications of the CNES, including for projections, tracking, program feeding, predicting CP requirements, comparative pricing of feedstuffs, estimating changes in efficiency, and estimating energy value of novel feeds. In practice, variables such as environmental conditions, biological types, nutrient deficiencies, associative effects, final shrunk body weights, and carcass transfer relationships mean that adjustments to the CNES must be and are made, generally in-house. However, the CNES remains a useful framework within which to work in the real world.

Jon Beckett also discussed the use of the CNES in practice, particularly for Holstein steers. The additive nature of feed NE values allows their use in ration formulation using linear programming. Limit feeding programs to achieve desired rates of gain, using appropriate coefficients for each feedstuff, produce improvements in efficiency and health. The CNES is also used to evaluate different feeding programs and growth-enhancing technologies with regard to animal performance. Feedlot accounting systems use bunk readings and feed DM and NE values to project animal body weights and make marketing decisions. Adjustments are required to account for variations in grain processing, silage grain content, different roughage types and degrees of maturity, interactions among feeds, and growth-enhancing technologies.

Kristin Hales presented new analyses of the relationships among DE, ME, and NE in current feedlot diets. In particular, the use of ME = 0.82 DE was shown to be inadequate, especially at higher values of DE. An alternative equation was given: ME (Mcal/kg DM) = -0.057 DE\textsuperscript{2} + 1.3764 DE – 0.9483. This equation implies that conversion of DE to ME is maximal (~ 0.93) around 3.65 Mcal DE/kg.

Bill Weiss spoke about the integration of DE predictions into NE systems, pointing out that the accuracy of the CNES depends on the accuracy of the feed ME values. Feed or diet ME values can be measured directly but are expensive and require specialized facilities; therefore, most ME values are estimated from DE values, which are often
estimated from tabular values of TDN. The digestibility coefficients of the components of
TDN are quite variable, and are affected by such factors as particle size and grain flake
density, but use of feed tables ignores this variation. Furthermore, the use of TDN to
estimate DE does not account for important variation in the gross energy (GE) value of
feeds. A widely used summative equation based on commonly measured feed fractions
(ash, crude protein, neutral detergent fiber, and fat) has been shown to accurately
estimate DE concentrations of many diets for cattle; however, deficiencies in that
equation have been identified and include an overestimation of DE provided by fat and
an exaggerated negative effect of intake on digestibility. Replacing the nonfiber
carbohydrate term (which included everything that was not measured) in the equation
with measured starch concentration and residual organic matter (i.e., non-fiber
carbohydrate minus starch) should improve accuracy by accounting for more variation
in starch digestibility. More accurate estimates of DE will improve the accuracy of ME
values, which ultimately will lead to more accurate NE values.

Session 3: The California Net Energy System for Breeding Animals

David Lalman presented some applications of the CNES to grazed forages. Challenges
include accurate assessments of feed intake and digestibility of grazed forages, as well
as the dynamic conversions from DE to ME and NE. Other unknowns include body
composition, fasting heat production, genetic trends in growth and milk yield potentials,
and environmental effects. Regarding grazing cows, most pastures are at or below 60%
TDN (~1.35 Mcal NE\textsubscript{m}/kg or below), at which the 0.82 ME:DE appears to work. The
partition of energy to tissue or milk varies according to feeding level, from ~17% to
tissue just above maintenance to 32% at very high intakes. Maintenance requirements
also vary greatly among individuals, as do milk yield (and weaning weights) in response
to increasing energy intake and genetic selection. These variables require updates to
the inputs used for CNES in grazing cattle.

Harvey Freetly presented the use of the CNES for cows and required changes in the
energy coefficients. The same model structure used to describe energy metabolism in
the growing animal is often used to model energy metabolism in the cow. Energy
requirements of the cow are modelled as the summation of energy required for
maintenance and recovered energy; where, recovered energy is the summation of
energy for the conceptus, milk, and tissue energy. Energetic requirements of the cow
fluctuate throughout the year production cycle depending on whether they are pregnant,
lactating, or both. The current model requires energy cost to be associated with either
net energy of maintenance or the partial efficiencies of conceptus growth, milk
production, and tissue energy change. Mathematically, they are not independent.
Incorrectly estimating one will result in an erroneous estimate in the other. Most of the
current models in production agriculture allocate energy use into maintenance, and
synthesis of tissues making it difficult to assign energy utilization by tissues that provide
support functions to pregnancy, lactation, and weight fluctuation. The consequence is
the assignment of partial efficiencies that reflect whole animal efficiencies rather than
tissue efficiencies. Historically these models have been predictive of energy
metabolism, but caution should be used when inferring the energetic efficiency at the
tissue level. Alternative modelling approaches more thoroughly describe tissue energy metabolism and have been used to estimate whole animal metabolism. These models resolve the problems associated with developing coefficients that lack biological meaning but are more complex. There is a critical need of independent data sets to test new components of the model for cows.

Joel Caton discussed maternal nutrition and programming of offspring energy requirements. Developmental programming is the concepts that stressors during critical windows of development can have both short and long-term consequences on growth, development, and health in offspring. Compromised offspring may have altered metabolic and body composition outcomes at various points postnatally, which could influence NE\(_{m}\) or NE\(_{g}\) requirements. Indirect evidence suggests that maintenance requirements are likely altered in offspring from dams with compromised nutrition. Energy requirements for gain are driven by energy retention, which is influenced by body composition. Suboptimal maternal nutrition can alter body composition in offspring at various stages postnatally. Most published research has investigated the influences of suboptimal maternal nutrition during the last two-thirds of gestation, but maternal nutrition during early pregnancy could be much more important to the developing conceptus than previously thought.

### Session 4: The California Net Energy System for the Tropics

Mario Chizzotti described work to apply the CNES for *Bos indicus* cattle in Brazil. He and colleagues at the Federal University in Viçosa, under the leadership of Professor Sebastião Valadares, have undertaken a large number of comparative slaughter experiments, with complete grinding and analysis to obtain actual RE values. This work has been summarized in the Brazilian tables of nutrient requirements known as BR-Corte, with editions in 2006, 2010, and 2016. This latter publication included 1,369 animals (62% bulls, 26% steers, and 12% heifers). Chizzotti pointed out that BR-Corte uses EBW rather than shrunk BW as in NASEM (2016). When placed on an equal BW basis, Zebu cattle have NE\(_{m}\) requirements that are 8 to 10% lower than *Bos taurus* breeds. Other differences include a lower ratio of NE\(_{g}\) to EBW gain. Both systems predicted similar NE\(_{g}\) for animals gaining 1.8 kg/d. For pregnancy and lactation of beef cows, the NE\(_{m}\) and NE for pregnancy (NE\(_{p}\)) of Zebu cows were lower than the values estimated by NASEM. Furthermore, the magnitude of differences between these systems regarding NE\(_{p}\) increased as pregnancy days increase. The NASEM and BR-CORTE systems have presented similar values for energy requirement for lactation (0.72 and 0.75 Mcal/kg milk, respectively).

Dante Lanna described application of the CNES for Brazilian feedlots, pointing out that Glen Lofgreen introduced the CNES to Brazil in 1965 as part of a USAID-funded project. The small proportion of Brazilian cattle that are finished in feedlots generally are fed for 70 to 100 days, and are typically harvested around 22% empty body fat. Some biological differences between the *Bos indicus* cattle most commonly raised in Brazil to the *Bos taurus* breeds used in the US include: an upper limit to observed TDN values
(around 68%), greater protein requirements, lower (-10%) NE\textsubscript{m} requirements that seem little affected by castration, and great plasticity in the NE\textsubscript{m} requirement.

Izabelle Teixiera reviewed the use of the CNES for goats. The approach taken by her group in Brazil was to follow the CNES rationale and methodology, while deriving coefficients for each animal category (breed, age and sex). NE\textsubscript{m} requirements of intact and castrated male Saanen goats were approximately 15% greater than female Saanen goats. Similarly, NE\textsubscript{m} of meat goats (i.e., > 50% Boer) was 8.5% greater than that of dairy and indigenous goats. At a given EBW, female and castrated male Saanen goats had greater NE\textsubscript{g}, therefore greater body fat than males. Indigenous goats had NE\textsubscript{g} 14% and 27.5% greater than meat and dairy goats, respectively. Sex and genotype also affect the efficiency of energy use for growth. Losses in urine and methane in goats are lower than previously reported for bovine and sheep, resulting in greater ME:DE ratio (i.e., 0.87 to 0.90). The CNES works well for goats, as long as goat-specific model coefficients are used. However, these models require real-world evaluation and adjustment.

**Session 5: Modelling and the California Net Energy System**

Jim Oltjen gave an overview of the mathematical bases of the CNES. Ideally, diet NE can be estimated from a feeding trial with at least two feeding levels, so that the slope of RE vs DMI is NE\textsubscript{g}, the x-intercept is DM\textsubscript{lm}, and NE\textsubscript{m} is 0.077 / DM\textsubscript{lm}. Alternatively, we can use a single feeding level plus a metabolism trial, with estimates of ME and heat production (HE). A plot of log HE vs ME intake allows estimation of maintenance ME (ME\textsubscript{m}) as the point where ME intake is equal to HE. Then the DM intake for maintenance is estimated as ME\textsubscript{m} / diet ME content, NE\textsubscript{m} is 0.077 / DM\textsubscript{lm}, and NE\textsubscript{g} = RE / (DMI - DM\textsubscript{lm}). A third alternative, most commonly used today, is to solve the Lofgreen & Garrett equations.

Carl Old described what he terms mathematical absurdities in the CNES, pointing out that the CNES is useful for prediction of input:output relationships but is not necessarily faithful to the laws of thermodynamics. The identity ME = HE + RE is basic to descriptions of energy utilization found in the CNES and is consistent with the laws of thermodynamics. Partial efficiencies of ME utilization for maintenance (km) and gain (kg) estimated using static linear models are often inconsistent with the biochemistry of processes underlying maintenance and gain. Thermodynamically, catabolism should be less efficient than anabolism, in the CNES km > kg, due to insufficient accounting of HE for maintenance. Variable efficiencies of ME utilization require that the first law may not be observed in all cases. The CNES is an excellent empirical tool for prediction of input:output relationships, but many CNES parameter estimates evaluated in this study lack consistency with biology and the laws of thermodynamics.

Luis Tedeschi examined relationships between retained energy and retained protein (RP). Interrelationships between RE and retained protein (RP) influence energy and protein requirements of growing cattle and feed efficiency. There are satisfactory correlations between observed and predicted RE (r = 0.93) and between observed and
predicted RP when using predicted RE to estimate RP \( (r = 0.939) \), but a much lower correlation between observed and predicted RP when using observed RE to estimate RP \( (r = 0.679) \). This indicates an interdependency between predicted RP and predicted RE. The unsatisfactory prediction of RP from observed RE might be related to the fact that body fat has a caloric value that is 1.6 times greater than body protein and the body deposition of fat increases exponentially as an animal matures, whereas body deposition of protein tends to plateau. Thus, body fat is more influential than body protein in determining RE, and inaccuracies in estimating body protein will impair the RP estimate to a much greater degree than the RE calculation. Another concern is the disconnect between \( k_g \) and the proportion of RE deposited as protein (the carcass approach) vs. the concentration of ME of the diet (the diet approach). The diet approach assigns energy losses that are associated with supporting energy-expending processes to the RE pool, whereas the carcass approach assigns these losses to the overall heat production that is used to support tissue metabolism. Opportunities exist for improving the California Net Energy System regarding the relationships of RE and RP in computing the requirements for energy and protein by growing cattle, but procedural changes might be needed such as increased accuracy in the determination of body composition and better partitioning of energy.

Luis Moraes presented some concepts of multivariate modeling for retained energy and protein. Partial energetic efficiencies and maintenance coefficients have been traditionally estimated with a linear regression model that treats ME intake as the dependent variable and protein and lipid depositions as the independent variables. There are statistical issues associated with this approach, such as the reverse role of dependent and independent variables and likely multicollinearity between protein and lipid depositions. Biased regression techniques partially address the harmful effects of multicollinearity. In the 1970s, L. J. Koong estimated energy parameters using a set of simultaneous equations. This multivariate approach has been considerably extended in the past two decades with the complete characterization of model's biological interpretation under different feeding conditions, the simultaneous estimation of maintenance requirements, the extension of the model to a mixed-effects framework and the implementation of a Bayesian framework for model fitting. However, multivariate models are generally harder to fit than linear regression models due to i) larger number of parameters, ii) issues with parameter identifiability and iii) overall lack of algorithm convergence. Therefore, with the recent availability of easy to use and efficient computer packages for model fitting, the use of a Bayesian framework seems to be an attractive approach for fitting multivariate models describing protein and lipid deposition.

Session 6: Nutrient Interactions

Isabelle Ortigues presented concepts and data used in the 2018 revision of the INRA feeding system, regarding the use of nutrient fluxes to complement the NE system. Energy units such as \( \text{GE, DE, ME, NE} \) are aggregated units, each of which is composed by a wide variety of diet components and molecules. Predictions of carcass fat content (main component of RE) from NE intake are quite poor. The INRA system now considers digestive interactions in the prediction of DE from GE, by explicitly
modelling production of UE (mainly from CP), and methane (from feeding level + % concentrate). Therefore, feedstuffs don’t have unique nutritional values. Compared to the previous system, lower energy diets have been downgraded, and higher energy diets have been upgraded. The poor predictions of carcass composition, however, were not improved. The next step was to decompose ME into individual metabolizable nutrients. In the rumen and small intestine, the system considers NDF, starch, CP, and lipids (FA), and the model predicts portal fluxes of VFA (C2, C3 and C4), individual amino acids, glucose, and FA. Absorbed energy may be estimated as the sum of the energies of metabolizable nutrients, or as ME + UE – heat of fermentation. Ortigues also pointed out that it may not be necessary to employ mechanistic modelling, rather simpler proxies may be useful. For example, the ratio starch:NDF is a proxy for the supply of glucogenic:ketogenic precursors, and preliminary data indicate that this ratio is linearly related to the carcass fat content.

Antonio Faciola discussed the effects of in vitro rumen fermentation on NE values, specifically the relationship between diet CP and NDF and amount of substrate (fermenter DMI) with microbial fermentation end-products in a dual-flow continuous culture system. A meta-analysis was performed using data from 75 studies. Digestibilities of OM, NDF and CP decreased as fermenter DMI increased (P < 0.04). Increasing fermenter DMI increased total VFA concentration and molar proportion of propionate, whereas, dietary NDF increased the molar proportion of acetate. Dietary CP increased bacterial-N flow and was positively associated with NH₃-N concentration. Overall, the dual-flow continuous culture system provides valuable estimates of ruminal digestibility, volatile fatty acids concentration, and nitrogen metabolism.

Stephanie Hansen discussed interactions between NE and mineral and vitamin status of feedlot cattle. Several minerals are involved in key physiological functions (e.g., immunity, skeletal and muscle growth, cellular metabolism) that in turn affect performance (e.g., health, DM intake, gain, feed efficiency, carcass quality). Minerals support optimal extraction and retention of diet energy, e.g., metalloenzymes such as amylases, proteases, and phospholipases and therefore affect digestibility. Although there is growing appreciation of the importance of the GI tract microbiome, its trace mineral requirements are unknown. Other interventions, such as the use of ionophores, are known to affect mineral absorption and retention. Mineral supplementation may not always be beneficial, since there are energy costs of mineral absorption and reabsorption. Other examples of minerals that affect energy balance include I (required for synthesis of thyroid hormones, major regulator of metabolic rate), as well as Se, a cofactor for the inactive-to-active conversion enzyme. Antioxidant minerals (Mn, Zn, Cu, Se, S) and vitamins (C, E) help mitigate the energetic cost of dealing with oxidative damage in the cell.

Evan Titgemeyer gave a presentation about protein and amino acid utilization by beef and dairy cattle and their interactions with the CNES. The underlying premise of the CNES is that growth is limited by energy, that is, there no deficiencies of protein or any other nutrient. In cases of metabolizable protein (MP) deficiency, protein deposition will decrease, and fat deposition will increase, increasing the RE but depressing gain. The
increased gain obtained with protein (or some amino acids) supplementation could easily be mistaken for increased dietary NE\(_g\). If MP requirements of cattle are not met, dietary NE values calculated from gain will be incorrect and inappropriate. At the other extreme, it appears that feeding excess protein has little or no negative impact on performance, indicating that the energy cost of urea excretion is negligible.

**Session 7: The California Net Energy System and Individual Efficiency**

Bob Sainz talked about different concepts of efficiency, starting with the simple feed conversion ratio, and ending with residual feed intake. Basically, a more efficient animal might: select a better diet, be better at digesting feed, have a greater lean:fat ratio (i.e., lower NE\(_g\) requirement for a given gain), have a lower NE\(_m\), or be more efficient at synthesizing ATP. Application of the CNES equations allows identification of several equations and their coefficients that would have to change in order to account for differences in feed efficiency, namely diet ME, HeE, \(k_m\), and \(k_g\). Data were shown to support each of these physiological and mathematical mechanisms, with strongest evidence for a negative relationship between feed efficiency and the maintenance energy coefficient (NE\(_m\)). Variations in NE\(_m\) are likely related to both energy-requiring processes (i.e., service, cell maintenance and repair functions) as well as ATP synthesis (via proton leakage across the inner mitochondrial membrane). Finally, consideration was given to overall beef production system efficiency, and the importance of other traits such as milk yield and reproductive performance.

Katie Wood discussed relationships between metabolism and feed efficiency. Drawing upon several studies with pregnant and lactating cows on different feeding levels, Wood presented the concepts of metabolism according to the push- as well as the pull-hypotheses. Based on gene expression data, she showed that pathways associated with protein turnover (pull), mitochondrial efficiency (push) and energy signaling (mainly insulin and SIRT1, both push and pull) were related to individual animal efficiency in different physiological and nutritional states.

Allison Meyer presented effects of maternal metabolic efficiency on cow lifetime productivity and offspring efficiency. We place many demands on cows, namely they must conceive no matter what, calve with no assistance, wean a heavy calf but not make too much milk, and graze all the time but not eat much. The inputs to the system are cow DM intake, which is very hard to measure, and the outputs are the weaned calf, and eventually the cull cow. Ultimately, the net result in terms of efficiency depends on the balance of nutrient use for cow maintenance vs, nutrients transferred to the calf, which is the result of the integral of Genotype x Environment interaction. Additional concerns have to do with developmental programming, and also calf death losses preweaning, which can change everything.

Dan Shike made a presentation of management practices to improve efficiency, at the group and individual level. Efficiency describes the relationship between inputs and outputs. Inputs are easy to measure in the feedlot, difficult in grazing cattle. Outputs are much simpler to obtain. Some management practices that are used to manage
efficiency include programmed feeding, heifer development, grazing management, supplementation and creep feeding, environmental modification, weaning age, and growth-promoting technologies. Since maintenance takes up 50% of all feed, it makes sense to focus on factors affecting maintenance, such as acclimation and previous nutrition (i.e., compensatory growth). Individual management options are increasing rapidly with the development of sensing and IT technology, as well as “big data” analytical methods.

Session 8: The Future of the California Net Energy System

Clint Krehbiel discussed how to incorporate disease effects in the CNES. The NASEM defines stress as a non-specific, abnormal or extreme physiological adjustment/response of the body to cope with adverse effects of the environment or management. Proper animal husbandry aims to reduce the impact of multiple stressors. For example, feedlot cattle are subject to morbidity and mortality due to respiratory, digestive, skeletal, and other disorders. Contributing factors include commingling, weather, feed changes, animal handling and processing, which tend to compromise the immune system. Performance losses are caused by reduced intakes, as well as the metabolic costs of mounting an immune response, so that NE\textsubscript{m} increases at the same time that ME intake is decreased, leading to a catabolic state. Even with short-lived inflammation, there may be long-term impacts on performance and carcass quality, especially for chronically-infected cattle.

Hutton Oddy speculated on what's next after ME and NE systems, which have remained essentially unchanged after more than 50 years. Feeding systems must be practical, and depend upon a robust support ecosystem (i.e., feed evaluation, delivery personnel, training, and interaction with R&D community for continual improvement). Deployment of needed changes to a feeding system (e.g., variable maintenance requirements and feed efficiencies, genotype x environment interactions, etc.) is slowed down by the size of the support ecosystem. Even so, the future might include individual animal predictions, contemplating grazing cattle, and will likely involve a dynamic data collection and modelling approach. Novel measurement systems and machine learning tools will create opportunities, but their deployment within a large support ecosystem and a mature industry is doubtful.

Gordon Carstens discussed how feeding-behavior patterns and the NE system could be utilized to predict intake. Precision livestock farming will use real-time monitoring of individual animals to assist in detecting and managing health and productivity. Applications will include improved animal health management, optimized feed delivery, and maximal-profit harvest endpoint determination. Automated feed intake monitoring has shown that individual variation in efficiency translates into variation in profitability. Feeding behavior patterns, including number and duration of bunk visits, head-down duration, meal duration, and non-feeding interval duration, are more easily and cheaply obtained. These variables may be useful to detect differences in individual intake and efficiency in a cost-effective manner.
Kris Johnson presented a talk on whether or not the CNES can help with methane and greenhouse gas (GHG) prediction. Increasingly, ration formulators are being required to consider environmental concerns such as methane (both enteric and manure), ammonia and nitrous oxide in manure, nitrate leaching, particulates, P in manure, odor and H₂S. The short answer to the title is no, because a) the CNES was not developed with this goal, and 2) methane energy losses in the feedlot are very low (1 - 3% of GE). Issues with methane prediction include the 0.782 ME/DE factor, feedstuff NE predictions, associative effects (e.g., fat vs. fiber digestion), and innumerable feed additives (e.g., ionophores, nitrate, seaweed, tannins, etc.) with variable and unknown impacts on methanogenesis.

