Executive Summary
Ethanol Co-Products – Beef Implications Summit

Introduction
The goal of the Center for Research and Knowledge Management at the National Cattlemen’s Beef Association (NCBA) is to serve as the catalyst for positive change for the beef industry using science-based information and programs. Given the steady increase in the use of ethanol co-products in cattle diets, the Center recognized the need to investigate the current status of research and to establish a list of research questions that still need to be answered about the impact of co-products on the industry, specifically beef safety and quality. As such, the first “Ethanol Co-Products – Beef Product Implications” meeting was held in Kansas City, MO November 7-9, 2006 with researchers from around the country to develop a summary of research and to establish research priorities.

Gregg Doud,
Chief Economist, NCBA
Doud started discussion with a review of the consistency and makeup of corn and ethanol. Corn is 62% starch, 15% moisture, 10% fiber, 9% protein and 4% fat/oil. Given those characteristics, one bushel of corn will produce 2.8 gallons of ethanol and 17.5 pounds of dry distillers grain (DDG). This is important because the renewable fuels standard requirements under the Energy Policy Act of 2005 (P.L. 109-58) call for production of a minimum of 4.7 billion gallons of renewable content by 2007, 6.8 billion by 2010, and 7.5 billion by 2012. It is probable that the U.S. ethanol capacity will reach 11 billion gallons by sometime in 2008. That level of production will require 3.8 billion bushels of corn and will produce 67 billion pounds of distiller’s grain and solubles (DGS). For comparison, today, 108 ethanol plants are in operation and produce 5.162 billion gallons of ethanol; there are new plants breaking ground every month and in the next 12-18 months those plants will produce hundreds of millions of additional gallons of ethanol and millions of pounds of DGS (Figure 1).

Figure 1
Ethanol Plant Location Map
Source: Bischoff, 2006; www.ethanolrfa.org
In recent data published by Iowa State University (ISU), equilibrium for U.S. corn and ethanol markets was outlined. The study identified that the drive for acres of corn committed to ethanol production will also drive the price of corn. In 2005/2006, the U.S. planted and harvested 81.8 and 75.1 million acres of corn, respectively. To maintain enough supply for domestic and export use, corn production will have to increase to 90 million acres by 2010. The ISU study outlines that 1) change cannot occur this quickly, and 2) the industry will need $4/bushel corn for a consistent period of time to get the change to happen. Doud pointed out that 85 million acres needed in 2007 is doable with the appropriate market incentives and that at the current pace of expansion, 90 million acres could likely be necessary in 2008, though this will be very difficult to accomplish.

Though there is currently not a corn deficit in the U.S., there might be in the future if ‘normal’ weather does not occur. Conservation Reserve Program (CRP) ground should not be considered a major source in which to increase corn acreage. Much of the increase in production must come from other crop acreage such as soybeans and from improved yields (Figure 2). It is not likely that there will be a structural change in the beef industry that moves cattle feeding closer to the corn belt. However, if future expansion occurs, it is likely to be in Nebraska. There could also be an emergence of background operations for mid-Atlantic and southeast U.S. feeder cattle in places like Illinois where lower costs of gain can be obtained via DGS.

We have seen that the cost of DGS relative to corn is low. However, the question still sits at how much DGS cattle can tolerate with the given oil, fiber, sulfur and moisture in DGS as compared to rolled or steam flaked corn. In addition, we have to determine if there are environmental consequences of increasing the level of DGS with increased levels of phosphorus.

Current recommendations for feeding beef cattle DGS from ISU, the University of Nebraska, and the University of Illinois are:

- Feed dry DGS at less than 20% of the ration dry matter to supply protein requirement.
- Feed wet DGS at less than 20% of the ration dry matter to supply protein and energy requirements.
- Producers can feed up to 40% wet DGS (of the ration dry matter), but will be overfeeding protein and phosphorus.
- In beef cows and backgrounding calves, feed the appropriate quantity to supply supplemental protein, energy, and phosphorus when needed with poor quality hay, crop residues, and stockpiled forages. There are cost benefits to feeding co-products to cows as compared to feeding rolled, whole, or steam-flaked corn.

There is potential