At the end of the symposium, Michael Galyean was given the unenviable task of summarizing in 10 minutes everything he heard over the past two days. Since I have attempted to do the same here, I will not repeat his comments except to allow that he probably did a better job than I.
Appendix 1 – The California Net Energy System 50th Anniversary Symposium
Program

**Session 1: History of the California Net Energy System**

History of energetics leading to the net energy system
*Cal Ferrell - USDA ARS, Retired, Ferrell Farms, Saronville, NE & Roberto Sainz, UC Davis*

Glen Lofgreen, Bill Garrett, and the California Net Energy System (CNES)
*Richard Zinn - University of California, Davis*

**Session 2: The California Net Energy System in Practice**

Can we really use animal performance data to determine feed NE values?
*Fred Owens - Oklahoma State University*

Real-world applications of the CNES
*Robbi Pritchard - Consultant, Aurora, SD*

How does the NE system work in practice? Is it really helpful?
*Jon Beckett - Feedlot Consultant, Fallbrook, CA*

Relationships among DE, ME, and NE in current feedlot diets
*Kristin Hales - USDA ARS, Clay Center, NE*

How do you integrate DE predictions into NE systems?
*Bill Weiss - The Ohio State University*

**Session 3: The California Net Energy System for Breeding Animals**

Applications of the CNES to grazed forages - Feed values and animal requirements
*David Lalman Oklahoma State University*

What are the energy coefficients for cows?
*Harvey Freetly USDA ARS, Clay Center, NE*

Maternal nutrition and programming of offspring energy requirements
*Joel Caton North Dakota State University*

**Session 4: The California Net Energy System for the Tropics**

The CNES for Bos Indicus
*Mario Chizzotti - Federal University Viçosa, Brazil*

How does the CNES have to change for Brazilian feedlots?
Dante Lanna - University of São Paulo, Piracicaba, Brazil

Does the CNES work for goats?
Izabelle Teixiera - São Paulo State University, Jaboticabal, Brazil

Session 5: Modelling and the California Net Energy System

How did Garrett and Lofgreen do the math?
Jim Oltjen - University of California, Davis

What about the mathematical absurdities in the CNES?
Carl Old – Consultant

Relationships between retained energy and retained protein
Luis Tedeschi - Texas A & M University

Multivariate modeling for retained energy and protein
Luis Moraes - The Ohio State University

Session 6: Nutrient Interactions

Are nutrient fluxes the next step?
Isabelle Ortuigues - INRA Theix, France

How does rumen fermentation affect NE values?
Antonio Faciola - University of Florida

Net Energy interactions with mineral status
Stephanie Hansen - Iowa State University

How does protein affect the CNES?
Evan Titgemeyer - Kansas State University

Session 7: The California Net Energy System and Individual Efficiency

What is efficiency?
Roberto Sainz - University of California, Davis

Metabolism and feed efficiency
Katie Wood - University of Guelph

Maternal metabolic efficiency on cow lifetime productivity and offspring efficiency
Allison Meyer - University of Missouri

Management practices to improve efficiency?
Dan Shike - University of Illinois
Session 8: The Future of the California Net Energy System

How do we incorporate disease effects in the CNES?
*Clint Krehbiel - University of Nebraska*

What's next after ME and NE systems?
*Hutton Oddy - New South Wales DPI, Armidale, Australia*

How can feeding-behavior patterns and the NE system be utilized to predict DMI?
*Gordon Carstens - Texas A&M University*

How does NE system help (or not) with methane and GHG prediction?
*Kris Johnson - Washington State University*

What have I heard? Conference summary
*Michael Galyean - Texas Tech University*
### Appendix 2 – Glossary of energy terms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
<th>Common units</th>
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<tbody>
<tr>
<td>CP</td>
<td>Crude protein</td>
<td>kg/kg or kg/d</td>
</tr>
<tr>
<td>DM</td>
<td>Dry matter</td>
<td>kg/kg</td>
</tr>
<tr>
<td>DMI</td>
<td>Dry matter intake</td>
<td>kg/d</td>
</tr>
<tr>
<td>DE</td>
<td>Digestible energy</td>
<td>Mcal/kg (feed)</td>
</tr>
<tr>
<td>ME</td>
<td>Metabolizable energy</td>
<td>Mcal/kg (feed)</td>
</tr>
<tr>
<td>NE&lt;sub&gt;m&lt;/sub&gt;</td>
<td>Net energy for maintenance</td>
<td>Mcal/kg (feed) or Mcal/d (animal)</td>
</tr>
<tr>
<td>NE&lt;sub&gt;g&lt;/sub&gt;</td>
<td>Net energy for gain</td>
<td>Mcal/kg (feed) or Mcal/d (animal)</td>
</tr>
<tr>
<td>km</td>
<td>Partial efficiency of energy for maintenance</td>
<td></td>
</tr>
<tr>
<td>kg</td>
<td>Partial efficiency of energy for gain</td>
<td></td>
</tr>
<tr>
<td>HE</td>
<td>Heat energy</td>
<td>Mcal/d</td>
</tr>
<tr>
<td>RE</td>
<td>Retained energy</td>
<td>Mcal/d</td>
</tr>
<tr>
<td>RP</td>
<td>Retained protein</td>
<td>Kg/d</td>
</tr>
</tbody>
</table>
Mineral and Vitamin Status in Cattle: Sampling and Diagnostics

Dwayne Hamar
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Topics

- Copper
- Vitamin A
- Selenium
- Vitamin E
- Zinc
- Manganese
- Cobalt

Cu Deficiency

- Result of feeding rations
  - high in Mo
  - low in Cu
  - low Cu:Mo ratio
- High sulfur intake
  - S potentiates Mo effect
Grasses normally low in Cu, may be high in Mo
May have high sulfur intake - Water

Mechanism of Action

- Formation of di-, tri- & tetrathiomolybdate which binds to Cu, and is not available
- Cu is found in many metalloenzymes
- With Cu deficiency there is a deficiency of Cu enzymes
COW vs FETUS LIVER Cu *

<table>
<thead>
<tr>
<th>TRIMESTER</th>
<th>DAM FETAL LIVER Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRST</td>
<td>DAM</td>
</tr>
<tr>
<td></td>
<td>&lt; 10</td>
</tr>
<tr>
<td>SECOND</td>
<td>164</td>
</tr>
<tr>
<td>THIRD</td>
<td>241</td>
</tr>
<tr>
<td></td>
<td>289</td>
</tr>
<tr>
<td>THIRD</td>
<td>299</td>
</tr>
<tr>
<td></td>
<td>346</td>
</tr>
<tr>
<td></td>
<td>434</td>
</tr>
</tbody>
</table>


Determine Cu Status

Normal

- Determine serum Cu, 0.8 – 1.2 ppm
- Determine liver Cu, 100 – 600 ppm, dw
- Determine dietary Cu & Mo ~ 8:1
- Determine dietary S, dietary S:Mo should be < 100:1 (consider H2O SO4⁻2 as dietary)

Determine Cu Status

- Determine serum Cu, < 0.6 ppm, Cu def.
- Determine liver Cu, < 40 ppm, dw, Cu def.
- Determine liver Cu, > 1000 ppm, dw, tox.
- Determine dietary Cu & Mo < 4:1, def.
- Determine dietary S, dietary S:Mo should be < 100:1 (consider H2O SO4⁻2 as dietary)

Cu Toxicity

- Cu accumulates in the liver
- Excess Cu damages the cell membrane (stress or ingestion of hepatotoxins exacerbates)
- Inc. circulating Cu, damages the RBC membranes
- Inc. circulating Cu, accumulates in the Kidney

Diagnosis of Copper Deficiency

COPPER Diagnostic level

Bovine (Adult): Serum

- Normal 0.8-1.2 ppm
- Deficient < 0.6 ppm
- Toxic not elevated

Dietary molybdenum and sulfur decrease copper utilization. Excessive zinc and iron may also decrease copper utilization.
COPPER Diagnostic level
Bovine (Adult): Liver(dw)
Normal 100-600 ppm
Deficient < 40 ppm is inadequate to maintain a normal serum copper level
Toxic > 1,000 ppm
Please note that fetal and newborn liver copper is accumulated during gestation at the expense of the dam. Fetal and neonatal liver copper (Normal > 300 ppm) will be higher than that of the dam.

Vitamin A
• green forages (β-carotene)
• Stored in the liver
• Liver levels maintain serum levels until liver is depleted

VITAMIN A Diagnostic level: Bovine (Adult): Serum
Normal, > 0.4 μg/mL.
0.2-0.4 μg/mL indicates a deficiency
< 0.1 μg/mL indicates advanced deficiency.
Newborn and fetal liver and serum are very low.

VITAMIN A Diagnostic level: Bovine (Adult): Liver (ww)
Normal, 30-80 μg/g
< 30 μg/g indicates an inadequate store to maintain a normal serum vitamin A
Newborn and fetal liver and serum are very low.

Se
• Deficiency
• Toxicity

• Vitamin E can replace some of Se requirement and visa versa
SELENIUM Diagnostic level: Bovine (Adult): Serum
Normal, 0.06-0.15 ppm
Marginal, 0.02-0.06 ppm
High, 0.80-3.50 ppm

Please note that whole blood better reflects the past few month's nutritional selenium status.

SELENIUM Diagnostic level: Bovine (Adult): Blood
Normal, 0.1-0.5 ppm
Marginal, 0.05-0.1 ppm
Deficient, < 0.05 ppm
Toxic, > 1 ppm.

SELENIUM Diagnostic level: Bovine (Adult): Liver (dw)
Normal, 0.3-1.0 ppm
Deficient, < 0.2 ppm
Toxic, > 5.0 ppm

Fetal Liver (dw)
Normal, < 5.0 ppm
Toxic, > 12 ppm.

SELENIUM Diagnostic level: Bovine: Hair - Toxic, >5.0 ppm
Can hair Se be used to determine overall Se nutritional status?

SELENIUM Diagnostic level: Bovine: Hoof - Normal, 0.34-0.72 ppm
Deficient, < 0.34 ppm
High, > 5.0 ppm
Toxic, > 10 ppm.
VITAMIN E Diagnostic level: Bovine (Adult): Liver (ww)
Normal, > 3 μg/g
Deficient, < 2 μg/g

Newborn and fetal liver and serum are lower than adult and probably do not obtain adult levels until at least 6 months of age.

VITAMIN E Diagnostic level: Bovine (Adult): Serum
Normal, > 4 μg/mL
Deficient, < 2 μg/mL

Please note that hemolysis and/or prolonged contact with red blood cells may artificially decrease serum vitamin E concentrations. Newborn and fetal liver and serum are lower than adult and probably do not obtain adult levels until at least 6 months of age.

ZINC Diagnostic level: Bovine (Adult): Serum
Normal, 0.7-1.4 ppm
Deficient, 0.2-0.4 ppm

Use Royal Blue Tubes
Please note that hemolysis and/or prolonged contact with red blood cells may artificially elevate serum and plasma zinc concentrations.

ZINC Diagnostic level: Bovine (Adult): Liver (DW)
Normal, 90-400 ppm
Deficient, < 75 ppm.

MANGANESE Diagnostic level: Bovine: Serum
Normal, 0.005-0.070 ppm
Marginal, < 0.005 ppm
Toxic, > 0.080 ppm.

MANGANESE Diagnostic level: Bovine: Liver (dw)
Normal, 10.0-24.0 ppm
Deficient, < 4.0 ppm
High, > 50.0 ppm.
COBALT Diagnostic level: Bovine: Serum - Normal, 0.0009-0.015 ppm

Please note that vitamin B12 levels may be a more reliable indicator of cobalt deficiency than serum cobalt concentrations.

COBALT Diagnostic level: Bovine: Liver (dw)
Normal, 0.08-0.34 ppm
Deficient, 0.02 ppm
Toxic, > 20.0 ppm.
Mid–Late Feeding Mortalities in Finishing Cattle and Potential Causes

Causes of hypoxia in mammals
- Altitude
- Exercise (endurance sports)
- Lung disease
- Heart disease
- Anemia (RBC)
- Blood flow restriction
- Tissue–metabolism (glycolytic)
- Obesity
- Etc.

Research Article
Cardiopulmonary remodeling in fattened beef cattle: a naturally occurring large animal model of obesity-associated pulmonary hypertension with left heart disease

Pulmonary Circulation 2019; 9(1) 1–13
DOI: 10.1177/1936359018817989
Important traits difficult to measure:
a. Feed efficiency
b. Fertility
c. Health traits (PH)
d. Grazing distribution
e. Consumption traits
f. etc.

Heart–lung Alphabet and Semantics
- PH
- RV
- PAP
- HMD (brisket disease)
- FHD (late feedlot death)
- BRD (BRSV)
- EPD

Distribution of yearling PAP Scores; n = 5659
(bulls, heifers, steers; Zeng, 2016).
- Low risk; ≤ 41 mmHg; 50.8%
- Moderate risk ≥ 42 to ≤ 49 mmHg; 38.1%
- High risk >50 mmHg; 11.1%
  (Holt and Callan, 2007)

Animals

<table>
<thead>
<tr>
<th>Animals</th>
<th>Altitude (m)</th>
<th>mPAP (mmHg)</th>
<th>Range (mmHg)</th>
<th>Reference, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angus fattening steers; n = 100</td>
<td>1,400</td>
<td>54.1 ± 2.7</td>
<td>42-143</td>
<td>Krafsur et al., 2017</td>
</tr>
<tr>
<td>Yearling Angus bulls; n = 1,397</td>
<td>2,200</td>
<td>45.8 ± 0.3</td>
<td>29-139</td>
<td>Zeng et al., 2016</td>
</tr>
<tr>
<td>Yearling bulls at 8C; n = 3,426</td>
<td>2,200</td>
<td>45.1 ± 0.8</td>
<td>29-145</td>
<td>Crawford et al., 2007</td>
</tr>
<tr>
<td>Mature Angus cows; n = 44</td>
<td>2,200</td>
<td>42.8 ± 0.8</td>
<td>31-55</td>
<td>Bailey et al., 2006</td>
</tr>
<tr>
<td>Yearling Angus heifers; n = 3489</td>
<td>2,200</td>
<td>43.4 ± 2.2</td>
<td>22-135</td>
<td>Zeng et al., 2016</td>
</tr>
<tr>
<td>Yearling Angus stockers; n = 773</td>
<td>2,200</td>
<td>41.1 ± 0.2</td>
<td>27-138</td>
<td>Zeng et al., 2016</td>
</tr>
<tr>
<td>Angus-crosed steers; n = 49</td>
<td>0</td>
<td>34 ± 0.5</td>
<td>28-41</td>
<td>Holt, personal comm.</td>
</tr>
<tr>
<td>Mature American Bison; n = 6</td>
<td>2,200</td>
<td>29.6 ± 1.6</td>
<td>26-34</td>
<td>Holt, personal comm.</td>
</tr>
<tr>
<td>Mature Himalayan Cows; n = 6</td>
<td>3,720</td>
<td>26.5 ± 1.4</td>
<td>24-30</td>
<td>Anand et al., 1986</td>
</tr>
<tr>
<td>Mature Himalayan Yak; n = 6</td>
<td>3,720</td>
<td>28.2 ± 1.4</td>
<td>18-21</td>
<td>Anand et al., 1986</td>
</tr>
<tr>
<td>Healthy Human, (meta-analysis)</td>
<td>≤ 400</td>
<td>25</td>
<td>15-35</td>
<td>Burren et al., 2013</td>
</tr>
<tr>
<td>Human hypertension (meta-analysis)</td>
<td>≤ 400</td>
<td>&gt;55</td>
<td>15-70</td>
<td>Burren et al., 2013</td>
</tr>
</tbody>
</table>

Table 1. mPAP and blood gases of fasted Angus steers (n = 25) one week prior to slaughter. Steers were fed at low altitude (1,400 m). Normal values from Burren et al. (1986) and Match et al. (2019).
**Heritability of mPAP**

<table>
<thead>
<tr>
<th>Study</th>
<th>Heritability</th>
<th>Breed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enns, et al. 1992</td>
<td>.46</td>
<td>Angus (Seedstock, registered)</td>
</tr>
<tr>
<td>Shirley et al. 2008</td>
<td>.34</td>
<td>Angus (Seedstock, registered)</td>
</tr>
<tr>
<td>Crawford et al. 2016</td>
<td>.25</td>
<td>Angus (Seedstock, research)</td>
</tr>
<tr>
<td>Zeng, 2013</td>
<td>.56 (weaning)</td>
<td>.31 (yearling)</td>
</tr>
<tr>
<td>Pauling et al. 2018</td>
<td>.25</td>
<td>Angus (AAA)</td>
</tr>
<tr>
<td>Culbertson et al. 2018</td>
<td>0.29</td>
<td>7 breed composites</td>
</tr>
</tbody>
</table>

**Table 4.8. Heritabilities (diagonal) and genetic correlations (above diagonal) \( x \) SE from the multi-trait model (for pulmonary arterial pressure (PAP), birth weight (BW), raw weaning weight (WW), direct and maternal), and raw yearling weight (YW, direct and maternal) in Angus cattle, 2000-2019.**

<table>
<thead>
<tr>
<th>Trait</th>
<th>PAP</th>
<th>BW</th>
<th>WW, ( a )</th>
<th>WW, ( m )</th>
<th>YW, ( a )</th>
<th>YW, ( m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAP</td>
<td>0.25 ± 0.03</td>
<td></td>
<td>0.19 ± 0.06</td>
<td>0.23 ± 0.06</td>
<td>0.05 ± 0.08</td>
<td>0.13 ± 0.08</td>
</tr>
<tr>
<td>BW</td>
<td>0.32 ± 0.02</td>
<td>0.34 ± 0.03</td>
<td>0.34 ± 0.04</td>
<td>-0.03 ± 0.05</td>
<td>0.04 ± 0.05</td>
<td>-0.06 ± 0.05</td>
</tr>
<tr>
<td>WW, ( a )</td>
<td>0.41 ± 0.04</td>
<td>-0.07 ± 0.04</td>
<td>0.01 ± 0.02</td>
<td>-0.06 ± 0.04</td>
<td>0.04 ± 0.05</td>
<td>-0.04 ± 0.02</td>
</tr>
<tr>
<td>WW, ( m )</td>
<td>0.28 ± 0.03</td>
<td>-0.53 ± 0.05</td>
<td>0.96 ± 0.02</td>
<td>0.04 ± 0.05</td>
<td>0.04 ± 0.05</td>
<td>0.23 ± 0.02</td>
</tr>
<tr>
<td>YW, ( a )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YW, ( m )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Colorado State University-Boise Improvement Center, Saratoga, Wyoming, elevation > 2,000 ft

* Additive direct
* Additive maternal

Crawford et al., 2015 (thesis); 2016 (J. Anim. Sci.)

**Genetic Trend of PAP EPD**

**Marker effects of PAP, mmHg**

Rouse Angus
Yearling bulls, heifers, steers
N > 3,000

**Days on feed to death in 10 Canadian and 5 U.S. feedlots feedlots over the years 2000, 2004, 2008 and 2012.**

Neary et al., 2015

Canovas et al., 2016. Most significant pathways identified in RV tissue using the list of DE genes (inflammation, metabolism, remodeling, etc.).

Krafsur et al., 2019
Mid–Late Feeding Mortalities in Finishing Cattle and Potential Causes

Krafsur et al., 2019
Mid–Late Feeding Mortalities in Finishing Cattle and Potential Causes
New Funds:
Investigation of calcium regulatory processes and their role in a natural large animal model of altitude-associated pulmonary hypertension sensitivity leading to heart failure. *Intelligence Young Investigator Program*, Stephen Coleman.

**Metabolism and inflammation predict cardiopulmonary outcomes in fattening beef cattle.** *USDA-NIFA (2018-67015-28241).*

**Battle Creek Angus:**
A. Influence of varied strategies of high elevation finishing on cardiopulmonary characteristics of Angus steers.
B. Discovery of genetic markers to select cattle for reduced susceptibility to PH-HMD

Conclusions:
1. PAP is an indicator trait of hypoxia–induced PH in cattle (high PAP relative most mammals).
2. PAP has a moderate h^2 and is polygenic.
3. High mountain disease (HMD) is the fatal consequence of right ventricle heart failure.
4. Feedlot heart disease (FHD) appears to involve right and left cardiac ventricle.
5. AAA–AGI released PAP EPD (> 6,000 ft).
6. We have a lot to learn about mid–late feeding mortalities in finishing cattle!
Questions
FEED INGREDIENTS: WHAT IS CONTRIBUTING TO VOLATILITY IN SUPPLY AND COST

Kendall J. Karr Ph.D.
Cactus Feeders
Plains Nutrition Council Spring Conference 2019

SUPPLY AND DEMAND

- GROWTH OF ANIMAL AG IN SOUTH PLAINS
- 2005 RFS
- PRODUCTION CHANGES
- EXPORT DEMAND
- BIOFUELS

New Mexico Milk Cow Operations and Inventory

Year: 1990, 2000, 2010
Milk Cow Operations: 250, 300, 350
Inventory (1,000 head): 280, 300, 330

Texas Milk Cow Operations and Inventory

Year: 1990, 2000, 2010
Milk Cow Operations: 250, 300, 350
Inventory (1,000 head): 280, 300, 330

Figure 2. Southern Ogallala Region livestock inventory, 1975–2014. Source: National Agricultural Statistics Service

ESTIMATED INGREDIENT USAGE
515,000 Dairy Cows

Source: USDA, National Agricultural Statistics Service
NORTHERN TEXAS PANHANDLE COTTON ACRES

U.S. Cottonseed Meal Exports

TEXAS COTTONSEED PRODUCTION AND PRICE

U.S. COTTONSEED MEAL
DDG IN SWINE DIETS

- Averages between 10 and 30%
- 50% in some cases
- Replaces 80% corn and 20% SBM
- Start reducing inclusion at 120% of corn price
- 45% of SBM price
Energy Policy Act of 2005
RFS

2007 ENERGY INDEPENDENCE AND SECURITY ACT

• In 1980 Corn used for beverage production was twice the amount of corn used for fuel production
• In 1992 the entire US distillers grains production was about 2 million tons, 25% of that production was from alcohol beverage production with roughly an equivalent amount of corn used for fuel and sweeteners.
• In 2017 the entire US distillers grains production was about 38 million metric tons <3% of that production was from alcohol beverage production. The amount of corn used for fuel was 12 times the amount used for sweeteners.

WDG SUPPLY IN TEXAS PANHANDLE

- 8,250 TONS CAPACITY
- 2 PLANTS SHUTTERED IN 2018
- 1,400 TONS DDG CAPACITY
- 3,800 TONS TODAY
- 625 DRIED TO DDG

Aaron Hart, White Energy
China’s Domestic and International Price For Corn

Corn Gluten Feed

FOR OVER 20 YEARS THE EU WAS THE LEADING MARKET FOR US REFINED CORN PRODUCTS

- 1981-1994 Gluten Pellets to EU at a premium to corn
  - EU will not accept new biotech traits
- 1995-2004 Post EU, Gluten sold domestically at a discount to corn
  - RFS
- 1995-2004 Post EU, Gluten sold as a significant discount to corn
  - 2013- Present Post RFS pull, Gluten values rebounding as a percent of corn
PER CAPITA HFCS CONSUMPTION IN THE US

HISTORICAL FAT AND OIL PRICES

BIODIESEL PRODUCTION
- $1.00/GAL TAX CREDIT
- TALLOW, SBO, YG AND CORN OIL
- 1 TON OF FAT YIELDS 266 GALLONS OF BIODIESEL
- 50MIL GAL PLANT REQUIRES 6 RAILCARS – Seaboard Plant Guymon OK
- 2 BIL GAL ANNUAL PRODUCTION IS 7.5 MIL TONS

RENEWABLE BIODIESEL
- 2013 .5 MIL GAL PLANT IN LA
- 2015 160 MIL GAL, 275 IN 2018
- ADJOINING PLANT INCREASES TO 675 MIL GAL
- REQUIRES 85 RAILCARS
HOW MANY CATTLE WOULD THAT FEED

- 1.7 MILL TONS OF OIL AND GREASE
- .5 LBS ADDED FAT/H/D EQUALS 90 LBS IN 180D PERIOD

38,000,000 HEAD!
1. On average 1 gal fat = 1 gallon of biodiesel
2. 1 ton of fat yields 266 gallons of biodiesel (on average)
3. 50 ml. Gal. biodiesel plant needs 540 tons/day of fat (6 talians)
4. 2 Bl. Gal. of annual biodiesel production requires over 7.5 million tons of fats and/or Oils

U.S. DDGS exports by selected destinations (1,000 metric tons)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>98</td>
<td>1,777</td>
<td>1,586</td>
<td>2,228</td>
<td>2,703</td>
<td>6,163</td>
</tr>
<tr>
<td>Mexico</td>
<td>281</td>
<td>606</td>
<td>1,001</td>
<td>1,561</td>
<td>1,613</td>
<td>1,359</td>
<td>1,273</td>
<td>1,496</td>
<td>1,962</td>
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<tr>
<td>Vietnam</td>
<td>13</td>
<td>48</td>
<td>101</td>
<td>184</td>
<td>383</td>
<td>456</td>
<td>456</td>
<td>375</td>
<td>556</td>
</tr>
<tr>
<td>South Korea</td>
<td>11</td>
<td>86</td>
<td>179</td>
<td>279</td>
<td>358</td>
<td>385</td>
<td>377</td>
<td>378</td>
<td>510</td>
</tr>
</tbody>
</table>

Estimated 2016 Hog Diet Composition

- Corn: 66.1%
- Soybean Meal: 15.7%
- Distillers Dried Grains: 12.8%
- Other: 2.5%
- Energy Feed: 1.5%
- Yeast Meals: 1.0%
- Grain Sorghum: 0.5%
CIF DDGS dropped off this week after statements from President Trump on increasing tariffs on steel and aluminum imports from Turkey. Turkey responded by increasing tariffs on imports of some US goods as well. There are concerns DDGS could get targeted and there were two vessels diverted away from Turkey based on these concerns. There have also been reports of sales to Turkey being cancelled as well. Turkey has been the second largest export market for DDGS this year, representing about 10%–15% of DDGS exports. Even if there are no tariffs levied, the uncertainty will deter buyers from even making purchases putting pressure on DDGS values until relations are more stable.

515,000 head, +200,000 head since 2005

Roughly 80% of Cotton Production is Exported
Table 2: Estimated feed requirements for dairy operations in the study area, 2010.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Daily Rations (lb)</th>
<th>Annual rations (ton)</th>
<th>Feed Requirement (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>8.77</td>
<td>1.77</td>
<td>19.41</td>
</tr>
<tr>
<td>Silage</td>
<td>19.01</td>
<td>16.79</td>
<td>7,610.450</td>
</tr>
<tr>
<td>Concentrate</td>
<td>19.04</td>
<td>10.44</td>
<td>1,554.027</td>
</tr>
<tr>
<td>Cornsilage</td>
<td>4.09</td>
<td>0.89</td>
<td>404.35</td>
</tr>
<tr>
<td>Protein Supplement</td>
<td>1.82</td>
<td>0.84</td>
<td>186.61</td>
</tr>
<tr>
<td>Mineral Supplement</td>
<td>1.22</td>
<td>0.22</td>
<td>131.28</td>
</tr>
<tr>
<td>Total</td>
<td>31.16</td>
<td>23.08</td>
<td>10,317.934</td>
</tr>
</tbody>
</table>

Notes: Converted to all-encompassing 1.1795 dry matter equivalent per person and dollar from; Weighted by 80% for alfalfa, silage, cornsilage, and concentrate, 50% for protein, and 10% for mineral. Feeds for livestock, poultry, and swine are based on estimated dry matter intake of 34.3 lb/dry matter/100 lb of feed.
## Supplement Differences

<table>
<thead>
<tr>
<th></th>
<th>1980</th>
<th>2011</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein Meals (CSM, SBM, etc.)</td>
<td>37%</td>
<td>&lt;1%</td>
<td>5%</td>
</tr>
<tr>
<td>Minerals &amp; NPN</td>
<td>33%</td>
<td>58%</td>
<td>60%</td>
</tr>
<tr>
<td>Mid-Proteins (Midds, Gluten, Alfalfa Pellets)</td>
<td>19%</td>
<td>25%</td>
<td>30%</td>
</tr>
<tr>
<td>Animal Proteins</td>
<td>7%</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Roughage Products (Soy Hulls, RMF, etc.)</td>
<td>4%</td>
<td>16%</td>
<td>5%</td>
</tr>
</tbody>
</table>

## SWINE INVENTORY GROWTH 1975 TO 2010 IN SOUTHERN PLAINS

![Graph showing swine inventory growth from 1975 to 2010 in Southern Plains](image)

## DDG USE, PRODUCTION AND EXPORTS

![Graph showing DDG use, production, and exports](image)

## China’s Agricultural Imports by Source Country, 2001–2015

![Graph showing China’s agricultural imports by source country from 2001 to 2015](image)

Source: Figure generated from UN Comtrade Data 2016.


![Graph showing U.S. agricultural exports by destination country from 2001 to 2016](image)

Source: Figure generated from USDA, 2017.
Texas Dairy Cow Inventory

515,000 head, +200,000 head since 2005
Introduction

Our feedlot program focuses in a few different areas that include: 1. Managing starch utilization, 2. Use of byproducts, 3. Use of silage/residues, 4. Nutrition and environment interactions, 5. Growth promotion through implants/additives, and 6. Systems work from weaning to slaughter. Under starch utilization, we have evaluated grain processing, adaptation programs, acidosis management, and additives/enzymes. For nutrition and environment interactions, we have focused on both the impact of cattle on the environment, and impact of environmental stresses on cattle. Previous work was on managing N and P, whereas current efforts relate to carbon management and methane. For brevity, I will focus on 3 recent research areas: Methane, Silage use, and Byproducts. I would invite you to read our Nebraska Beef Report (https://beef.unl.edu) and/or attend the annual Husker Nutrition Conference in early November. I want to thank the Plains Nutrition Council (leadership committee and Dr. Ted McCollum) for supporting our meeting efforts the past decade and contributing annual financial support. We normally have around 75-100 consultants and allied industry, and 25 university or student attendees.

Methane

We are using 3 methods to assess methane production by cattle, and in cow, growing, and finishing systems. The methods include calorimetry headboxes, pen based chambers (methane barn), and using micrometeorological methods on pasture or fields being grazed. Biochar (High Plains Biochar, Laramie, WY) from pine trees was used in headbox experiments because it is not approved to be fed in the U.S. so numbers of cattle fed/exposed was minimized as they were euthanized and composted. Feeding 0.8 or 3.0% biochar appears to decrease methane production by 10-20%, but was only marginally significant ($P < 0.20$ in finishing and $P < 0.11$ in growing study) due to design and variation (Winders et al., 2019a). Our intent is to test impact of biochar in the methane barn and quantify performance impact to support these DE and digestibility data. Using the methane barn, we have measured impact of intake in growing systems (ad libitum versus 75% of ad lib) as well as feeding 3% corn oil in finishing diets. As expected, decreasing DMI in forage based diets by 26% decreased methane by 19.6% (Winders et al., 2018), but also decreased ADG by 23%. Per unit of intake, methane increased for restricted intake cattle while methane per unit of ADG was not different. For finishing cattle, supplementing 3% corn oil in diets containing 15% silage, 15% wet distillers grains, and a blend of high-moisture and dry-rolled corn improved F:G by 7% but also decreased methane production by 12.9% ($P < 0.01$; Winders et al., 2019b). We will continue to focus on efficient use of feeds and impact on CO2 and CH4 production. A new 5 year project was initiated in 2018 to evaluate two beef production systems from conception to slaughter for Eastern Nebraska. Advanced methods
(micrometeorological) are being used to monitor pasture grazing as well as use of the methane barn with confined cows/calves and calves post-weaning.

**Corn Silage**

We have focused on how much silage should be fed as a roughage source. Given hay prices, fluctuating supply, and lack of control of inventory, silage has lots of economical and management advantages with yards that can store silage. We have focused on protein characteristics, hybrid differences, moisture content at harvest, and inclusion of silage. Feeding corn silage is not a new concept for finishing beef cattle. Most feedyards feed silage at low inclusions for roughage. In general, corn silage contains 48-50% forage and 50-52% grain (DM basis) and is commonly fed at 5 to 15% of diet DM in finishing diets. Because of the silage only containing 50% forage and 50% high-moisture corn, we have commonly doubled inclusion compared to feeding traditional forages. Clearly, the work from Texas suggests exchanging on equal NDF from forage is the best approach (Defoor et al., 2002). Wilson et al. (2019a) fed 0, 7.5, or 15% silage and also compared this to feeding 7.5% alfalfa hay to individually fed steers. In the metabolism study (Wilson et al., 2019b), rumen pH data were quite similar between feeding 15% silage and 7.5% alfalfa hay. As silage decreased from 15 to 0% inclusion, rumen pH decreased, area and time below a pH of 5.6 and 5.3 increased, and digestibility increased, which were all expected. Performance data (in this study), suggested feeding no roughage as cattle were more efficient while DMI numerically decreased (expected), but ADG numerically increased (unexpected). Interestingly, performance data suggested that feeding 7.5% silage was equivalent to feeding 7.5% alfalfa hay which supports observations by nutritionists in the field.

Conversely, we have also focused on feeding more than traditional inclusions of silage (doubling or tripling inclusions from 15%) as an option for smaller, private, farming/feeding operations that can raise their own silage. We have conducted numerous experiments in the past 7 years evaluating elevated amounts of silage for finishing cattle. In 5 experiments (Burken et al., 2017a; Burken et al., 2017b; Hilscher et al., 2019; Hilscher et al., 2018) that compared 15% inclusion to 45% inclusion for finishing cattle, ADG decreased by 5.2% or 0.2 lb/d (Table 1). Feed conversion is consistently poorer with F:G being 6.7% greater for cattle fed 45% silage compared to 15%. Corn silage, if priced correctly, is likely one of the lowest costs per unit of energy. Economics depend on accurately pricing with fall corn price, valuing manure nutrients if charged nutrient removal, and managing shrink. Despite being economical, very few nutritionists/producers have adopted this practice of elevating silage inclusions. Many feedyards are open to growing cattle for a period prior to finishing. We tested feeding 45% corn silage (on average) by feeding 75% silage for the first half of the feeding period and 15% silage for the second half of finishing, compared to feeding either 15% or 45% silage continuously over the whole feeding period (Ovinge et al., 2019). In past studies, cattle fed 45% silage were consistently less fat than cattle fed 15% silage. Therefore, ultrasound was used and we attempted to slaughter cattle at equal fatness by feeding cattle on the treatments with elevated silage 28 days longer. Cattle fed 75/15 or 45% silage had similar intake, ADG, and F:G to one another (Table 2). However,
both treatments resulted in lower ADG and poorer (i.e., greater) F:G than cattle fed 15% silage. Because cattle fed 75/15 or 45% silage continuously were fed 28 days longer to get to similar fatness, HCW was greater for those treatments.

Many silage choppers have the capability to process kernels at harvest by essentially rolling the silage after chopping. These can be set to varying distances similar in concept to adjusting chop length. A typical energy response was observed for kernel processing whereby ADG was not impacted by kernel processing silage and feeding it at 40% inclusion (Ovinge et al., 2018). However, steers fed silage that was kernel processed ate less feed to get the same ADG, resulting in a 2.9% improvement in F:G (Table 3). These data suggest that kernel processing of silage is worth about 7.25% improvement in F:G assuming the entire change in F:G is due to improving the silage fed at 40% of the diet (2.9%/0.4). A recent growing silage study that evaluated kernel processing with silage inclusion of 80% of diet DM suggests a 6.6% improvement in the silage due to kernel processing (Brinton et al., unpublished).

If corn silage is priced correctly, then feeding 2 or 3 times more silage to finishing cattle than typical will result in poorer feed conversion by about 5% but is dependent on silage hybrids and kernel processing. If more silage is going to be used during finishing, having sufficient bypass protein from distillers grains is important. Most of these studies used 20% or more distillers grains on a DM basis. If producers don’t want to use 45% silage, but want to grow cattle on high-silage diets and step them down halfway through, then performance is the same as if feeding 45% silage continuously, therefore is more economical too and can sell more weight. Lastly, for silage growing programs, corn silage is much lower in RUP (< 10% RUP and RUP digestibility of less than 40%) than book values or previously thought, and a response to supplementing RUP (presumably with distillers grains) is highly suggested (Hilscher et al., 2019; Oney et al., 2019)

**Byproduct Research**

We have done numerous experiments with distillers grains and Sweet Bran over the years, much which is presented in the 2016 NASEM Nutrient Requirements of Beef Cattle. There is an interaction between how distillers grains plus solubles feeds with different corn processing methods. This same interaction does not exist with Sweet Bran. In concept, distillers inclusion is limited to 15% or less of the diet if fed in combination with steam-flaked corn whereas at least twice as much can be fed with high-moisture or dry-rolled corn (Corrigan et al., 2009a). This was also recently observed with DDGS as well (Ovinge et al., unpublished). For finishing cattle, DDGS (dry) has lower fiber digestion than wet or modified distillers grains and leads to poorer performance (Nuttelman et al., 2011a, 2011b, 2013), and much less value as a replacement or substitute for corn. More steam-flaked corn is being fed in Nebraska in recent years, which will limit our use of distillers grains.

More recently, we have been researching the value of the components found in distillers that are improving feedyard cattle performance when replacing dry-rolled corn or high-moisture corn. The reason to test the components is because dry mill ethanol plants will
continue to evolve and change their process, which changes the nutritional value of distillers grains to cattle. In 2012, many ethanol plants began removing a portion of the corn oil in distillers grains by centrifuging the distillers solubles stream. Instead of distillers grains containing 12-13% fat, the de-oiled distillers contained 8-9%. Over time (and different processes with or without additives to further reduce oil), distillers is more likely 7-9% fat today. We fully understand that removing oil should remove energy from the feed product. Our data suggests that the oil only explains a portion of the response observed when feeding distillers grains plus solubles in diets with dry-rolled or high-moisture corn. When comparing distillers from the same plant with and without the oil removal process suggests distillers value is reduced by 8%, so impact on the diet will be dictated by inclusion (Jolly-Breithaupt et al., 2018; Bremer et al., 2015a; Bremer et al., 2015b). In addition, we have seen a response to adding corn oil back into the diet on feed conversion (Burhoop et al., 2018). More recently, some processes will be adopted that concentrate protein (or fiber) in different feed products. These may still be called distillers grains, or high-protein distillers grains, or fiber plus solubles. Nutritionists will need to know the plant source of distillers and what research is available on impact to performance. High-protein distillers grains will generally be marketed as dry product to swine and poultry, or aquaculture and contain 38% or more protein as compared to 28-32% protein in conventional distillers grains. In a recent study with a process being used by some plants adopting the ICM process, the 2 feeds being produced in these new processes feed better than corn still and are comparable to wet or dry distillers grains depending on their moisture (Garland et al., 2019a; Garland et al., 2019b). More work is ongoing in this area.

We have researched distillers solubles with and without oil removal and is often economical as a feed ingredient, not just used as an ingredient in liquid protein/mineral supplements (Hansen et al., 2018; Jolly-Breithaupt et al., 2018; Pesta et al., 2015).

As inclusion of distillers grains in diets decrease, there may be need for supplementing urea. Historically, if distillers grains inclusion was greater than 25% of diet DM, so much excess protein was fed that supplementation was clearly unnecessary (Jenkins et al., 2011). In computer programs, rumen degradable protein may have been predicted to be deficient. However, so much excess metabolizable protein was fed from rumen undegradable protein in distillers that excess protein was deaminated, recycled if needed to the rumen, and met any deficiency. Distillers contain 30% crude protein, that is 63% RUP, and over 90% digestible in terms of RUP digestibility (NASEM, 2016; Castillo-Lopez et al., 2013; Corrigan et al., 2009b). With inclusions of distillers in finishing diets generally decreasing and many yards feeding less than 20% inclusion today, we need to revisit whether RDP (i.e., urea) is needed in diets with 10 to 20% inclusion. Boyd et al (2019a, 2019b) has attempted to determine whether urea is required or not. In one study, 10, 15, or 20% distillers were fed with 0, 0.5, or 1.0% urea as a 3×3 factorial (Boyd et al., 2019a) with the expectation that a significant interaction would be observed between inclusion and urea where more urea is needed with less distillers grains. The results are a bit confusing, but in general, a small response was observed to urea and was not consistent across inclusions. It appears that 15% distillers responded to 0.5% urea. The main effect of distillers showed that performance is
enhanced going from 10 to 20% inclusion, and that the main effect of urea addition improved F:G. In the second study, performance was improved going from 12 to 20% distillers inclusion, again with little impact of adding urea to either inclusion of distillers grains (Boyd et al., 2019b).

We are researching new feeds that are byproducts or unique and will impact meat quality. One example is algal biomass or remnants of algae produced for other reasons. A specific algal residue from Veramaris (DSM and Evonik sponsored) has been evaluated for safety (Norman et al., 2018) and self-certified as GRAS. This feed product (CARS, condensed algal residue solubles) is being tested for energy content and impact on performance in finishing cattle in the near future, but based on the 100 day feeding exposure test, ADG and G:F are positively impacted when fed at 2.5 to 5% of the diet. Future work will address not just how performance will be impacted, but some will be purposely developed to impact meat composition and sensory traits.

**Literature Citations**

Nebraska Beef Reports [http://beef.unl.edu](http://beef.unl.edu);


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determination of rumen undegradable protein of dried distillers grains with solubles
processing method and corn wet distillers grains plus solubles inclusion level in
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27:312-318.
Jolly-Breithaupt, M. L., B. L. Nuttelman, C. J. Schneider, D. B. Burken, J. L. Gramkow,
Finishing performance and diet digestibility for feedlot steers fed corn distillers grains
plus solubles and distillers solubles with and without oil extraction. J. Anim.


**Table 1.** Effect of 15% or 45% corn silage (DM basis) on performance and carcass characteristics across 5 experiments.

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment¹</th>
<th>15</th>
<th>45</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pens, n</td>
<td></td>
<td>58</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>DMI, lb/day</td>
<td></td>
<td>24.5</td>
<td>24.9</td>
<td>0.17</td>
</tr>
<tr>
<td>ADG, lb²</td>
<td></td>
<td>3.86</td>
<td>3.66</td>
<td>&lt;0.01</td>
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<tr>
<td>Feed:Gain²</td>
<td></td>
<td>6.29</td>
<td>6.71</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

¹ Across 5 experiments, 22 pens of yearlings, 36 pens of calf-feds. Diets fed with 20 or 40% distillers.
²Calculated from hot carcass weight, adjusted to a common 63% dressing percentage.

**Table 2.** Effect of growing cattle on corn silage at 75% followed by 15% compared to cattle fed 15% or 45% continuously, with cattle fed elevated silage longer to equal fatness (Ovinge et al., 2019).

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment¹</th>
<th>15</th>
<th>45</th>
<th>75/15</th>
<th>P-Value²</th>
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<tbody>
<tr>
<td>DOF, d</td>
<td></td>
<td>153</td>
<td>181</td>
<td>181</td>
<td>0.09</td>
</tr>
<tr>
<td>DMI, lb/day</td>
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<td>23.7</td>
<td>23.6</td>
<td>23.0</td>
<td>0.09</td>
</tr>
<tr>
<td>ADG, lb³</td>
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<td>4.02ᵃ</td>
<td>3.82ᵇ</td>
<td>3.73ᵇ</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Feed:Gain³</td>
<td></td>
<td>5.88ᵃ</td>
<td>6.18ᵇ</td>
<td>6.17ᵇ</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

ᵃᵇMeans with different superscripts differ (P < 0.05).
¹ Treatments were 15% silage inclusion, 45% silage inclusion, and 75 to 15% silage inclusion.
²P-Value for the main effect of corn silage inclusion.
³Calculated from hot carcass weight, adjusted to a common 63% dressing percentage.

**Table 3.** Main effect of kernel processing of corn silage when fed at 40% of diet DM on growth performance and carcass characteristics (Ovinge et al., 2018).

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment¹</th>
<th>SEM</th>
<th>P-Value²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pens, n</td>
<td>-KP</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>DMI, lb/day</td>
<td>+KP</td>
<td>32.6</td>
<td>31.8</td>
</tr>
<tr>
<td>ADG, lb³</td>
<td>-KP</td>
<td>4.38</td>
<td>4.38</td>
</tr>
<tr>
<td>Feed:Gain³</td>
<td>+KP</td>
<td>7.45</td>
<td>7.24</td>
</tr>
</tbody>
</table>

¹Treatments were not kernel processed (-KP) or kernel processed (+KP).
²P-Value for the main effect of kernel processing.
³Calculated from hot carcass weight, adjusted to a common 63% dressing percentage.
TTU – Research update: Guided efforts in beef cattle nutrition
Jhones O. Sarturi, Ph.D. - Texas Tech University, Lubbock

Collaborators: Dr. Darren D. Henry (AFS); Dr. Bradley Johnson (AFS); and Dr. Charles “Chuck” West (Plant and Soil Sciences).

Executive summary

Current research endeavors in nutrition have involved collaborations between the Department of Animal and Food Sciences and the Department of Plant and Soil Sciences. The research update that follows will be directed to a selection of ten studies on beef cattle nutrition with focus on grazing/backgrounding, growing, finishing diets, and proof of concept. Some of these efforts have been completed, some published, while others are in on-going assessment, and so, specific note will be made regarding stage of current process. Moreover, an additional section was included to express transdisciplinary efforts towards nutritional technique development regarding measurement of digestibility. Research depicted was or has been conducted at the Texas Tech University experimental site (New Deal Research and Education Center – Idalou, TX), with the involvement of multiple units (Burnett Center; Ruminant Nutrition Center; Beef Cattle; and Grazing Unit), and laboratories (Ruminant Nutrition Lab; Sustainable Ruminant Nutrition Lab; and Growth Development Lab). Graduate students, staff support, faculty involvement, industry support, and state agencies have been the center of the working-force and funding sources related to the content that follows. Beyond specific research interests, we strive to discover solutions, empower students, and serve society.

With focus on grazing/backgrounding

The Department of Plant and Soil Sciences has been a partner in our research objectives, especially, but not limited to, situations involving grazing systems. Summer forage production on the southern High Plains is often restricted by climatic factors which include high ambient temperatures and evapotranspiration potential. As a result, regional backgrounding of growing beef calves can be hindered by forage availability limitations during late summer and early fall. Climate is likely at least part of the reason that the use of warm-season, annual forages for grazing in beef production is not common practice. Teff grass (Eragrostis tef [Zucc.] Trotter) is an annual C4 species which has demonstrated potential to produce a high-quality forage crop in semi-arid regions. Additionally, teff is a vigorous species which enhances its value as an emergency crop. The use of DDGS supplement to improve animal growth performance while simultaneously reducing voluntary intake of a low-input, drought tolerant forage, would serve to strategically extend the forage supply and enhance the efficiency of regional beef production. Therefore, a two-year grazing assessment with beef steers (n = 44) on teff grass (supplemented with DDGS or cottonseed meal), as well as a metabolism experiment evaluating ruminal fermentation characteristics comparing teff grass to a warm season perennial grass with or without supplementation were conducted. These experiments are currently under dissertation committee review for
publication in a peer reviewed journal, and an abstract will be submitted to the annual meeting of the ASAS in Austin, TX. In experiments 1 and 2, four adjacent sub-surface irrigated paddocks (experimental unit, 6.6 acre each) were seeded with teff and continuously grazed for 63 d, for 2 consecutive years, in which animals were supplemented with DDGS (0.5 % BW) or cottonseed meal-CSM (1 lb/d). In experiment 2, six ruminally-cannulated beef steers were fed following a 2 × 2 factorial treatment arrangement: either ‘WW-B. Dahl’ Old World bluestem [Bothriochloa bladhii (Retz) S.T. Blake (WWBD) or teff; and DDGS supplementation (0.5% kg BW), using a Latin square design. Estimated total grass yield in paddocks did not differ by supplement over the course of the grazing seasons. Steers supplemented with DDGS on teff backgrounding had greater ADG relative to those supplemented with CSM. Nutrient yield of teff remaining after grazing was similar between supplement treatments. Soil moisture differed by grazing day and depth but not by supplement type fed to cattle. With the cannulated steers (metabolism experiment) DMI was greater with teff and DDGS-fed animals. Daily digestible intake of all nutrients measured were greater with teff-fed steers. No difference in chewing activity per kg NDF or peNDF intake were observed for the two hay types. Average ruminal pH of teff-fed steers was lower than WWBD-fed animals. Supplementing teff forage is expected to reduce teff forage intake. Such reduction may be of greater magnitude when compared to perennial forages. Despite reduced forage intake, animal growth performance is likely to be greater. Regardless of supplement type, total forage and forage nutrient yield should not be affected. The difference in animal growth performance in conjunction with similar yield of forage nutrients equates to improved use of irrigation water resources with DDGS supplement. When assessed relative to both perennial and teff forages alone, DDGS supplement increased total DMI (grass + suppl.) while imposing no negative effects on ruminal digestion.

Recent research efforts conducted by Dr. Darren D. Henry’s research team has also shown interests in grazing cattle. Dr. Henry has invested time in the assessment of nitrate supplementation on beef cattle growth performance and greenhouse gas emissions. Beef steers will be used in a generalized randomized block design with 3 treatments to investigate supplementation of encapsulated calcium-ammonium nitrate (eCAN) on grazing cattle growth performance, nutrient digestibility, enteric methane emissions, and fecal greenhouse gas emissions. Treatments include: 1) 0.3% of live body weight supplement (CTRL); 2) Supplement plus eCAN; and 3) Supplement plus urea (UREA). Since eCAN is a non-protein nitrogen source, it is being evaluated as a replacement of urea; therefore, eCAN and UREA treatments will be isonitrogenous. The steers will have ad libitum access to a 3-way mixture of cool-season forages (wheat, triticale, and rye). Steers testers (n = 30) will be blocked by body weight and sorted into six 6.6-acre pastures. Put-and-take steers (n = 14) will be used to control grazing pressure in paddocks.

From the Department of Plant and Soil Sciences, Dr. Charles West has combined independent and collaborative efforts related to animal nutrition. “Chuck”, as he likes to be addressed, is the program leader of forage research, which has focused on testing methods of integrating forages into Texas High Plains cropping systems to lessen
demands on irrigation groundwater. Most recently, key research endeavors have been related to several areas, including but not limited to, legume composition and responses of cattle growth and water-use efficiency of Old World bluestem (OWB) ‘WW-B. Dahl’ growing alone or with alfalfa. Chuck’s team has observed that inclusion of alfalfa increased CP and forage in vitro digestibility. Longer, less frequent rotations into the alfalfa protein bank resulted in greater ADG and translated to greater seasonal ADG/unit of area in the grass-legume treatment in each trial year (Baxter et al., 2017a), and reduced the water footprint of stocker grazing systems (Baxter et al., 2017b). They have also observed that high-density planting of alfalfa depleted more soil water than low density by exacerbating the competition with grass for soil water. In addition, interseeding alfalfa at a low density into native grasses on the Texas High Plains can enrich the CP and digestible energy concentrations, and forage yield of the pastures with minimal exacerbation of soil water depletion.

With focus on beef cattle growing and finishing diets

Due to low water supply from rainfall, agriculture in Texas High Plains region is dependent on irrigation. Adoption of strategies involving selection of more water-efficient crops, such as changing from grain corn to lower water-use crops such as grain sorghum offers one of the greatest water savings strategies (Colaizzi et al., 2009). However, sorghum silage has lower energy concentration than corn silage, due to its lower starch content and increased fiber concentration (NRC, 2000). To balance for the lower energy content, grain inclusion can be adjusted in the diet, but replacing corn with sorghum silage in beef cattle finishing diets may affect rumen dynamics. More information about the nutritive properties of new sorghum varieties is critical for better understanding of how these forages can be fed to high-producing beef cattle. Therefore, the effects of BMR-sorghum (AF7401) and corn (BH 8895) silages fed at 10 and 20% (DM basis) in finishing diets for beef cattle on ruminal fermentation, apparent digestibility of nutrients, feeding behavior, and the ruminal degradability of intact ensiled sorghum grain were examined. A 4 × 6 unbalanced Latin square design was used (6 steers; 4 diets: corn or sorghum silage, both at 10 or 20% inclusion, DM basis) Sorghum material induced desirable roughage effect in feeding behavior (rumination and chewing activities). Interestingly, when sorghum silage was included at 10% in the diet, ruminal pH average pattern was like diets containing 20% silage inclusion (Figure 1). Intact ensiled sorghum grain ruminal degradability (Figure 2) exhibited dramatic potential for improvement.

Still attempting the improvement of forage utilization strategy for beef cattle, a different approach has also been recently assessed. Many studies in the past two decades have assessed the effect of fibrolytic enzymes on high concentrate diets, and in a few situations, the ruminal fermentation characteristics were assessed in vivo, none of which considered the quality of diets. In addition, digestion assessment involving a more comprehensive list of forage types submitted to pre-treatment with fibrolytic enzymes has not been published yet. The research manuscript is currently under preparation for publication in a peer review journal (abstracts published: Kondratovich et al., 2017 and 2018). Thus, the objectives were: 1) to investigate the effects of exogenous fibrolytic
enzymes (xylanases and cellulases) on ruminal fermentation characteristics of beef steers fed high and low-quality growing diets; and 2) perform in vitro digestion evaluation of twelve forage substrates commonly fed to beef cattle. Addition of enzymes did not affect apparent total tract digestibility of beef steers fed high- or low-quality diets. However, DMI was increased by 6%, accompanied by an increase in ruminal molar proportion of propionate and a reduction of acetate:propionate ratio when steers were fed fibrolytic enzymes, regardless of diet quality. Assessment of substrates showed ADF digestibility improvement of approximately 13.6% when forages were treated with fibrolytic enzymes.

Dr. Henry’s research has also focused on growing/finishing cattle endeavors. The team has previous data indicating interesting effects of bismuth subsalicylate (BSS) on liver mineral concentrations. Although still in the infant stage and no preliminary data are available yet, liver biopsies collected at the beginning and those to be collected near future will help to determine changes in mineral status of beef steers supplemented with BSS. In the meantime, a study evaluating the effects of BSS and encapsulated calcium-ammonium nitrate (eCAN) on beef cattle growth performance and nutrient digestibility will shortly yield results. The study currently enrolls 200 Angus crossbred steers in a RCBD, with a $2 \times 2 + 1$ factorial arrangement of treatments. Factors include two dietary concentrations of BSS (0.0 and 0.33%) and two concentrations of eCAN (0.0 and 2.0%). The $2 \times 2$ portion of this experiment will contain approximately 0.28% ruminally available sulfur. The "+ 1" treatment will be a low sulfur (0.14% ruminally available sulfur) control without BSS or eCAN. Since eCAN is a non-protein nitrogen (NPN) source, it is being evaluated as a replacement of urea; therefore, all treatments have been made isonitrogenous. The steers are provided ad libitum (clean bunk feeding) access to feed and water. Steers were blocked by body weight and sorted to 50 slotted-floor pens (4 steers/pen). The current experiment will assess feedlot cattle performance, nutrient digestibility, liver mineral concentration, and feeding behavior.

Dr. Bradley Johnson’s research team has also been involved in a nutrition research initiative recently. The evaluation of dietary vitamin A requirements of finishing steers via systematic depletion and repletion model, and its effect on beef cattle growth performance and carcass characteristics was the topic for the research recently conducted. Concentrations of vitamin A (Rovimix® A 1000; DSM Nutritional Products Ltd., Sisseln, SUI) were evaluated using a RCBD with 30 yearling crossbred steers fed a steam-flaked corn-based diet, subsequent to a depletion phase (no added dietary vitamin A during 91-d). After depletion phase, steers were blocked by BW and assigned to one of the following dietary treatments: no added vitamin A (0.0 IU/kg), vitamin A at (2,200 IU/kg), and vitamin A supplemented at (11,000 IU/kg). The basal diet included minimal vitamin A activity (< 200 IU of vitamin A activity/kg) via the provitamin A, beta-carotene. The additional vitamin A was top-dressed at feeding via a ground corn carrier. Liver biopsy, sera, BW, and carcass data were collected. Vitamin A status did not affect interim ADG or G:F. The DMI 0IU fed cattle was depressed. No differences were observed for carcass characteristics. Liver retinol changes were predicted by sera retinol level during the repletion phase ($P < 0.01$; $R^2 = 0.682$). However, models used to
evaluate depleted animals were less effective. Study confirmed that current vitamin A requirement recommendation (NASEM, 2016) should be sustained.

**Proof of concept**

Alternative ways to adapt beef steers to steam-flaked corn-based finishing diets have also been topic of interest in our nutrition research team. Alternative substrates such as grape pomace (Pellarin et al., 2016) and cotton burrs (Ovinge et al., 2016) were topics of recent years. Recently, a more basic approach was used to investigate the effects of manipulation of steam-flaked corn bulk density during grain adaptation phase on ruminal fermentation characteristics and feeding behavior of beef steers. It was hypothesized that greater flake density (32 vs. 26 lb/bu) could minimize sudden changes in ruminal fermentation characteristics as step-up diets advanced towards the finishing diet. In addition, aiming to model the effects of a sudden change in grain bulk density during the adaptation phase, during the finisher diet, the 32 lb/bu fed steers were suddenly allocated to the 26 lb/bu density treatment. Crossbred Angus ruminally cannulated steers used (n = 6; BW = 892 ± 93 lb) had never received grain before, except for DDGS (0.5% of BW) during an 84-d backgrounding phase. Prior to experiment initiation, steers were fed a wheat hay and mineral supplement only, for 14 d, then assigned to a randomized complete block design to one of two grain adaptation flake densities. Steers were confined to an indoor facility, individually fed ad-libitum (minimum 5% refusals) during 6, 7-d phases consisting of: HAY (wheat hay), STEP-UP1, 2, 3, and 4 diets, respectively, in which forage was gradually removed while grain was included until the finisher diet (65% steam-flaked corn, DM basis) was fed. Wireless ruminal pH probes were utilized for continuous assessment of ruminal pH. Multiple ruminal fluid samples and feeding behavior were measured in each phase. Except for NDF and a tendency for ADF, there was an improvement in ruminal degradation for 32lb/bu in STEPs 2 and 3 compared to 26 lb/bu flaked-corn fed steers, steam-flaked corn bulky density did not affect measured variables. Changes within adaptation strategies as they advance through the phases seems to be more important than corn flake density individually. Regardless of flake bulky density, steers fed 32 lb/bu during STEP 3 and STEP 4 consumed more DM compared to their finisher diet. Greater digestible DM during STEP 4 and finisher was observed compared to other phases. Ruminal acetate:propionate decreased as steers moved through grain adaptation phases. Ruminal NH₃-N was greatest for STEP-UP 1 and 2 compared to other phases. When feeding steam-flaked corn, the change between HAY and STEP 1 was the most critical aspect of the grain adaptation phases. Current data claims the attention to the importance of receiving diets, once all other phases were consistent and stable within each strategy (Figure 3). By the end of the adaptation phase, a sudden change in flake density in the finisher diet from 32 to 26 lb/bu induced a dramatic change ruminal pH.

**Measuring digestibility: a novel approach**

The value of knowing the coefficient of digestion is crucially important for nutrition studies. It is one of the initial steps to differ research questions into two different categories. Knowing such research outcome, scientists start to dive into the arena of
“why” it happens (basic research) to complement other research questions, such as “what” happens (applied research). Both applied and basic research have their own strengths and challenges, thus, it explains why researchers usually use both approaches in their endeavors, or alternatively, collaborate to whomever can complement their work. Research collaborations open an additional venue in academia, in which transdisciplinary knowledge might bridge opportunities for discoveries and innovative application of current knowledge. Then, the well-known popular saying “learning from each other” truly finds its definition.

With that in mind, our research team has been routinely measuring coefficient of digestion within our research facilities at TTU. Total tract apparent dry matter digestion can be estimated by simply measuring total fecal output and subtract such value from intake (both on DM basis). Such calculation yields the amount of dry matter that disappeared (digested). For those that already had a chance to measure total fecal output know that the word “simply” aforementioned does not apply to such procedure. Due to logistic challenges, the use of markers (indigestible components) is a valuable alternative to estimate the digestion coefficient. If one measures the concentration of marker fed to an animal (example: 0.35%, DM basis), and measures the concentration of the same element in feces (example: 2%, DM basis), then 0.35 / 2 = 0.175 (17.5%) of apparent indigestible coefficient, and (100 - 17.5 = 82.5%) would be the apparent digestion coefficient. Great! It seems simple, so, what marker should I measure? How such measurement is performed? Wet chemistry? How long does it take to be analyzed? How much does it cost? Are hazard residues generated in such analysis? Can consultants perform such analysis on-to-go? Can feedlot operations do it on-site? Is it possible to be performed on commercial settings? For commercial applications?

By now, hopefully I opened your mind to what is coming next. The answer to most of those questions above are not very optimistic. The studies previously mentioned in current research update measured apparent total tract digestibility by assessing a dietary internal marker (acid insoluble ash, AIA). The method for such analysis was described by Van Keulen and Young (1977). Currently in our laboratory, assessing such marker in cattle growing and finishing diets has not been a challenge, and reasonable coefficient of variation (2-4%) have been experienced. But the use of AIA as a marker does not mitigate most of the challenges that are also observed with the analysis of other markers, falling within the same questions aforementioned.

A recent collaboration with the Department of Plant and Soil Sciences at TTU made us re-think some of our techniques. The use of a portable X-ray fluorescence spectrometry (PXRF) has been growing in Soil Sciences (Weindorf et al., 2014). The technique allows for on-site elemental analyses with results obtained in approximately 60 sec. No wet chemistry, no hazard residuals, no lab time, on-site analyses, and real-time feedback. Several parameters are known to affect PXRF accuracy, among them physical particle size, surface irregularity, and moisture. Among these, moisture is the most influential sources of error for the device, especially when above 20% (Ge et al., 1997).
Such technique has not been yet validated for detection of nutrients of other types of specimens, such as animal feces (low inorganic/high organic matter type of sample). Our current research focus has been on the assessment of elements identified by the instrument on diets and feces of beef and dairy cattle, sheep, equine, and companion animals. Physical structure, moisture, degrees of processing, and coefficient of variation of such types of specimens are under current assessment in comparison with more traditional markers used for measurement of digestion coefficients in Animal Science. If experimentally validated, such technique might provide an important tool for assessment of digestion coefficients for feedlot operations, consultants, laboratories, and academia.

**Figure 1.** Average ruminal pH by time after-feeding of beef steers fed steam-flaked corn-based finishing diets containing sorghum (AF7401) or corn (BH 8895) silages at 10 or 20% inclusion (DM basis). Steers fed diets containing 10% corn silage, regardless of time after-feeding, had lower average pH compared with other treatments (silage x level interaction; \( P < 0.01; n = 6 \)). (Adapted from Campanili et al., 2017)
Figure 2. Ruminal DM disappearances of ensiled intact sorghum grain (AF7401). Average from 2 fields at Texas Panhandle. Experimental silos (n = 10) from both locations were stored for 112 d. Intact grains were incubated (in situ) into ruminally-cannulated beef steers (n = 3). Effect of incubation time ($P < 0.01$, n = 10). (Adapted from Campanili et al., 2017)
Figure 3. Average ruminal pH-change from hay phase to consequent grain adaptation step-up diets of beef steers fed steam-flaked corn bulk density of 26 or 32 lb/bu. Only one bulk density was offered during the finisher diet (26 lb/bu). The Y-axis at level “zero” equals the average of ruminal pH exhibited by steers during the initial hay phase (6.46; n = 6). Regardless of bulk density, steers fed hay had greater ruminal pH average than other step-up diets and finisher (P < 0.01; n = 3). Steers fed 32 lb/bu during step-up 4 diet had greater ruminal pH average than subsequent finisher diet for the same treatment (P < 0.01; n = 3).

Literature citations


Net Protein Contribution of Feedlots from 2006 to 2017  Jessica R. Baber¹, Jason E. Sawyer¹, Ben P. Holland², Kendall J. Karr², Alyssa B. Word², Tryon A. Wickersham¹
¹Texas A&M University, College Station, ²Cactus Feeders, Amarillo, TX
Feedlot efficiency has increased as technologies are adopted and new feed ingredients, generally byproducts, have become available and readily incorporated. Cereal grains, human-edible, have been, to some extent, replaced with byproducts, generally human-inedible, as they provide comparable levels of energy. To evaluate the effect of diet changes and other feedlot production over time on net protein contribution (NPC) and human-edible protein conversion efficiency (HePCE), a deterministic NPC model was used. Net protein contribution was assessed for the feedlot industry using lot level production data from 2006 to 2017 for 8 commercial feedlots in the Texas panhandle (n = 6) and Kansas (n = 2). Ingredient and nutrient composition was collected for a representative starter and finisher diet fed for each year from each feedlot. Net protein contribution was calculated by multiplying the ratio of human-edible protein (HeP) in beef produced to HeP in feed by the protein quality ratio (PQR). A NPC > 1 indicates that the production system is positively contributing to meeting human protein requirements, whereas a NPC < 1 indicates the sector is competing with humans for HeP. Net protein contribution was regressed on year to evaluate temporal change in NPC, and feedlots were categorized as increasing NPC (INC; slope > 0) or constant NPC (CON; slope = 0) according to significance. Four feedlots were categorized as INC and 4 were CON. A common slope was estimated for CON and INC over time for PQR (P ≥ 0.79). Slopes differed between INC and CON byproduct and cereal grain inclusion (P ≤ 0.01) across years evaluated. Feedlots categorized as INC reduced HeP consumed by 2.39% per year, but CON feedlots did not reduce HeP consumed each year (0.28%). Cattle received and shipped by INC were lighter than CON cattle (P < 0.01). Across years, INC produced more HeP (46.1 vs 42.3 lb in 2006) than CON (P < 0.01), and both feedlot types tended to improve HeP gained over time (0.22 lb per year; P = 0.10). Differences in slope over time for INC and CON were observed for conversion efficiency of HeP (P < 0.01). Net protein contribution increased 0.027 units per year for INC (P < 0.01) and was 0.94 in 2017. Net protein contribution by the feedlot sector improved from 2006 to 2017, utilizing less human-edible feeds to produce more high-quality human-edible protein as beef.

Feedlot performance and carcass characteristics of steers fed diets containing steam-flaked grain and corn silage from Enogen® Feed Corn  Adrian N. Baker, Lucas P. Barros, Vanessa A. Veloso, and James S. Drouillard, Kansas State Univ., Manhattan
Enogen Feed Corn (Syngenta Seeds, LLC) is genetically modified to express high concentrations of amylase. Our objective was to evaluate Enogen as corn silage and as steam-flaked corn in diets fed to finishing cattle. A 2 x 2 factorial experiment was conducted with steers (n=960; 856 ± 16.3 lb initial body weight), with factors consisting of silage source (Control or Enogen) and grain source (Control or Enogen). Steers were blocked by initial body weight, assigned randomly within block to treatments, housed in 48 pens with 15 or 25 cattle per pen, and harvested after 138, 152, or 166 days on feed.
Grains were steam flaked to densities of 28 lb/bu or 30 lb/bu for Control and Enogen, respectively. Diets (dry basis) consisted of 8% corn silage, 2% alfalfa hay, 74.5% flaked corn, 12% Sweet Bran, and supplement. Incidence of liver abscesses and carcass weights were recorded at harvest, and longissimus muscle area, 12th-rib subcutaneous fat thickness, marbling score, and USDA yield and quality grades were determined after 36 h of refrigeration. There were no interactions between grain source and silage source \( (P > 0.05) \) for feedlot performance. Cattle fed diets containing Enogen silage consumed less dry matter \( (P < 0.01) \) and efficiency of gain was improved by approximately 5.3% \( (P < 0.01) \) compared to cattle fed Control silage. Average daily gain and dry matter intake were unaffected by grain source, but cattle fed Enogen grain were less efficient \( (P = 0.02) \) compared to cattle fed control grain. Carcass weight was greater for cattle fed the combination of Enogen silage and Control grain compared to other treatments \( (P < 0.05) \), but liver abscess incidence and other carcass measurements were unaffected by grain or silage source. Feeding Enogen feed corn as corn silage, but not as grain, improved feedlot.

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† \( P < 0.05 \). Silage = S; Grain= G; Interaction between grain and silage = I.

a,bMeans without a common superscript letter are different, \( P < 0.05 \)

1BW, body weight; ADG, average daily gain; DMI, dry matter intake.

**Effect of varying backgrounding rates of gain on finishing performance and carcass characteristics**  
E. J. Blom1, R. H. Pritchard2, and K. E. Hales3; 1South Dakota State University, Brookings, 2Annawan Cattle, Aurora, SD, 3USDA-ARS, U.S. Meat Animal Research Center, Clay Center, NE

Effects of varying backgrounding phase growth rate (BGR) on subsequent finishing phase performance and carcass characteristics were evaluated in 2 experiments. In Exp. 1, 240 steers were randomly assigned to 1 of 3 BGR treatments from study initiation to 875 lb: 2.0 lb/d (LOW), 2.5 lb/d (MID), or 3 lb/d (HIGH). Net energy equations were used to prescribe sufficient dry matter (DM) to achieve each the BGR for each group. When each treatment reached the target body weight (BW) of the backgrounding phase, it was transitioned to a finishing diet. From this point on, treatments were managed similarly. The cattle within each treatment were harvested independently at a common 12th-rib fat endpoint. By design, backgrounding phase average daily gain (ADG) linearly increased \( (P < 0.01) \). The backgrounding phase lasted 92, 78, and 62 d for LOW, MID, and HIGH, respectively. Finishing phase ADG and DM intake (DMI) were linearly decreased with greater BGR \( (P < 0.01) \), but no difference in feed:gain (F:G) was observed \( (P \geq 0.41) \). Cumulatively, ADG linearly increased with greater BGR \( (P = 0.04) \), but F:G was not different \( (P \geq 0.22) \). Hot carcass weight (HCW) decreased linearly with greater BGR \( (P < 0.01) \). Marbling score responded quadratically as it increased from LOW to MID, then decreased with HIGH.
BGR \((P = 0.02)\). In Exp. 2, 144 steers were randomly assigned to the same 3 treatments used in Exp. 1. Backgrounding phase endpoint BW was 900 lb in Exp. 2. As expected, backgrounding phase ADG linearly increased \((P < 0.01)\). The backgrounding phase lasted 76, 61, and 54 d for LOW, MID, and HIGH, respectively. Finishing phase ADG and DMI linearly decreased \((P \leq 0.02)\) as BGR increased, with no difference in F:G \((P \geq 0.16)\). Cumulative ADG linearly increased with greater BGR \((P = 0.03)\) while F:G responded quadratically \((P = 0.03)\) where it increased from LOW to MID, then decreased with HIGH. Restricting BGR linearly increased HCW \((P = 0.04)\). Similar to Exp. 1, marbling score tended to respond quadratically to increasing BGR as it increased from LOW to MID, then decreased between MID and HIGH \((P = 0.06)\). When data from Exp. 1 and 2 were combined, the regression of marbling score on BGR was quadratic \((P = 0.03)\) and accounted for approximately 8\% of the variation in marbling score. Restricting BGR can result in improved finishing phase performance and greater final BW; however, a greater number of days on feed is required. Increases in HCW can also be achieved with lesser BGR, although optimum carcass quality may be realized with only modest restriction in BGR as marbling responds quadratically to BGR.

**Effect of Urea and Distillers Inclusion in Dry Rolled Corn Based Diets on Steer Performance and Carcass Characteristics**

B.M. Boyd, J.C. MacDonald, M. Luebbe, G.E. Erickson, Univ. of Nebraska-Lincoln

Two experiments evaluated the effects of adding urea to a dry rolled corn based finishing diet containing low inclusions of distillers grains at the University of Nebraska Panhandle Research and Extension Center. Experiment 1 treatments were designed in a 3 x 3 factorial arrangement with factors consisting of distillers inclusion (10, 15, or 20\% of diet DM) and urea inclusion (either 0, 0.5, or 1.0\% of diet DM). Experiment 2 treatments were designed as a 2 x 4 factorial arrangement with factors consisting of distillers inclusion (12 or 20\% of diet DM) and urea inclusion (0, 0.4, 0.8, or 1.2\% of diet DM). In experiment 1, increasing inclusion of distillers linearly improved F:G and linearly reduced DMI. An interaction for F:G \((P = 0.03)\) was observed. There was no effect of added urea when 10\% distillers was fed, a quadratic effect was observed when 15\% distillers grains was fed where 0.5\% urea appeared to be optimum, and for 20\% distillers inclusion a quadratic effect was observed where 0.5\% urea appeared to have a negative effect on F:G. In Experiment 2 increasing inclusion of distillers grains improved carcass adjusted ADG and F:G and reduced DMI \((P < 0.04)\). There were no significant interactions \((P > 0.17)\) observed between distillers inclusion and urea inclusion in the diet except for F:G where a tendency \((P = 0.14)\) was observed. Increasing levels of urea in the 10\% distillers diet had no effect on F:G but in the 20\% distillers diet there was a linear increase in F:G with increasing inclusions of urea. There were no other significant responses for increasing urea inclusion in the diet \((P \geq 0.11)\). Increasing distillers inclusion in DRC diets improved animal performance. When feeding at least 20\% distillers in the diet, supplemental urea may have a negative impact on animal performance; however, a small improvement in performance may been observed when feeding less than 20\% distillers in the diet.
The effect of Syngenta Enogen Feed Corn in finishing beef cattle diets with the inclusion of distillers grains  

*M.M. Brinton1, B.M. Boyd1, F.H. Hilscher1, B.B. Conroy1, L. McPhillips1, H.C. Wilson1, J.C. MacDonald1, G.E. Erickson1, E. Watson2, 1Univ. of Nebraska – Lincoln, Lincoln, 2Syngenta Seeds, LLC, Greensboro, NC.

Two experiments were conducted to compare Syngenta Enogen Feed Corn™ containing an α-amylase enzyme trait (SYT-EFC) with commercially available corn grain without the α-amylase enzyme trait (CON) on finishing cattle performance and carcass characteristics at two locations. Experiment 1 utilized 336 crossbred yearling steers (917 ± 37 lb of BW) at the University of Nebraska – Lincoln Eastern Nebraska Research and Extension Center near Mead, NE. Treatment design was a 2×3+1 factorial, with two hybrids that included a conventional commercial corn (CON) and Syngenta’s Enogen Feed Corn (SYT-EFC). Corn was processed and fed as dry-rolled corn (DRC), high-moisture corn (HMC), or a 50:50 blend of the two for each hybrid. An additional treatment included 50% SYT-EFC DRC and 50% CON HMC, to evaluate a blend of the two hybrids and processing types. In experiment 2, 480 crossbred steers (829 ± 69 lb of BW) were utilized at the University of Nebraska – Lincoln Panhandle Research and Extension Center, Scottsbluff, NE. Treatment design was an incomplete 2×4 factorial with SYT-EFC and 0, 15, 30 or 45% wet distillers grains plus solubles (WDGS), and CON with 0 or 30% WDGS. In experiment 1 an interaction between hybrid and processing method was observed for ADG and F:G ($P < 0.10$). Cattle fed SYT-EFC had numerically better F:G and similar ADG when fed SYT-EFC compared to CON as DRC or a 50:50 ratio of DRC:HMC. For cattle fed HMC, ADG and F:G were better for CON compared to SYT-EFC, which led to the interaction. Cattle fed a blend of SYT-EFC as DRC with CON hybrid as HMC at a 50:50 blend did similar to feeding a blend of the CON hybrid at a 50:50 ratio of DRC:HMC. Feeding SYT-EFC appears to work better when processed as DRC but was not statistically different than feeding CON hybrid despite a 3% improvement in efficiency. In experiment 2, cattle fed SYT-EFC based diets had a linear increase in HCW, DMI, ADG, and feed efficiency as WDGS inclusions increased in the diet from 0 to 45% ($P = 0.04$). There were no significant differences in any performance or carcass characteristics for cattle fed either SYT-EFC or CON with 0% WDGS ($P = 0.17$). Cattle fed SYT-EFC with 30% WDGS displayed significantly greater back fat thickness over those fed CON with 30% WDGS (0.68 and 0.62 respectively; $P = 0.01$). However, no significant differences were observed for any performance characteristics when steers were fed SYT-EFC vs. CON DRC with WDGS included at 30% of the diet ($P = 0.26$). Feeding Syngenta Enogen Feed corn, which contains an alpha amylase enzyme trait, at both locations, did not statistically improve performance in finishing beef cattle.

Effect of corn variety and amylase enzyme on cattle performance and carcass characteristics  

*Renan Regatieri Casagrande, Terry Engle, John Wagner, Colorado State Univ., Fort Collins*

Four hundred and thirty-three Angus and Angus cross-bred steers (Body Weight 344 ± 13.3 kg) were utilized in this experiment to compare different varieties of grain corn and α-amylase enzyme on feedlot cattle performance and carcass characteristics. Steers were blocked by body weight and breed and randomly assigned to treatments. Treatments consisted of: 1) Commercial commodity corn (CON); 2) Experimental test
corn (TEST), 3) 50:50 blend of CON and TEST corn sources (BLEND), and 4) CON with 5g of α-amylase enzyme added/hd/d (AMZ; Amaize®, Alltech). Steers were slaughtered after 138 days on feed. Feedlot performance, net energy recovery, hot carcass weight, dressing percentage, subcutaneous adipose tissue depth, longissimus muscle area, marbling score, and calculated yield grade data were analyzed as a randomized complete block design using PROC MIXED of SAS. Dietary treatment had no effect (P > 0.20) on BW, average daily gain, feed efficiency, or net energy recoveries. There was a tendency for daily dry matter intake (DMI) to be influenced by treatment: d 0 – d 90 (P < 0.09), d 91 – slaughter (P = 0.11), and d 0 – slaughter (P < 0.08). Dry matter intake was consistently greater for steers receiving the AMZ treatment when compared to all other treatments. Daily DMI for the TEST treatment was consistently lower than DMI for all other treatments. Hot carcass weight (P = 0.56), dressing percentage (P = 0.10), 12th subcutaneous fat depth (P = 0.88), longissimus muscle area (P = 0.84), yield grade (P = 0.91), marbling score (P = 0.76), quality grade (P = 0.67), and the distribution of USDA yield and quality grades (P > 0.74) were similar across treatments. These results indicate the value of the TEST corn as an energy source in feedlot cattle diets is similar to the value of COM corn an energy source.

**Injectable vitamin C improves post-transit performance of beef steers**  
*E. L. Deters and S. L. Hansen, Iowa State Univ., Ames*

The objectives of this study were to determine the effects of injectable vitamin C (VC) before vs. after a long-distance transit event on feedlot performance and antioxidant status of beef steers. Angus-based steers (n = 72; 784 ± 39 lb) from a single-source were received on d -52 into open dirt lots and fed a common corn silage-based diet. On d -17 steers were moved to partially covered concrete pens equipped with GrowSafe bunks (6 steers/pen). On d 0 steers were blocked by BW and randomly assigned to 1 of 3 injectable VC treatments (n = 24 steers/treatment): CON = saline injection pre and post-transit, PRE = VC injection pre-transit and saline injection post-transit, or POST = saline injection pre-transit and VC injection post-transit. Treatment injections, 20 mL of saline or 20 mL sodium ascorbate (250 mg/mL; 5 g/steer), were delivered intramuscularly (10 mL/injection site) immediately prior to (d 0) and after (d 1) an 18 h (1,041 mi) transit event. After the transit event steers were sorted into pens equipped with GrowSafe bunks (6 steers/pen) and housed there for the remainder of the 57-d trial. Blood was collected (n = 12 steers/treatment) on d 0, 1, 2, and 7 for plasma ascorbate and total antioxidant status measured by ferric reducing antioxidant potential. Data were analyzed as a randomized complete block design using Proc Mixed of SAS with the fixed effects of treatment and block; steer was the experimental unit. Blood variables were analyzed as repeated measures and outliers were determined based on a Cook’s D statistic ≥ 0.5; one PRE steer was removed from all performance analyses due to a suspected EID failure. Post-transit plasma ascorbate concentrations were decreased in all treatments except for PRE, while on d 2 POST-steers had the greatest concentrations and all treatments were similar by d 7 (treatment × day; P < 0.01). Additionally, total antioxidant status was decreased post-transit and on d 7 (day; P < 0.01). Injectable VC affected mid (d 30/31; P = 0.01) and final (d 56/57; P = 0.02) BW with PRE-steers having the greatest BW. Injectable VC (PRE and POST) tended to improve overall (d 1 to 57) DMI vs. CON-steers (P = 0.07). However, PRE-steers had
greater overall ADG than POST (P = 0.04) or CON-steers (P = 0.01). Overall G:F was not affected by injectable VC (P = 0.30). Steers that received VC prior to transit had a BW advantage 56 d post-transit of 21 lb compared to steers that did not receive a VC injection and 15 lb compared to steers that received VC post-transit. These data suggest administering injectable VC prior to transit is an effective way to overcome the negative effects of transit on cattle performance.

Effects of starch concentration in growing diets on feeding performance and composition of gain during the growing and finishing period in early-weaned beef calves  A. L. Fuller1, T. A. Wickersham1, J. E. Sawyer1, R. H. Klett2, G. B. Holcomb2
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Backgrounding programs allow cow-calf producers to add value to early-weaned calves, primarily through weight gain, and can increase annual gross revenue. Various management practices during the growing phase affect finishing phase performance; therefore, managing early-weaned calves to avoid potential price discounts is essential. Corn based byproducts low in starch offer an alternative to traditional grain-based growing diets that may accelerate physiological maturity. Lightweight (initial BW = 175.59 ± 1.3 kg), crossbred bull and steer calves (n = 970) were utilized in a randomized complete block to determine the effects of starch level in growing diets on growing and finishing phase performance, ultrasonic measurements, and final carcass composition. Loads of cattle were blocked by receiving week with 10 replications (pens) per treatment and an average of 32 head per pen. All cattle were fed a common receiving diet from d 0 to 44. The growing period began on d 45 and ended on d 119 of the experiment. Growing diets were formulated to contain 1 of 3 levels of starch; 1) LOW, 22.3% starch, 2) MED, 26.4% starch, or 3) HIGH, 31.0% starch on a DM basis and to provide similar energy and protein intake (isocaloric and isonitrogenous). Ultrasonic measurements were collected at the beginning (d 45) and end of the growing period (d 119) and a common finishing diet was fed to all cattle for the remainder of the trial. Two blocks of cattle were shipped on each harvest date to a commercial slaughter facility (Tyson Fresh Meats, Amarillo, Texas) when approximately 65% of the cattle within each block were expected to grade USDA Choice or greater based on visual appraisal. The model for all measurements included treatment as a fixed effect and block and pen within treatment as a random effect. Contrast statements were used to test the linear and quadratic effects of level of dietary starch in the growing diet. Starch concentration in the growing diet did not significantly affect ADG or DMI during the growing (P ≥ 0.15), finishing (P ≥ 0.20), or overall period (P ≥ 0.26; d 45 - harvest). There was a tendency for G:F to decrease linearly (P = 0.06) during the growing phase as the concentration of starch in the growing diet increased but was not different during the finishing (P ≥ 0.40) or overall period (P ≥ 0.20). At the end of the growing period, 12th rib fat linearly decreased (P = 0.04) as starch level increased while marbling score was not affected (P = 0.57). At slaughter, there was a quadratic response (P < 0.01) in dressing percent and a tendency for a quadratic response (P = 0.09) for marbling score, both increasing from the LOW to MED treatment then decreasing. Final HCW and 12th rib fat were not different (P ≥ 0.66). There was a quadratic response (P = 0.01) to treatment for the percentage of steers grading USDA Choice, increasing from the LOW to MED treatment then decreasing from the MED to HIGH treatment. In conclusion,
starch concentration in isocaloric and isonitrogenous growing diets did not affect feeding performance or final HCW.

Effect of anabolic hormone exposure during the backgrounding-phase in calf-fed steers of different frame sizes  W. W. Gentry¹, R. H. Pritchard², and K. E. Hales³;
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The frame size (FS) of the U.S. cowherd is diverse, which leads to diversity in feeder cattle FS and fed cattle hot carcass weights (HCW). Feedlots must manage inherent variation in the FS of feeder cattle. Given that implants alter FS, they may be an effective tool to manage variation in HCW across groups of cattle. Two experiments were conducted to evaluate the potential interaction of FS and implant status in calf-fed steers. Steer calves from the same 2 sources were used in each experiment and were managed similarly from weaning to study initiation. Steers were product of a 50-d calving season, so it was assumed differences in FS were reflected in weaning weight (WW). Smaller-framed (SM) and larger-framed (LG) steers were identified from the tails of the WW distribution. Forty and 57% of the steers nearest to the mean WW were excluded from Exp. 1 and 2, respectively. Within each FS group, steers were implanted with Synovex-S (SS) or Synovex Choice (CH) on d 1 (Exp. 1), and nonimplanted (NI) or implanted with SS on d 2 (Exp. 2). In both experiments, all steers were terminally implanted with Revalor-S on d 84 and fed for 161 (Exp. 1) and 168 d (Exp. 2). For each experiment, data were analyzed as a randomized complete block design with a 2 × 2 factorial treatment structure. No FS × implant interactions were observed in either experiment (P ≥ 0.08). In both experiments LG steers had heavier body weights (BW), HCW, and BW adjusted to 28% empty body fat (AFBW), greater average daily gain (ADG), dry matter intake (DMI), and feed:gain (FG) than SM steers (P ≤ 0.02). No differences were evident in marbling score or USDA Quality Grade distributions between SM and LG steers (P ≥ 0.13). In Exp. 1, no differences in growth performance, carcass characteristics, AFBW, or calculated FS were observed for steers initially implanted with SS or CH (P ≥ 0.12). In Exp. 2, steers implanted initially with SS had heavier final BW, greater ADG and DMI (P ≤ 0.01), and no difference in FG (P = 0.78) than NI steers. Steers initially implanted with SS had heavier HCW (P < 0.01), but no other differences in carcass characteristics were observed (P ≥ 0.23). Additionally, steers implanted with SS tended to have heavier AFBW (P = 0.07) and greater calculated FS (P = 0.05) than NI steers. Steers of different FS responded similarly to implants while in the feedlot. Estradiol increases the FS of steers; however, when similar doses of estradiol are compared, trenbolone acetate does not further increase FS.

Manipulation of steam-flaked corn bulk density during grain adaptation phase of beef steers: ruminal fermentation characteristics and feeding behavior  C. A. Hoffmann, J. O. Sarturi, D.D. Henry, L.B Kondratovich  Texas Tech University, Lubbock
The effects of steam-flaked corn bulk density during grain adaptation phase on ruminal fermentation characteristics and feeding behavior were evaluated. Beef crossbred Angus ruminally cannulated steers were used (n = 6; BW = 892 ± 93 lb; experimental units) having never received grain before, except DDGS (0.5% of BW) during an 84-d
backgrounding phase. Prior to experiment initiation, steers were fed a wheat hay and mineral supplement only, for 14 d, then assigned to a randomized complete block design (block = body weight) to one of two grain adaptation strategies: 1) steam-flaked corn bulk density of 26 lb/bu; and 2) 32 lb/bu. Steers were confined individually in indoor facility, fed at ad-libitum (minimum 5% refusals) during 6-7 d phases consisting of: HAY (all animals received a 97% dietary inclusion (DM basis) of wheat hay), followed by the STEP-UP1 (receiving diet), STEP-UP2, STEP-UP3, and STEP-UP4 diets, respectively, in which forage was gradually removed while grain was included until FINISHER diet was fed. Respective grain bulk density treatment was fed throughout STEP-UP diets, while the FINISHER diet consisted of 26 lb/bu treatment only. FINISHER phase was used to model the effect of a sudden change in grain bulk density during the adaptation phase. Wireless ruminal pH probes were utilized for continuous assessment of ruminal pH. Ruminal fluid samples were collected on d-5 of each step, at 2, 6, 12, 18, and 24 h after-feeding for analysis of ammonia-N, and 6 h for VFA analysis. Feeding behavior was continuously measured (24h – visual observation) on d-7 of each phase. Data were analyzed using the GLIMMIX procedures of SAS; collection day or sampling hour as repeated measures. Steam-flaked corn bulk density did not affect ($P \geq 0.19$) measured variables, except for NDF ($P < 0.01$) and a tendency ($P = 0.09$) for improved ADF ruminal degradation for 32 lb/bu in STEPs 2 and 3 compared to 26 lb/bu flaked-corn fed steers. Steers fed 32 lb/bu flake during STEP 3 and STEP 4 consumed more DM ($P \leq 0.05$) when compared to FINISHER. Steers consumed more ($P \leq 0.01$) digestible DM during STEP 4 and FINISHER compared to other phases. Digestible NDF and ADF intake was greatest ($P \leq 0.05$) during the HAY phase. The DM and OM digestibility was lowest ($P \leq 0.05$) during HAY phase. During HAY phase, steers ruminated more ($P \leq 0.05$) than FINISHER phase, with remaining phases being intermediate. Time steers spent chewing was greatest ($P \leq 0.05$) for HAY phase, and intermediate for STEP 1. Ruminal C2:C3 ratio decreased ($P < 0.01$) as steers moved through grain adaptation phases. Ruminal ammonia-N was greatest ($P < 0.01$) for STEP-UP 1 and 2, intermediate for STEP-UP 3, 4 and FINISHER. Changes within adaptation strategies as steers advance through the phases seems to be more important than corn flake density individually. When feeding steam-flaked corn, the change between HAY and STEP 1 was the most critical aspect of the grain adaptation phases. Further investigation is warranted to understand ruminal kinetics of such specific phase (receiving diet).

**Impact of handling frequency on drylot-housed heifer behavior** Amanda J. Hubbard, J. Sawyer, R. Cooke, C.L. Daigle, Texas A&M Univ., College Station

Feedlot cattle are rarely removed from pens due to concerns that handling events will disrupt behavior and compromise productivity. Research cattle are weighed at specific intervals to precisely calculate growth and performance—yet the impact of weighing frequency on the outcome of these research trials and cattle behavior are unknown. The study objective was to quantify the impact of handling frequency on drylot-housed heifer behavior. Sixty Angus short-yearling heifers were randomly assigned to one of 12 pens ($n = 5$ heifers/pen). Pens were randomly assigned 1 of 3 treatments ($n = 4$ pens/treatment) for a 42-d feeding period. Pens of heifers were weighed either weekly (7DAY), biweekly (14DAY), or at the beginning and end of the study (42DAY). Feed was delivered after all cattle had been weighed. Live behavior observations were conducted
on all handling days (0800 to 1200 (AM) and 1300 to 1700 (PM)). Instantaneous scan sampling (n = 48 scans/d; 10-min intervals) recorded number of heifers standing, walking, lying, eating and drinking for each pen. Latency (sec) for each individual heifer to eat (LTE), drink (LTD), and lie down (LTL) after feed delivery, as well as latency for all 5 heifers within a pen to lie down simultaneously after feed delivery was recorded. Linear mixed models (PROC MIXED) evaluated impact of treatment, week, and treatment ´week on behavior. Orthogonal contrasts analyzed linear and quadratic effects of treatment on average daily gain (ADG), and average exit velocity (AEV). Treatment did not influence standing or eating ($P > 0.05$). Larger proportions of the pen laid down in 7DAY and 14DAY compared to 42DAY ($P = 0.02$). Week influenced the proportion of pen standing, eating, and lying ($P < 0.01$). The proportion of the pen eating increased over time ($P < 0.01$). Latency for all heifers within a pen to lie down simultaneously was longer in weeks 4 ($132.21 \pm 9.58$ min) and 6 ($132.25 \pm 11.47$ min) than all other weeks. Individual heifer LTE was longest ($P < 0.01$) in week 1 ($115.17 \pm 2.97$ min) and 2 ($41.11 \pm 2.97$ min). A treatment × week interaction was observed for individual heifer LTL ($P = 0.04$) and LTD ($P = 0.01$). Neither linear ($P > 0.27$) nor quadratic ($P > 0.23$) effects of treatment were detected for ADG, AEV, or CEV. Mean ADG per treatment was $2.04 \pm 0.09$, $2.12 \pm 0.10$, and $2.31 \pm 0.13$ lb/d for 7DAY, 14DAY, and 42 DAY respectively. Results indicated cattle behaviorally adapt to their new surroundings in approximately 3 weeks. Also, while repeated handling increased lying behavior, it appeared to negatively impact average daily gain, though the difference was insignificant in this study. Thus, feedlot cattle weighed more frequently during research trials will perform more resting behavior but may have reduced ADG compared to cattle handled infrequently.

Evaluation of Grain Sorghum Hybrids Reveals Potential for Improving Ruminal Fermentation  
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In vitro incubation procedures were used to compare fermentation characteristics of corn (uncharacterized hybrid) to a broad range (25 separate cultivars) of sorghum parent lines and hybrids (Richardson Seeds Inc., Lubbock, TX; Clemson University; Scott Seed Company, Hereford, TX). Two experiments were conducted as randomized complete block designs using ruminal contents from two ruminally-fistulated steers (blocks) as sources of ruminal microorganisms. Grains were ground to pass a 1-mm screen and used as substrates (2 g, dry matter basis) in laboratory fermenters containing strained ruminal contents and bicarbonate buffer to emulate ruminal digestion. Fermenters were equipped with pressure monitoring devices (ANKOM Technology, Macedon, NY) to quantify production of fermentative gases as an indicator of microbial digestion. Cultures were incubated for 24 (experiment 1) to 30 hours (experiment 2), and gas production was recorded at 15-minute intervals. Dry matter disappearance was determined, and organic acid concentrations in the spent culture media were analyzed after incubation was complete. Experiment 1 compared corn to 24 sorghum cultivars, and experiment 2 compared corn to six sorghum cultivars, five of which were represented in experiment 1, plus one waxy hybrid. Data were analyzed using mixed model with cultivar as a fixed effect and block as a random effect. For gas production data, time and the interaction between time and cultivar also were used as
fixed effects. For both experiments, there was an interaction between cultivar and time ($P < 0.0001$) for gas production, revealing large differences among cultivars with respect to their relative susceptibility to microbial fermentation. Similarly, dry matter disappearance; production of acetate, propionate, and butyrate; and acetate:propionate varied substantially among cultivars ($P < 0.01$), and in many cases exceeding measurements obtained with the corn control. In conclusion, sorghum cultivars used in these experiments varied widely in terms of their susceptibility to digestion by ruminal microorganisms, revealing potential for development of hybrids that can compete with corn as energy sources whilst contributing toward improved sustainability of feedlot production systems.

Syngenta Enogen® Feed corn silage containing an alpha amylase expression trait improves feed efficiency in growing calf diets M.A. Johnson¹, T.J. Spore⁴, S.P. Montgomery², W.R. Hollenbeck¹, R.N. Wahl¹, E.D. Watson³ and D.A. Blasi¹, ¹Kansas State Univ., Manhattan, ²Corn Belt Livestock Services, Papillion, NE, ³Syngenta Crop Protection, Greensboro, NC, ⁴University of Nebraska, Lincoln

Three hundred fifty-two crossbred steers of Tennessee origin, averaging 656 lbs, were allocated to pens based on weight. All calves were previously enrolled for 63 days on a health related study at the Kansas State Beef Stocker Unit. At that time, all animals were vaccinated for viral and clostridial diseases and treated for internal and external parasites. Thirty-two pens were used (8 pens/treatment), composed of 11 animals each. The steers were stratified by weight and randomly assigned to pens, which were randomly allocated to 1 of 4 treatments. The four treatment diets were formulated to provide 50 Mcal NEg/100 lbs dry matter and all diets were offered ad libitum. The experiment was a 2 x 2 factorial design with two varieties of corn silage (Enogen vs control) and two varieties of dry-rolled corn (Enogen vs control). Pen was the experimental unit. All steers were fed their respective diets once daily at approximately 0700 for 90 days. Individual animal weights were taken on day -6 (allocation), day 0 (initial processing), day 49 and day 91 (final weights). Fecal starch samples were obtained individually on day 49 and analyzed the same week. Pen weights were collected on day 14, day 28, day 42, day 56, day 70, day 77, and day 91. Feed delivery was adjusted based on daily refusals to ensure ad libitum intakes without an excess of left over feed. Bunk and individual ingredient samples were taken weekly. Over the entire 90-day trial, average daily gain for calves fed Enogen Feed corn silage was significantly greater ($P<0.01$) than for calves fed control silage. Dry matter intake tended to be greater ($P<0.07$) for calves fed Enogen Feed corn silage over the entire 90-day trial. This difference was especially apparent through day 42, where Enogen-fed calves consumed significantly more than their control-fed counterparts ($P<0.01$). Feed efficiency (G:F) was greater in calves fed Enogen Feed corn silage ($P<0.02$). Towards the end of the study (day 77 and day 90), feed efficiency (F:G) was significantly greater for calves fed Enogen Feed corn silage ($P<0.02$). No significant effects of corn grain type were noted over the entire 90-day trial, nor any significant interactions between corn silage type and corn grain type. When fed in an ad libitum fashion to growing calves, Enogen Feed corn silage improves the efficiency of feed conversion by 4.4% and improves average daily gain by 6.0%.
Effects of roughage type on rumination and fiber mat characteristics of beef steers  
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Research is limited on how physically effective fiber from various roughage sources aids in strata formation within the rumen, rumination time, and ruminal pH of finishing beef cattle. We hypothesized that increased roughage particle size would increase ruminal pH and daily rumination. The objective of this experiment was to evaluate rumination and fiber mat characteristics of beef steers consuming finishing diets with varying roughage sources (corn stalks, cotton burrs, or wheat silage). Ruminally cannulated steers (n = 6; average BW = 791 ± 71 kg) were used in a 3 × 3 Latin square design experiment with 3 dietary treatments and 3, 30 d periods (7-d recovery, 21-d diet adaptation, 2-d sampling). Steers consumed a finishing diet containing corn stalks (CS), cotton burrs (CB), or wheat silage (WS) included at 7% (DM basis) of the diet. Steers were fitted with a sensory collar to record daily rumination (Allflex Livestock Intelligence) and given a ruminal pH bolus that recorded pH in 15-min intervals (WellCow). On d 30 of each period, rumen evacuations were performed on all steers. The total fiber mat was removed and weighed, and a subsample was kept for particle separation, DM, NDF, ADF, and ash analysis. Ruminal DM and crude fiber degradation of individual roughages were measured using in situ techniques. Following the completion of period 3, forage (10 × 20 cm) and concentrate (5 × 10 cm) bags were placed in the rumen of 2 steers receiving the respective dietary treatment and bags were removed at timepoints 0, 12, 24, 48, 72, and 96 h. Dry matter intake was greatest for steers consuming the CS diet (P = 0.02) and was similar for steers consuming CB or WS diets (P = 0.21). Daily rumination was greatest for WS and CS and least for CB (min/d; P < 0.001) diet. Rumination min/kg of DM, NDF, and peNDF was greatest for CS (P ≤ 0.001) and similar for WS and CB (P ≥ 0.35). Ruminal pH was greatest for steers consuming the CB diet (P < 0.001) and similar for steers consuming CS or WS (P = 0.28). For DM degradation, wheat silage had the greatest percentage of degradation, CS were intermediate, and CB was the least (P = 0.01). For crude fiber degradation, steers fed CS had the greatest percentage of fiber loss (P = 0.003), WS was intermediate, and CB was least (P = 0.003). Estimate physical effective NDF (peNDF) was greatest for CB, intermediate for CS, and least for WS (P < 0.001). The greater estimated peNDF of CB and the lack of disappearance may have allowed for an increased ruminal pH, while CB as a roughage source has a smaller particle size than CS and WS. The results of this experiment indicate that a sustained existence in the rumen when steers were fed finishing diets with WS or CS roughage sources. Regardless of particles size, corn stalks and wheat silage were beneficial in promoting rumination, cotton burrs were beneficial in promoting increased ruminal pH.
Evaluating water intake prediction equations for growing and finishing feedlot steers

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Water is the most important nutrient for cattle. The objective of this study was to evaluate precision and accuracy of published water intake (WI) equations for predicting WI of growing and finishing feedlot steers. Two datasets of growing (GRW) crossbred Angus steers (n = 124; BW 237 ± 27 kg and n = 119; BW 259 ± 29 kg) and a dataset of finishing (FIN) Angus steers (n = 48; BW 431 ± 33 kg) were used. Steers in all 3 datasets had access to ad libitum feed and water. Individual WI were measured using an Insentec Roughage Intake Control (RIC) system during a 70 d period for GRW and a 51 d period for FIN. Days with excessive rain, system failures, or animal processing were removed. Weather variables were obtained from the Stillwater, OK Mesonet station. Individual animals’ predicted WI were calculated daily for 42 d during each period based on 8 published WI equations, and observed WI was regressed on predicted WI. Coefficient of determination (R²), root mean square error (RMSE), slope, and intercept were obtained using REG procedures of SAS 9.4. The 2 datasets for GRW were combined for analysis due to similar intakes, BW, and management. Differences in means for weather variables were determined using MIXED procedures of SAS. Equations 1, 5, and 7 had the highest R² (0.39, 0.41, and 0.41, respectively) and lowest RMSE (6.91, 6.81, and 6.79, respectively) for GRW. Equation 5 had a slope of 0.86 and intercept of 3.60 meaning that this equation predicted WI with higher accuracy than equations 1 or 7. However, equations 1, 5, and 7 overpredicted WI for GRW. Equations 2a, 2b, 5, and 7 explained the greatest amount of variation (R² = 0.34, 0.36, 0.37, 0.34, respectively) in WI and had the lowest RMSE (5.46, 5.37, 5.35, and 5.47, respectively) for FIN. Equations 2a and 5 had slopes (Eq2a = 1.13; Eq5 = 0.64) closest to 1 and intercepts (Eq2a = 0.47; Eq5 = 2.27) close to 0 demonstrating a higher level of accuracy compared to equations 2b and 7. Equations 2a and 2b underpredicted WI while equations 5 and 7 overpredicted WI for FIN. To predict WI with the highest levels of accuracy and precision, equation 5 could be used for growing steers while equations 2a or 5 could be used for finishing steers. However, equations 5, 6, and 7 were developed using individual animal WI using the RIC unit which could bias these results. When excluding those equations for evaluation, equation 1 had the highest precision (R² = 0.39; RMSE = 6.91) and accuracy (slope = 0.83; intercept = 5.39) for GRW. For FIN, equations 2a (R² = 0.34; RMSE = 5.46; slope = 1.13; intercept = 0.47) and 2b (R² = 0.36; RMSE = 5.37; slope = 0.98; intercept = 3.80) had the highest precision and accuracy; however, these equations underpredicted WI. More research is needed to determine the best WI prediction equation for various types of cattle under different feeding and management scenarios.
Effect of Zn supplementation on performance, carcass characteristics, and liver mineral concentrations of heifers receiving a single Revalor-XH or a Revalor-200/Revalor-200 re-implant program E.M. Messersmith, E.K. Niedermayer, G.I. Crawford, S.L. Hansen, Iowa State Univ., Ames

The effect of Zn supplementation on performance of beef heifers receiving different implant strategies was examined through a 2 × 2 factorial utilizing 208 Angus-cross heifers (642 ± 51 lb) from 4 sources in a 169-d study. Factors included 2 inclusions of dietary Zn (as ZnSO₄) at national (NRC; 30 mg Zn/kg DM; NASEM, 2016) or industry (IND; 100 mg Zn/kg DM; Samuelson et al., 2016) recommendations. Within Zn treatment heifers received either the extended-release implant Revalor-XH (REV-XH; 20 mg estradiol + 200 mg trenbolone acetate; Merck Animal Health, Madison, NJ) on d 0 or Revalor-200 (REV-200; 20 mg estradiol + 200 mg trenbolone acetate; Merck Animal Health) on d 0 and again on d 91. Heifers were blocked by weight within source (n = 5 or 6 heifers/pen), received a corn silage-based growing diet from d 0-56, then transitioned to a dry rolled corn-based finishing diet and were fed once daily via concrete bunks. Data were analyzed in Proc Mixed of SAS with fixed effects of Zn treatment, implant (IMP) treatment and the interaction, and source. Pen was the experimental unit (n = 9 per treatment) and initial BW was used as a covariate for performance and carcass data analysis. There was no Zn × IMP effect for overall ADG analyzed as repeated measures (P = 0.49). However, there was an IMP × Day (P = 0.02) effect in which REV-200 had greater ADG from d 0-28 and 91-120, while REV-XH peaked during d 56-91, corresponding to likely periods of greatest hormone payout from each implant. Further, IND heifers were more feed efficient during the initial implant period (P = 0.04) and tended to have heavier BW on d 91 (P = 0.06). Hot carcass weight, overall ADG, G:F, and DMI were not affected by IMP (P ≥ 0.18). Liver Mn was affected by IMP × Day where concentrations decreased on d 14 regardless of implant but d 105 and 164 values were lesser in REV-200 heifers (P = 0.02). Superior interim performance in IND vs. NRC during times of peak hormone payout for each implant may reflect the need for greater Zn supplementation during times of greater N retention.

Effect of Zinc Source and Optaflexx® on the Growth Performance and Carcass Characteristics of Steers Fed in Confinement to Harvest J.J. Wagner¹, W.T. Nelson¹, T.E. Engle¹, J.W. Spears², J.S. Heldt³, S.B. Laudert⁴, ¹Colorado State Univ., Fort Collins, ²North Carolina State University, Raleigh, ³Micronutrients USA LLC, Indianapolis, IN, ⁴Private Consultant, Woodland Park, CO

A study was conducted to determine the effect of different zinc sources on feedlot cattle fed Optaflexx®. A randomized block design was used in which 432 cattle were sorted into 48 pens and placed on six treatments using a 3 x 2 factorial arrangement. Zinc sources were fed at 90 mg/kg zinc DMB: zinc sulfate, 67:33 zinc ratio zinc sulfate and ZINPRO 100 (zinc methionine complex), and Intellibond Z. Optaflexx® was fed at zero and 30.1 mg/kg DMB during the final 29 days on feed. A single interaction was found between zinc source and Optaflexx® on dressing percentage. Optaflexx® cattle fed Intellibond Z were found to have an increased dressing percentage (P < 0.05) when compared to Optaflexx® cattle fed other zinc sources. Optaflexx® cattle fed zinc sulfate were found to have a decreased dressing percentage (P < 0.05) when compared to Optaflexx® cattle fed other zinc sources. No significant difference (P = 0.76) was found
in average daily gain. No significant difference (P = 0.61) was found in gain-to-feed ratio. No significant interaction was observed between zinc source and Optaflexx® effectiveness on growth performance. Interaction was found to be unlikely between zinc source and Optaflexx® response for growth and carcass traits. Cattle fed Optaflexx® had an improved final weight (P < 0.01), improved gain in the final 29 days (P < 0.001), improved ADG throughout the feeding period and in the last 29 days (P < 0.001), gain-to-feed ratio throughout the feeding period when initial weight was included as a covariate (P < 0.001), and gain-to-feed ratio in the last 29 days (P < 0.001). Cattle fed Optaflexx® had heavier carcass weight (P < 0.01) and larger loin muscle area (P < 0.05).

Evaluation of the safety of an algal biomass as an ingredient cattle in feed

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Algae production is increasing to supply the growing demand for Omega-3 fatty acids for aquaculture, human food and pet food; co-products from the algae industry could be a suitable feed ingredient for cattle feeding. An FDA GRAS approval safety study was conducted to evaluate feeding algal biomass to cattle. Crossbreed cattle (20 steers and 20 heifers, 563 lb. initial BW, SD = 30.8) were individually fed 4 concentrations of condensed algal residue solubles (CARS; 0, 2.5, 5, 7.5 % of diet DM) displacing dry rolled corn in a finishing diet (62.5 to 70% corn, 15% distillers grains, and 10% grass hay) for a minimum of 97 days. At harvest, organs were weighed and sampled. Blood was collected every 30 days. Performance data were analyzed as a RCBD with treatment, gender, and treatment by gender interactions as fixed effects, BW block as a random effect and individual animal as the experimental unit. Orthogonal contrasts were used to test for linear, quadratic and cubic responses due to CARS inclusion. Increasing CARS in the diet quadratically increased DMI and ADG (P ≤ 0.01). A linear increase was observed for NEₘ and NE₉ as CARS increased in the diet (P < 0.01). A linear decrease was observed for F:G as CARS inclusion increased in the diet (P < 0.01). All organ weights measured were within expected ranges for cattle, with 6 out of 27 having differences in weight due to treatment (P ≤ 0.05). Histopathology analysis of organs revealed no differences due to treatment (P ≥ 0.24). Out of 21 blood chemistry measures, 8 were affected by treatment (P ≤ 0.02). Nearly all blood chemistry parameters were within expected ranges for cattle. No adverse effects of feeding CARS were observed in hematology, blood chemistry, or histopathology analyses. The feedstuff CARS demonstrated to be a safe and efficacious feed ingredient for cattle diets and maximized HCW and ADG when fed at 2.5 or 5% of the diet.

Effect of feeding high protein DDGS in SFC-based diets on growth performance, starch digestibility and rumen fermentation parameters

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Two experiments, one finishing and one metabolism trial, evaluated the effects of high protein dried distillers grains plus solubles (DDGS) in steam flaked corn (SFC) and dry rolled corn (DRC) based diets. The experimental design of both trials was a 2 × 3
factorial. Treatments included a corn processing factor, either steam flaked corn (SFC) or dry rolled corn (DRC), and the other factor was a distillers grains plus solubles (DGS) treatment with no DGS inclusion (CON), the inclusion of traditional dried DGS (DDGS) or high protein dried DGS (HiPro). The finishing trial used steers (n = 360; initial BW 635 ± 0.9 lb) to evaluate their response to treatments over a period of 202 d. Treatments were assigned to each pen (n = 36; 10 steers/pen) within one of three blocks, one replication in a light block, four replications in a medium, and one replication in the heavy block, resulting in six replicates per treatment. Growth performance and carcass characteristics were analyzed using the MIXED procedures of SAS, with pen as the experimental unit and block as a fixed effect. In the metabolism trial, 6 ruminally and duodenally cannulated heifers were utilized in a 6 × 6 Latin square design with six, 21 d periods, each heifer receiving each treatment once. Titanium dioxide was used to analyze fecal and duodenal samples for post ruminal and total tract nutrient digestibility. Whole rumen contents were analyzed for purines to correct ruminal flow for microbial biomass. Rumen fluid was analyzed for VFA and NH₃ concentration. Data were analyzed using the MIXED procedures of SAS with fixed effect of period and heifer within period as the experimental unit. There was an interaction (P = 0.02) between corn processing and DGS treatment for G:F in the growth performance trial. Feeding DDGS and HiPro in DRC-based diets improved G:F by 3.5%, while in SFC-based diets, DGS treatment did not affect (P > 0.10) G:F response. Steam flaking corn reduced (P = 0.01) DMI by 1.3 lb/d, without affecting (P = 0.98) ADG. Feeding DGS or HiPro increased (P < 0.01) DMI by 7.3% and increased (P < 0.01) ADG by 7.5% as compared to CON, resulting in greater (P < 0.01) HCW for DDGS and HiPro. True ruminal starch digestibility was not affected (P = 0.18) by DGS treatment but was lower (P < 0.01) for DRC as compared to SFC. Total starch flow to the duodenum from the rumen was not affected (P = 0.68) by DGS treatment, as DMI was greater (P < 0.01) for cattle consuming DDGS and HiPro. There was an interaction (P < 0.01) between corn processing and DGS treatment on post ruminal starch digestibility, with a similar response observed to G:F, with SFC not affected by DGS treatment, while DRC-CON and DRC-DDGS were lower than all SFC treatments, and DRC-HiPro was the lowest at 59.1% starch digestibility post ruminally. Apparent total tract starch digestibility followed a similar trend to post ruminal starch digestibility, with DRC DDGS and DRC HiPro having the lowest (P < 0.01) starch digestibility. Improvements in growth performance due to DDGS inclusion in the diet are not likely due to improvements in starch digestibility, but likely more due to a response in greater DMI and digestion of other nutrients. The use of HiPro DDGS results in similar performance to traditionally produced DDGS and, as a result, should be valued similarly in DRC-based diets. Steam flaked corn reduced DMI and improved G:F through an improvement in starch digestion throughout the entire digestive tract.

Impact of environmental enrichment on feedlot steer productivity and aggression
Rachel M. Park¹, Jenny S. Jennings² and Courtney L. Daigle¹, ¹Texas A&M University, College Station, ²Texas A&M AgriLife Research, Amarillo
The objective of this study was to determine if cattle housed in a feedlot pen with a cattle brush had improved productivity and engaged in fewer aggressive behaviors compared to cattle without a brush. Pre-dominantly British and British continental
crossbred steers (n= 51) were blocked by weight and assigned to one of two treatments 1) No enrichment (CON; 3 pens at 9 animals/pen; n = 26) or 2) a cattle brush (BRUSH; 3 pens at 9 animals/pen; n = 25) across a 256 day experimental period. Cattle arrived at the feedlot on d -55 relative to brush implementation and were slaughtered on d 161 and d 198 respective to weight block. Video recordings were decoded from 0800 to 1730 on d -2, -1, 0, 1, 2, 4, 8, 16, 32 and 64. Continuous observations recorded headbutting, mounting and kicking frequency. Production metrics were calculated (ADG, G:F and weekly DMI) and carcass data was collected at slaughter. A General Linearized Mixed Model (PROC MIXED) evaluated the impact of day, treatment and their interaction on behavior and the impact of treatment on productivity. Liver abscess presence was evaluated using PROC GLIMMIX in SAS. Treatment did not impact steer productivity, carcass traits or kicking frequency (P > 0.05). An interaction between day and treatment was observed for headbutting (P = 0.01) with BRUSH cattle performing fewer headbutts than CON cattle on d 1, 2, 4, 8 and 16. Treatment impacted mounting with BRUSH cattle performing fewer mounts than CON cattle (P = 0.03) and for both treatments, mounting decreased over time (P = 0.002). Cattle housed in BRUSH pens performed fewer aggressive behaviors and the presence of the brush did not negatively impact productivity. This suggests that a cattle brush could provide a lasting benefit to cattle welfare without compromising productivity.

Effect of diet, rumination time and activity on the performance of non-nutritive oral behaviors by beef cattle  
Emily E. Ridge¹, Rachel M. Park¹, Jenny S. Jennings², Courtney L. Daigle¹,¹Texas A&M University, College Station, ²Texas A&M AgriLife Research, Amarillo

Pre-dominantly British and British-continental crossbred steers (n = 51) were used to evaluate the effect of dietary corn stalk inclusion level, rumination time, and activity on the performance of non-nutritive oral behaviors (NNOB) during the first 9.5 weeks of the finishing period in a beef cattle feedlot. Cattle were blocked by weight and randomly assigned to dietary treatments containing one of three corn stalk inclusion rates: 5, 10, or 15% (DM basis). Cattle were housed in 6 feedlot pens each containing 9 Calan gate feeders. Each individual animal was fitted with a rumination collar upon arrival to the feedlot to collect rumination time and activity. Video recordings were decoded from 0800 to 1730 h on d 0, 1, 2, 3, 4, 6, 10, 18, 34, and 66 relative to dietary treatment implementation. Continuous observations were used to collect frequency and duration of bar licking and tongue rolling. A Generalized Linear Mixed Model (PROC GLIMMIX in SAS) evaluated the impact of diet on NNOB performance. Relationships between individual animal rumination and activity duration and NNOB duration were analyzed using a linear regression (PROG REG). Level of dietary corn stalk inclusion affected neither tongue rolling duration or bar licking duration (P > 0.05). Irrespective of diet, as individual rumination duration (min/d) increased, the duration of time (min/d) engaged in tongue rolling decreased (β = -2.22, P < 0.01). The duration of time an individual animal spent engaged in of tongue rolling and bar licking (min/d) behaviors was positively related to individual activity levels (min/d; β = 1.03, P = 0.003 and β = 0.96, P = 0.004, respectively). Individual animals that engaged in shorter durations of rumination behavior performed more tongue rolling. The relationship between activity and NNOB performance suggests either that NNOB performance may either artificially inflate
activity levels collected electronically, or cattle that are more physically active may be more orally active. Cattle may adopt the performance of NNOB as coping mechanism as part of their adaption to shorter durations of time spent ruminating and eating in confinement relative to the time spent grazing on forages while on pasture.

**Evaluation of sources of RUP for use in an organic beef production system**

Elizabeth A. Schumacher, Galen E. Erickson, Jim C. MacDonald, Terry J. Klopfenstein, Andrea Watson, Hannah C. Wilson, Zac Carlson, F. Henry Hilscher, Levi McPhillips, Univ. of Nebraska – Lincoln

Two studies were conducted to establish a viable source of supplemental rumen undegradable protein (RUP) for use in organic beef production systems. The first study evaluated the effect of RUP sources on performance of Holstein steers. Holstein steers (n = 58; initial BW = 469lb) were fed individually for 214 days. Diets contained 30% alfalfa haylage, 5% supplement, and varying proportions of dry rolled corn and a protein source to supply RUP. Steers were stratified by BW and assigned randomly to dietary treatments: a protein-deficient control (CON) or supplemental field peas (FP), field peas and fish meal (FPFM), soybean meal (SBM), and a soybean meal treated to increase RUP (Soypass; SP). Experimental unit was steer. Over 214 days, no differences (P ≥ 0.25) were observed between treatments for final BW or ADG but calves fed FP or FPFM had the lowest DMI at 17.6 lb / d and those fed SP had the highest DMI at 20.5 lb / d, with CON and SBM intermediate at 19.6 lb / d and 19.1 lb / d respectively (P = 0.02). This resulted in a tendency (P = 0.06) for steers fed FPFM to be more efficient than calves fed CON, FP, SBM, SP (F:G of 8.33, 10.20, 8.93, 8.85, and 9.35, respectively). The CON diet resulted in the highest cost of gain at $2.02 / lb compared to $1.82 / lb, $1.92 / lb, $1.92 / lb, and $1.42 / lb for FP, FPFM, SBM, and SP, respectively. The objective of the second study was to compare in situ RUP content (RUPc) and digestibility (RUPd) of conventional and USDA Certified Organic sources of feeds. Two heifers with rumen and duodenal cannulas were utilized for this study and were fed the CON diet from the first study. Conventional feeds included field peas (FP), soybean meal (SBM), and dehydrated alfalfa (DA). Organic feeds included field peas (FPO), soybean meal (SBMO), and dehydrated alfalfa (DAO). Each sample was weighed into dacron bags, distributed between animals and ruminally incubated for 16 hours, replicated twice, to measure RUPc. Half of the bags were inserted into the duodenum and retrieved from feces to measure RUPd. Digestible RUP (DRUP) was calculated as follows: DRUP = CP % X RUPc % X RUPd %. Experimental unit was sample. The DRUP of SBMO was 14.25% greater (P < 0.01) than SBM. The DRUP of DAO was 1.25% greater but not significantly higher (P = 0.28) than DA. No differences (P = .24) were detected between FPO and FP although FPO was 2% higher in DRUP than FP. These data indicate that there may be some differences in RUP content and digestibility between conventional and certified organic feeds when measured in situ.
Liver abscesses are a major financial, welfare, and production concern in feedlot cattle. Previous studies have shown that prevalence of liver abscesses are greater in cattle harvested in the central plains region compared with the desert southwest region of the United States, and calf-fed Holsteins have greater prevalence of liver abscesses than beef-breed cattle. The objective of this study was to evaluate a link between microorganisms found in liver abscesses with those isolated from feedlot pen soil organic material (SOM) from different regions of the United States. We hypothesized that microbial load in SOM is a predisposing factor to liver abscesses in cattle. Samples of SOM and liver abscesses were collected for bacterial analysis. Liver abscess samples were collected from two commercial processing facilities that harvest cattle from the desert southwest region (Tolleson, AZ) and central plains region (Greeley, CO). Liver abscess samples were linked to pen SOM samples from which the cattle were finished. A soil-sampling probe was used to collect a 15-cm core sample of SOM from each of the four quadrants of corresponding feedlot pens. Deoxyribonucleic acid (DNA) was extracted from SOM and liver abscesses using Qiagen DNA Extraction Kits. Extracted DNA was sequenced on an Illumina MiSeq and bacteria were identified using sequence databases. Bacterial phyla and genera were reported with the diversity indices, richness and Shannon Wiener Index (SWI). Richness is the number of different phyla or genera, and SWI is the number of different phyla or genera and their abundance. In experiment 1, 32 Holstein and beef-breed cattle liver abscesses with corresponding SOM were examined. All cattle were fed diets containing tylosin phosphate. Feedlot pen SOM housing Holstein cattle had less Actinobacteria ($P = 0.01$) and Firmicutes ($P = 0.03$), and greater Bacteroidetes ($P < 0.01$) populations compared with beef-breed cattle. However, bacterial phyla in liver abscesses did not differ between Holstein and beef-breed cattle. In experiment 2, 48 liver abscess and SOM samples were analyzed from the AZ and CO regions. Feedlot pen SOM in AZ had greater Bacteroidetes ($P < 0.01$) and Proteobacteria ($P < 0.01$), but fewer Firmicutes ($P < 0.01$) and Fusobacteria ($P < 0.01$) compared with CO. Similar to experiment 1, bacterial phyla of liver abscesses did not differ between AZ and CO regions. Fusobacteria comprised the majority of liver abscesses ranging from 63.4% to 80.4% of the population but was not the only bacteria identified. Actinobacteria, Bacteroidetes, and Proteobacteria were identified in liver abscess samples and ranged from 15.5% to 33.0% of the total bacterial population. Richness did not differ for SOM ($P = 0.14$) or liver abscesses ($P = 0.73$), but SOM SWI was lower ($P < 0.01$) for the AZ than CO region. In conclusion, bacterial populations in SOM differed between pens housing Holstein compared with beef breeds and between pens in AZ compared with CO region. However, the differences in bacterial populations of feedlot pen SOM did not have an impact on the bacterial populations of liver abscesses. Further research is warranted to determine if differences in SOM bacterial populations are linked to previously observed differences in liver abscess incidences in different regions.
Effects of *Bacillus subtilis* PB6 and/or chromium propionate supplementation on health, performance, and blood parameters of high-risk cattle during the feedlot receiving period

Taylor M. Smock¹, Kendall L. Samuelson¹, Dexter J. Tomczak¹, Hannah A. Seiver¹, Jerilyn E. Hergenreder², P. Whitney Rounds², John T. Richeson¹, ¹West Texas A&M University, Canyon, ²Kemin Industries, Inc., Des Moines, IA

The study objective was to determine the effects of *Bacillus subtilis* PB6 and/or chromium propionate supplementation on health, performance, and serum chemistry and complete blood count variables in high-risk beef calves during a 56-day feedlot receiving period. Four truckload blocks of crossbred beef bull (n = 300) and steer (n = 84) calves (BW = 485 ± 35.71 lb) were sourced from regional auction markets and assigned randomly to treatments arranged in a 2 × 2 factorial. The generalized complete block design consisted of 3 pen replications per treatment within block, totaling 12 replications per treatment with pen as the experimental unit. Treatments were: 1) placebo control (CON); 2) 13 g/animal/d of *Bacillus subtilis* PB6 (CLOSTAT®, Kemin Industries, Des Moines, IA; CST); 3) 1 g/animal/d Cr propionate (KemTRACE® Chromium, Kemin Industries; CHR); and 4) 13 g/animal/d of *Bacillus subtilis* PB6 and 1 g/animal/d Cr propionate (CST+CHR). Treatments were top dressed in feed bunks daily using 1 lb/animal/d ground corn carrier immediately following feed delivery. Cattle fed CON received an equivalent amount of ground corn only. Feedlot personnel were blinded to experimental treatments by assignment of color codes to treatment pens and ear tags. Blood samples were collected via jugular venipuncture on days 0, 14, 28, and 56 for analysis of serum chemistry (VetScan VS2, Abaxis, Union City, CA) and complete blood count (ProCyte Dx Hematology Analyzer, IDEXX Laboratories, Westbrook, ME) variables from a pen subset (n = 2/pen). Data were analyzed using the MIXED and GLIMMIX procedures of SAS where appropriate. Repeated measures analysis was used for blood variables. The DMI was increased for CST during each interim period (P ≤ 0.03) and overall DMI was increased by 0.78 lb/animal/d for CST (P = 0.01). Likewise, ADG was improved for CST from day 0 to 14 (P = 0.04) and for the overall receiving period (day 0 to 56; P = 0.04). Main effects of both CST (P = 0.02) and CHR (P = 0.03) were observed to decrease the overall percentage of calves treated for bovine respiratory disease (BRD). Morbidity was 28.0 and 39.9% for cattle with and without CST supplementation, respectively. Similarly, BRD morbidity was 28.6 and 39.3% for cattle with and without CHR supplementation, respectively. Cattle fed CHR had increased total leukocyte count (P = 0.04) and neutrophil count (P = 0.02). In addition, cattle fed CHR had greater serum aspartate aminotransferase concentration (P = 0.04) and less (P = 0.02) serum calcium. Day affected (P ≤ 0.03) all serum chemistry variables evaluated except total CO₂ (P = 0.34). Feed intake and performance outcomes during the receiving period were improved by CST, but not CHR supplementation. However, both CST and CHR supplementation decreased BRD morbidity rate.
Projecting live cattle slaughter value based on Performance Cattle Company’s Cattle Classification and Sorting System  Jessica L. Sperber1, Max G. Garrison2, David G. Lust1, Ty E. Lawrence1, 1West Texas A&M Univ., Canyon, 2Performance Cattle Company, Amarillo

An experiment was conducted to determine the proficiency and value in sorting cattle upon feedyard arrival into end-weight marketing groups with improved uniformity. Commercial beef heifers (n = 370) and steers (n = 372) were sorted five-ways per sex (10 pens total) using a proprietary cattle classification and sorting system, that utilizes feedlot arrival weight (kg), hip height (cm) and hip length (cm). The sorting system was equipped with a database to document live traits and projected appropriate number of days on feed by estimating incoming empty body fat, adjusted finished body weight, dry matter intake, and average daily gain. Sort pens differed in targeted harvest date and days on feed. Cattle were harvested at a commercial processing facility and graded after a 30-hr chill period. Carcass traits included liver and lung abnormalities, hot carcass weight, individual quality and yield grade parameters, and total carcass value. A completely randomized experimental design structure was used; data were analyzed using a mixed model with sort pen as the fixed effect, and harvest date as a random effect. Linear and quadratic contrasts were generated to assess trends across the sort pens. Heifer carcasses did not differ (P > 0.36) with increasing number of days on feed for 12th rib fat (cm), ribeye area (cm²), yield grade, or marbling score. Empty body fat (%) was similar across pens, suggesting uniformity in doneness of individual animals at harvest. Total carcass value per cwt did not differ (P = 0.27) between heifer pens, suggesting that cattle were of similar value apart from their number of days on feed. Steer carcass data tended to differ (P = 0.08) with increasing number of days on feed for longissimus muscle area (cm²) yet did not differ (P = 0.61) for calculated yield grade. Steer carcass data followed a linear trend for measured fat thickness (cm) and EBF (%), both decreasing as number of days on feed increased. There was less variation in calculated EBF (%) for both heifers and steers when compared to the projected outgoing EBF (%), suggesting that the sort system had greater accuracy in sorting cattle into uniform finished groups than what was originally predicted. These data suggest that the sort system was successful in sorting cattle upon feedyard arrival to improve uniformity, ensure the likelihood of achieving target empty body fat, and maximizing dollar value of individual animals.

Performance, rumination characteristics and rumen pH responses to differing dietary energy density and feed management strategies in newly received feedlot cattle  Dexter J. Tomczak1, Catherine L. Lockard2, Jenny S. Jennings2, John T. Richeson1, 1 West Texas A&M Univ., Canyon, 2Texas A&M AgriLife Research, Amarillo

Auction derived crossbred steers (n=36; 625 ± 25 lb) were received to compare performance, rumination characteristics, and rumen pH differences due to alternative ration energy densities and feed management strategies during the initial 56 d following feedlot arrival. Cattle were weighed on day -1 and randomized to 1 of 3 treatments (CON, FIN+H, FIN). The following day steers were administered a 3-axis accelerometer ear tag to quantify time spent ruminating, and a random subset (n=6/treatment) were administered a pH and temperature data logging ruminal bolus prior to being sorted into individual pens. Identical routine processing was employed for steers. The modified-live
virus respiratory vaccination was delayed until day 28. The FIN cattle were provided their daily feed as a high energy density (0.63 Mcal NEg/lb) diet during the entirety of the study. The FIN+H cattle were provided the same diet, but were also offered 0.5% BW DM as long stem hay on days 1, 4, 7, 10, 13, 16, 19, 22, 25 and 28. The CON cattle were fed a low energy density (0.42 Mcal NEg/lb) diet from day 0 to 7, then transitioned to the FIN diet by replacing an additional 25% of the daily feed call with FIN every 7 d until 100% of the diet was FIN on day 29. All cattle were initially offered 1% of BW DM of their respective diets. Feed calls for CON were increased more aggressively (1 lb DM daily for day 1 to 7, every other day for day 8 to 14) than FIN and FIN+H (1 lb DM every other day for day 1 to 7, daily for day 8 to 14). Performance and DMI were analyzed using PROC MIXED in SAS with treatment as a fixed effect. Rumination, pH, and temperature models included a repeated measures statement (hour, day or week). There was no treatment difference observed for BW, ADG, DMI or G:F ($P \geq 0.12$). There was a treatment × day interaction ($P = 0.06$) for rumen temperature, such that the rumen temperature for FIN increased more rapidly following vaccination on day 28 compared to CON ($P \leq 0.04$). Daily rumination minutes were greater ($P < 0.01$) for CON than FIN from day 7 to 22. Additionally, CON had the greatest ($P < 0.01$) hourly rumination from 2000 to 0800 h. Lower minimum daily rumen pH occurred in FIN+H ($P \leq 0.06$) on weeks 1, 2 and 5 to 8 compared to CON. There were minimal statistical differences in area under the curve or time below pH thresholds 5.6 or 5.2 probably due to large animal to animal variation. Hourly rumen pH was reduced ($P \leq 0.05$) for FIN vs FIN+H and CON during the initial 28 d, but greater ($P = 0.05$) for FIN and FIN+H during the final 28 d. When cattle are individually fed, greater energy density rations can be fed initially without compromising performance, but this needs to be evaluated at the pen level where greater DMI variation is probable.

Effects of Ruminally-Protected Lysine and *Megasphaera elsdenii* on Performance and Carcass Characteristics of Finishing Cattle  V. A. Veloso, L. M. Horton, A. N. Baker, J. S. Drouillard, Kansas State Univ., Manhattan

Four hundred and forty-eight crossbred steers (776 ± 55 lb initial body weight) were used to evaluate impact of *Megasphaera elsdenii* (ME; Lactipro®, MS Biotec, Wamego, KS), alone or in combination with ruminally-protected lysine (RPL; USA Lysine, Kemin Industries, Inc., USA), on performance and carcass traits of finishing steers in a randomized complete block design. Steers were blocked by initial body weight and randomly allocated to one of 64 pens (7 steers/pen) in a 2 x 2 factorial treatment arrangement. Treatments were: RPL fed at 0 (-RPL), or 0.45% (+RPL) diet dry matter; and two step-up regimens: conventional 21-d without ME (-ME), or accelerated 10-d step-up with ME (+ME). Four step-up diets were used to transition cattle to finishing diets containing (dry basis) 60% steam-flaked corn, 30% Sweet Bran, 7% wheat straw, and supplement. Diets were fed once daily *ad libitum*. Freeze-dried ME was re-hydrated and dosed orally (1 x 10$^{10}$ CFU/steer) on d 1, and top-dressed (dry; 1 x 10$^7$ CFU/steer daily) onto diets daily thereafter. Cattle were weighed and harvested after 144 or 172 days to determine ADG, DMI, and F:G. Data were analyzed using a mixed model with ME, RPL, and the interaction as fixed effects, pen as experimental unit, and block as the random effect. No interactions between ME and RPL ($P > 0.05$) were observed for feedlot performance or carcass traits. Steers given ME consumed 16% less roughage
compared to their counterparts without \( P < 0.05 \), but gain, dry matter intake, and F:G were similar \( P > 0.10 \). Administering ME tended to increase percentage of USDA Prime carcasses compared to control \( 2.7 \) vs \( 0.5\% \) respectively; \( P < 0.06 \). Feeding RPL did not affect feedlot performance, carcass weight, longissimus muscle area, marbling score, 12th-rib fat thickness, or liver abscess incidence \( P > 0.10 \), but tended to increase yield grade \( P < 0.07 \). In conclusion, use of \textit{Megasphaera elsdenii} with an accelerated step-up program yielded feedlot performance and carcass traits comparable to those of traditionally adapted cattle, but supplemental lysine was without effect.

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†I = interaction effect; L = effect of lysine; M = effect of \textit{Megasphaera}; \( P < 0.05 \). ‡Means without a common superscript letter are different, \( P<0.05 \).

Effect of monensin intake during a stocker phase and subsequent finishing phase on performance, carcass characteristics, and rumen bacterial diversity of beef steers

\textsc{Caleb P. Weiss\textsuperscript{1}, Paul A. Beck\textsuperscript{2}, Jiangchao Zhao\textsuperscript{1}, John T. Richeson\textsuperscript{3}, Dexter J. Tomczak\textsuperscript{3}, Colton A. Robison\textsuperscript{2}, Jianmin Chai\textsuperscript{1}, Tom Hess\textsuperscript{4}, and Donald S. Hubbell III\textsuperscript{4}, \textsuperscript{1}Univ. of Arkansas, Fayetteville, \textsuperscript{2}Oklahoma State Univ., Stillwater, \textsuperscript{3}West Texas A&M Univ., Canyon; \textsuperscript{4}University of Arkansas, Batesville}

Three monensin levels during a stocker phase \((0, 800, 1600 \text{ g/ton fed in a free choice mineral})\) and two levels during finishing \((0 [\text{U}] \) or 37.5 mg/kg diet DM \([\text{M}]\)) arranged as a \(3 \times 2\) factorial were used in a completely randomized block experiment to determine the effects of monensin supplementation during a stocker and subsequent finishing phase on performance and carcass characteristics of beef steers. Calves \((n = 605, \text{ BW } = 613 \pm 60 \text{ lb})\) were fed pearl millet \((\textit{Pennisetum glaucum})\) hay with soybean hull and corn gluten feed supplement \((0.5\% \text{ BW daily [AF basis]} \text{ Block 1})\) or grazed fall wheat \((\textit{Triticum aestivum}; \text{ Block 2})\), spring wheat \((\text{Block 3})\), summer bermudagrass \((\textit{Cynodon dactylon}; \text{ Blocks 4 & 5})\) or winter wheat with mixed-grass baleage \((\text{Block 6})\). Following the stocker phase, a subset of calves were transported 664 mi to Canyon, TX \((\text{blocks 1, 2, and 4})\) or 395 mi to Stillwater, OK \((\text{block 6})\) for finishing. Rumen fluid was collected on a subset of cattle \((n = 30, 5\text{ per treatment})\) from blocks 1 and 2 upon feedlot arrival \((\text{feedlot d 0})\) and 14, 28 and 56 days after being placed in the feedlot. Additionally, samples were collected immediately prior to a diet change to include the beta-adrenergic agonist \((d 101 \text{ and } 131)\) and before shipping for harvest \((d 131 \text{ and } 161)\). Rumen and fecal microbiota were characterized by next generation sequencing the 16S v4 hypervariable region with the Illumina MiSeq platform. There were no treatment \(\times\) diet interactions \((P \geq 0.96)\) during the stocker phase or location \(\times\) treatment interactions.
(P ≥ 0.19) during finishing, therefore data were pooled for statistical analysis. The Shannon Index for alpha diversity were analyzed using the Wilcoxon Rank Sum test and beta diversity was measured using the Bray-Curtis distance matrices and analyzed in mothur using the ANOSIM command. During the stocker phase, cattle consuming monensin had greater (P = 0.01) final BW compared with the 0 treatment. Steers on the 800 and 1600 treatments had linearly greater ADG (P = 0.02) and total gain (P = 0.02) than 0. Mineral intake decreased linearly (P < 0.01) as monensin level increased. Stocker × feedlot treatment interactions were not observed for feedlot performance data (P ≥ 0.50), but were observed for carcass characteristics. Cattle consuming monensin in the feedlot had decreased (P< 0.01) DMI and increased (P < 0.01) G:F than those that did not. Cattle on 1600U treatment had the greatest LM area whereas 0U had the least. Steers on 800U and 1600U treatments had decreased YG and 800M had the greatest. Cattle consuming monensin during finishing had increased (P = 0.03) fat thickness. Steers who were previously on the 0 and 1600 treatments during the stocker phase and were fed monensin at the feedlot had decreased alpha diversity (P =0.04) on d 14 compared to those that did not. Monensin at the feedlot tended to increase alpha diversity on d 28 for cattle previously on the 1600 treatment (P = 0.06), and on d 56 for cattle previously on the 0 treatment (P = 0.06). No other differences (P ≥ 0.10) for the rumen bacterial diversity were observed. Supplementation of monensin to stocker cattle improved performance compared to an unmedicated control, but had minimal impact on subsequent feedlot performance. Providing monensin still decreases DMI and improves feed efficiency of feedlot cattle.

**Identifying Optimal Levels of Silage Used as a Roughage Source in Finishing Beef Cattle Performance, Liver Abscess Rate, and Digestion Characteristics**


Including a roughage source in high grain finishing diets can minimize the potential for acidosis and decreased animal performance. Two experiments three concentrations of corn silage as a roughage source on finishing performance and liver abscess rate. In an individual feeding study (Exp. 1), sixty crossbred steers (950 lbs ± 0.99 lbs) were stratified by BW and assigned randomly to 4 treatments with 15 head per treatment. Treatments consisted of 3 inclusions of corn silage at 0 (CS0), 7.5 (CS7.5) and 15% (CS15) of the diet DM and a control treatment with 7.5% alfalfa (Alf). Steers were fed for 117 days in a Calan gate controlled individual feeding system. Refusals were taken weekly and corrected for DM. In a digestion study, 3 ruminally cannulated steers (946 lbs ± 0.44 lbs) were utilized in a generalized randomized block design with 8 periods. The same treatments for Exp. 1 were utilized in Exp. 2 (Alf, CS0, CS7.5, and CS15). For Exp. 1, there were no differences in final BW (P < 0.88), DMI (P < 0.51), ADG (P < 0.88), or G:F (P < 0.20). There were no differences for carcass characteristics such as HCW (P < 0.83), marbling (P < 0.59), LM area (P < 0.84), or fat thickness due to treatment (P < 0.45). There were also no differences in dressing percentage (P < 0.26) or calculated yield grade (P < 0.63). Only 3 out of the 60 animals had liver abscesses with 2 animals fed CS0 and 1 animal fed Alf. In Exp. 2, DMD, OMD, NDF digestibility, and ADF digestibility were greatest for cattle fed CS0 followed by CS7.5, CS15, and Alf (P < 0.01). Average ruminal pH was least for CS0, CS7.5 was intermediate, followed by
Alf and CS15 with the greatest pH \((P < 0.01)\). Total VFA production was greatest in cattle fed CS0 followed by CS7.5 and Alf with CS15 having the least. Acetate to propionate ratio was least for cattle fed CS0, intermediate for CS7.5 and CS15 and greatest for Alf. Cattle ate the same number of meals which were similar in size as a % of total DMI \((P \geq 0.60)\). However, cattle fed Alf and CS0 spent more time eating compared to cattle fed CS7.5 and CS15 \((P = 10)\). The rate of intake (lbs/hr) was greatest for CS15 (9.55) and decreased linearly for CS7.5 (9.44), Alf (8.12) and was least for CS0 (7.68; \(P = 0.04\)). These data suggest that cattle, typically at high risk for reduced performance, are less likely to experience negative effects of high grain diets, like acidosis, when fed individually. When managed accordingly, no roughage in needed in the diet. However, when feeding corn silage as a roughage source, it should be included at 15% DM to minimize risk for acidosis, but similar performance can be achieved feeding only 7.5%.

**Impact of Shade in Beef Feedyards on Performance, Body Temperature, and Heat Stress Measures**  
T. M Winders\(^1\), B. M. Boyd\(^1\), C. Macken\(^2\), A. K. Watson\(^1\), J. C. MacDonald\(^1\), and G. E. Erickson\(^1\), \(^1\)Univ. of Nebraska, Lincoln, \(^2\)Performance Plus Liquids, Grand Island, NE  
A study using crossbred steers (\(n = 1713\); initial BW = 834 lb, SD = 23) was conducted at a commercial feedyard in Eastern NE to determine the effects of shade on cattle performance, body temperature, and cattle activity. Two treatments were evaluated using a randomized complete block design (\(n = 5\) blocks based on arrival). Treatments were assigned randomly to pen and consisted of 5 pens without shade (NO SHADE) and 5 pens with shade (SHADE). Cattle per pen ranged from 120 to 200 based on size of pen. Steers were allowed 410 ft\(^2\)/steer of pen space and the shaded area was 30 to 45 ft\(^2\)/steer. Cattle were assigned to pen based on processing order, switching the sort gate after every third steer. Body temperatures were collected throughout the trial using Quantified Ag biometric sensing ear tags on a subset of cattle (30 steers per pen selected randomly based on processing order). Panting scores were collected on the same subset of steers a minimum of twice weekly from May 29 until July 24. Dry matter intake and ADG were greater for SHADE cattle \((P \leq 0.04)\) and LM area tended \((P = 0.06)\) to increase for SHADE relative to NO SHADE. Two heat events and one cool event were defined for the feeding period based on wind adjusted temperature-humidity index, with event 1 from May 24 to June 1, event 2 from July 9 to July 16 and the cool event from June 2 to June 7. In addition, overall trial data (February 26 to July 25) were compared for ear temperature and cattle activity when all cattle were in pens simultaneously prior to first block being harvested. During event 1, SHADE cattle had greater DMI \((P < 0.01)\) and lower panting scores \((P < 0.01)\) than NO SHADE cattle. During event 2, SHADE cattle had lower panting scores \((P < 0.01)\) and tended \((P = 0.08)\) to have more movement. The cool event resulted in greater DMI \((P < 0.01)\) and lower panting scores \((P = 0.01)\) for SHADE compared to NO SHADE cattle. Ear temperature for NO SHADE cattle was greater \((P < 0.05)\) for event 1 from 1400 to 1900 plus hour 2400 and greater for Event 2 at 1500, 1700 and 1900 hours, suggesting cattle in shaded pens were cooler in the afternoon during heat events. SHADE cattle ear temperature was greater \((P < 0.05)\) during event 1 from 0100 to 0800 hours compared to NO SHADE cattle. Movement for NO SHADE cattle was greater \((P < 0.05)\) from 1100
to 1700 hours plus hours 2000 and 2100 compared to SHADE cattle during Event 1, while SHADE cattle had greater movement from 1700 to 2000 hours plus hour 2300 during Event 2. Temperature and movement were not significantly different between treatments during the cool event ($P \geq 0.08$). During the entire feeding period, movement and ear temperature were not different between the two treatments ($P \geq 0.80$). SHADE cattle had greater DMI and ADG and lower panting scores ($P \leq 0.04$), while no other performance differences were observed. These data suggest that providing shade lessened the negative impacts of heat events on DMI and was an effective way to reduce heat stress in feedlot operations.

**Effects of FluidQuip distillers grains high-fiber fraction on finishing performance and carcass characteristics and high-protein fraction on growth performance of steers**

A.R. Wiseman¹, B.M. Boyd¹, Z.E. Carlson¹, L. McPhillips¹, A.K. Watson¹, J.C. MacDonald¹, G.E. Erickson¹, S. Tilton², ¹Univ. of Nebraska-Lincoln, Lincoln, ²Flint Hills Resources, Wichita, KS

Two experiments were performed to evaluate distillers grains products produced by a Flint Hills Resources ethanol plant using the FluidQuip process. High-fiber dried distillers grains plus solubles (DDGS) were evaluated in finishing cattle diets and a high protein DDGS (NexPro) was evaluated in a corn silage based growing diet. In Exp. 1, yearling crossbred steers ($n = 240$, initial BW = 1020 ± 76 lb) were blocked by initial BW, stratified by BW, and assigned randomly to pen ($n = 30$; 8 steers/pen). Treatments were arranged as a 2×2+1 factorial with DDGS type (High-fiber DDGS [FIBER]; Conventional DDGS [CONV]) and inclusion level (20 or 40% diet DM) as the factors. All treatments were compared to a corn-based control (CON). DDGS replaced a 60:40 blend of high-moisture corn and dry-rolled corn. All diets contained 7.5% alfalfa hay and supplement. Increasing concentrations of CONV or FIBER resulted in a linear increase in DMI ($P < 0.01$). Steers fed 40% FIBER had the greatest DMI ($P < 0.01$) while CON steers had the least ($P < 0.02$). Gains for FIBER steers linearly increased ($P = 0.03$), while CONV steers showed a tendency for ADG to increase quadratically ($P = 0.08$). Feed conversion of CONV steers had a quadratic response ($P = 0.04$), with the lowest Feed:Gain at 20% inclusion. Feed conversion tended to increase linearly ($P = 0.09$) for steers fed FIBER. In Exp. 2, 120 crossbred steers (initial BW = 551 ± 53 lb) were individually fed using the Calan gate system and assigned randomly to treatment. Treatments were arranged as a 3×4+1 factorial with test protein type (Soybean meal [SBM]; non-enzymatically browned soybean meal [SoyPass]; High-protein DDGS [NexPro]) and supplemental protein concentration (4.5, 9.0, 13.5, or 18.0 % diet DM) as the factors. All treatments were compared to a control with 0 inclusion of test protein and a corn-based, urea-containing RDP supplement. Diets contained 80% corn silage with test protein replacing RDP supplement as inclusion increased. By design, RUP intake increased linearly ($P < 0.01$) across all treatments. Final BW responded linearly ($P \leq 0.04$) for all treatments. Steers fed SoyPass or NexPro had no change ($P \geq 0.18$) in DMI, while DMI for SBM cattle tended to increase quadratically ($P = 0.07$). Gains increased linearly ($P < 0.01$) for SoyPass steers and increased quadratically ($P = 0.01$) for SBM and NexPro. This resulted in linear improvements ($P < 0.01$) in feed conversion with increasing inclusion of all test proteins. Inclusion of FIBER DDGS resulted in linear increases in DMI and ADG compared to the corn control, but
decreased feed efficiency by 1.0 and 5.3% for 20 and 40% inclusion, respectively. NexPro is a good source of RUP for growing calves and increasing concentration up to 18% of diet DM resulted in a linear increase in feed efficiency. Feed products from the FluidQuip process improved growing calf performance while increasing DMI and ADG, in finishing diets.


Ruminal pH decreases as greater concentrations of grain are consumed. As a result, rumen function may be altered changing nutrient flow post-ruminally. Polyunsaturated fatty acids (PUFA) are extensively hydrogenated by rumen microbes to stearic acid 18:0, which is a saturated fatty acid (SFA). Our objective was to investigate effects of pH, resulting from feeding grain or grass-based diets in vitro, on biohydrogenation by ruminal microbes. Eight dual-flow, continuous culture fermenters (1,045 mL) were blocked by side of the room (North or South) and randomly assigned, within block, to 1 of 4 dietary treatments in a completely randomized block design. Dietary treatments consisted of feeding 100:0 roughage-to-concentrate ratio (Grass), 50:50 roughage-to-concentrate plus flax oil supplement (Mix+F), 10:90 roughage-to-concentrate ratio plus corn oil supplement (Con+C), or 10:90 roughage-to-concentrate ratio plus flax oil supplement (Con+F). Differences in fermenter pH were expected due to dietary composition; therefore, fermenter pH was regulated between 5.5 and 7.0. Liquid and solid flow rates were maintained at 8.66% and 4.51%, respectively, and fluid temperature was maintained at 38.5° C. Average fermenter pH, area under the curve, and maximum pH were lowest for Con+C and Con+F (P < 0.05). Apparent and true DM, OM, and NDF digestibility were greater with grain inclusion (P < 0.05) while ADF digestibility was not affected by treatment (P > 0.10). Protein degradation was lowered as grain inclusion increased (P < 0.05). Total VFA concentrations were lowest for Grass, highest for Con+C and Con+F, and intermediate for Mix+F (P < 0.05). Acetate-to-propionate ratio was lowest for Con treatments (P < 0.05). Biohydrogenation of both 18:2n-6 and 18:3n-3 fatty acids were significantly reduced (P < 0.01) with the inclusion of concentrate regardless of roughage-to-concentrate ratio. Concentrations of stearic acid (18:0), the product of complete biohydrogenation, recovered from lyophilized effluent was greatest for Grass, intermediate for Mix+F, and lowest for both Con+C and Con+F (P < 0.05). Linoleic acid (cis9,cis12-18:2) proportions in effluent were greatest for Con+C and Con+F and intermediate for Mix+F (P < 0.05). Acetate-to-propionate ratio was lowest for Con treatments (P < 0.05). Biohydrogenation of both 18:2n-6 and 18:3n-3 fatty acids were significantly reduced (P < 0.01) with the inclusion of concentrate regardless of roughage-to-concentrate ratio. Concentrations of stearic acid (18:0), the product of complete biohydrogenation, recovered from lyophilized effluent was greatest for Grass, intermediate for Mix+F, and lowest for both Con+C and Con+F (P < 0.05). Linoleic acid (cis9,cis12-18:2) proportions in effluent were greatest for Con+C and Con+F and intermediate for Mix+F (P < 0.05), and inclusion of concentrate, regardless of amount, increased the amount linoleic acid recovered from fermenter overflow (P < 0.01). Between Con+C and Con+F concentrations of alpha-linolenic acid (cis9,cis12,cis15-18:3; ALA) was greater when flax oil was supplemented (P < 0.01). Proportions of ALA in effluent was similar (P > 0.10) between Grass and Con+C; however, between Mix+F and Con+F ALA concentrations tended (P = 0.06) to be greater for Con+F. Omega-6 to omega-3 ratios (n-6:n-3) were similar across Grass, Mix+F, and Con+F (P > 0.10) and greatest for Con+C (P < 0.05). Between high concentrate treatments, when corn oil was supplemented n-6:n-3 was significantly greater (P < 0.01) than when flax was incorporated into the diet. Observations of
roughage-to-concentrate ratios effects on fermenter pH, nutrient digestibility, and nitrogen metabolism were expected and are consistent with those made in previous studies. The observed decrease in biohydrogenation activity in diets containing greater amounts of concentrate, accompanied by the impact of differing oil sources between high concentrate diets, indicate that diet type and oil supplement can be utilized to manipulate post-ruminal fatty acid profile.
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PLAINS NUTRITION COUNCIL

LEGENDS OF FEEDLOT NUTRITION

CLASS OF 2019

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Ben Holland, Past President Plains Nutrition Council, Chairman
2018-19 Plains Nutrition Council Legends of Feedlot Nutrition Selection Committee
Plains Nutrition Council Legends of Feedlot Nutrition

Purpose of award
Honor, recognize, and memorialize those who have significantly contributed to and who have had a profound and lasting impact on the feedlot industry as it relates to innovation, leadership, advancement, service, and education in the area of feedlot nutrition.

Categories
Honorees are selected from three categories for their contributions to the feedlot industry-

Consultant  Academia/Extension  Allied Industry

WELCOME THE CLASS OF 2019
Plains Nutrition Council Legends of Feedlot Nutrition Past Honorees

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<td>Danny G. Fox</td>
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PAST HONOREES

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<td>Mel Karr</td>
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<td>Donald R. Gill</td>
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<td>Terry J Klopfenstein</td>
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Stephen L. Armbruster was born in Hardtner, Kansas and grew up on a wheat and beef cattle operation near Burlington, Oklahoma where he graduated Burlington High School. He received his BS degree in Agricultural Economics in 1967 and his MS degree in Animal Science in 1969, both from Oklahoma State University. He then continued his education at the University of Nebraska where he completed his Ph.D. in Ruminant Nutrition.

Dr. Armbruster worked as an Extension Feedlot Specialist at Kansas State University, and as a Consulting Nutritionist with Scott-Pro, Inc. in Scott City, Kansas, prior to joining the Animal Science faculty at Oklahoma State University in 1975 as an Extension Beef Cattle Specialist. At OSU, he was responsible for extension programs in cow/calf and stocker cattle nutrition and management, and for research in cow/calf nutrition and management.

He formed Steve Armbruster Consulting, Inc. in 1981 to focus on consulting work in the area of feedlot cattle nutrition and management. He quickly distinguished himself as one of the premier independent consultants in the feedlot industry. At one time, Steve and the fellow consultants in his firm served clients with about 1 million cattle on feed. Steve is a visionary, and constantly sought to provide cutting-edge advice and service to his clients, and to continually grow and reposition his firm always with total transparency and the best interest of his clients as the paramount driving force.

Dr. Armbruster was a very early catalyst for the development and use of portable computer technology for making daily feedlot management decisions. He worked with in-house company programmers to transition feedlots from hand-written feed sheets to computer records. This greatly decreased the time from initial morning feed calls to when cattle were first fed. He was an early herald and teacher of the importance of cattle comfort long before animal well-being became a contemporary issue, and pioneered much of the thinking about how cattle were managed during the step-up period in order to minimize acidosis and feed aversions with the goal of maximizing intakes during finishing.

Steve is known as a consummate teacher and mentor. He taught basic animal husbandry to individuals that often had little to no livestock experience, and taught bunk readers to incorporate cattle behavior into their feed calls. He mentored many undergraduate and graduate students through job shadowing “ride alongs”, and many young company nutritionists during his service on advisory boards. In total, Dr. Armbruster has greatly impacted the present and future human resources of the feedlot industry.

Dr. Armbruster is recognized by academicians, industry leaders, feedlot employees, and his peers as a true gentleman of impeccable integrity who never missed an opportunity
to do what was best for the cattle, people and businesses he served. He always
demonstrated an extreme level of professionalism that never changed no matter the
 circumstance. Many will tell you that no one taught them more about the industry or had
 a greater influence on them as a person and professional.

Steve and his wife, Patty, reside in Stillwater, Oklahoma and will celebrate their 50th
wedding anniversary this coming June.

**Dr. Danny G. Fox**

Dr. Danny Fox is a Professor Emeritus in the Department of Animal Science at Cornell
University. He was born and reared in Northwest Ohio and received his B.S. in Animal
Science in 1962, his M.S. in 1968 and his Ph.D in Ruminant Nutrition in 1970; all from
The Ohio State University. Dr. Fox's MS and PhD work studied compensatory gain and
the composition of gain in feedlot cattle. After graduation, Danny spent time as Feedlot
Extension Specialist at South Dakota State University and at Michigan State University.
In 1977 Dr. Fox joined the research, extension, and teaching programs in beef and dairy
cattle nutrition at Cornell University.

Dr. Fox was one of the first to realize the future importance of computers in agriculture,
giving an invited presentation titled “The use of computers in research, extension, and
teaching programs” at the 1981 annual meeting of the American Society of Animal
Science. His 35-year career in ruminant nutrition research focused on leading a team
that developed data sets, mathematical models, and computer software to more
accurately predict cattle nutrient requirements and to ascertain the effects of cattle
types, environments, and feed carbohydrate and protein fractions on utilization of
nutrients in feeds. This culminated in development of the Cornell Net Carbohydrate and
Protein System (CNCPS) for evaluating and formulating rations for beef and dairy cattle.
The CNCPS is the basis for the computer models used today in the National Academies
of Sciences publications *Nutrient Requirements of Beef Cattle* and the *Nutrient
Requirements of Dairy Cattle*. During his career Danny served on multiple National
Research Council (NRC) committees, including the 1996 committee that revised the
*NRC Nutrient Requirements of Beef Cattle* and he developed the computer model that
was first used in that publication.

Dr. Fox’s team at Cornell later developed the Cornell Value Discovery Program (CVDS)
for sorting and tracking cattle according to the predicted days needed to reach a target
grade, and to allocate pen feed consumption to individual animals in the pen.
Modifications of these models are currently used by a number of beef cattle nutrition,
management, and feeding companies including Micro-Beef, Performance Cattle Co.,
Purina, Cargill, and others. It has been estimated that the CVDS system has been
used on over 10 million head of feeder cattle and has saved feedlot operators an
average of $15/head.
From the early 1990’s until he retired in 2005, Dr. Fox’s expanded his modeling program to produce the Cornell University Nutrient Management Planning System (CUNMPS) that integrated knowledge about crops, soils, animals, and manure to reduce feed costs and excretion of nutrients that impact water quality.

Dr. Fox’s research has resulted in more than 330 publications, including over 105 referred journal papers and over 150 invited presentations at conferences in the U.S., Canada, Central American, South America, Asia, and Europe. He has also led in the training of 61 graduate students and consulted with numerous commercial companies on the application of the CNCPS and CVDS models.

Because of his outstanding contributions to the cattle feeding industry, it is our pleasure to present the 2019 PNC Legends of Feedlot Nutrition to Dr. Danny Fox.

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Dr. R. Spencer Swingle

Dr. Swingle has described himself as a data-driven, pessimistic-optimist who enjoys challenging conventional practices, creatively solving problems and helping others achieve success. He’s well-known for attention to detail, and his anecdotes, stories, and analogies are quoted by those he influenced.

Born in Illinois in 1944, Spencer’s family moved to Arizona where he grew up mostly a “city kid.” His father was from a farming background and influenced Spencer’s interest in livestock. He participated in athletics and FFA at Amphitheater High School in Tucson. Spencer earned a BS in Agriculture (Animal Sciences) from the University of Arizona in 1966 and MS (1969) and PhD (1972) degrees at Washington State University (Graduate Program in Nutrition). Irwin A. Dyer, LOFN Class of 2017, was his major professor for both graduate degrees.

After completing his PhD, Dr. Swingle had the good fortune to return to the University of Arizona where he served on the Animal Sciences faculty for over 21 years. He was involved with a feedlot research program that had an earned reputation for industry relevance. One of his colleagues and an influential mentor, William H. Hale, is a Charter Member of the LOFN. Dr. Swingle’s research at Arizona emphasized the utilization of, and interrelationships between, structural and nonstructural carbohydrates in ruminant nutrition. A major interest was the effect of steam-flaking of grains on the site and extent of starch digestion, the impact on rumen environment, and the dynamics of rate of passage. Utilization of low-quality roughages, evaluation of non-conventional feedstuffs, and the performance of feedlot cattle and lactating dairy cows were other areas of study. Among his most satisfying university experiences were teaching, counseling, and mentoring undergraduate and graduate students. He is especially proud of the students who completed 13 MS and 6 PhD degrees under his direction.

Upon leaving Arizona in 1994, Dr. Swingle spent two and a half years as Technical Services Manager, with Syntex Animal Health and Roche Animal Nutrition and Health.
His responsibilities included support for cattle feed additives, sales training, design and monitoring of research studies, and troubleshooting problems in the field. The experience broadened his perspective on the cattle feeding industry and enlightened him to the opportunities for collaboration and cooperation among academia and government, the allied industries, and the production sector. He spent the remainder of his career encouraging and fostering these collaborative efforts. Dr. Swingle has been a member of the Plains Nutrition Council for over 20 years and served on the Executive Committee (2002 through 2005 - President 2004), and on the LOFN Nominating Committee.

Dr. Swingle joined Cactus Feeders in 1996 as Director of Nutrition and Research (later Vice President of Nutrition and Research) and was their first in-house consultant. Responsibilities included development and oversight of feeding programs for company feedyards and developing Cactus Research into one of the leading large-pen feedlot research facilities in the U.S. He took great pride in working for feedlot managers in training personnel and implementing strategies to improve economic performance of company and customer cattle. Dr. Swingle retired from Cactus Feeders in 2015.

Over the years he has been an avid hunter, fly fisherman, and a sports enthusiast. He coached Little League Baseball for ten years and has taken pleasure in applying lessons learned from that experience to other life situations. Spencer and Carmen (his wife of 52 years!) reside in Oro Valley, Arizona, near their two sons and three grandchildren. Although mostly retired, Dr. Swingle enjoys an occasional consulting opportunity and participation on consultant advisory boards.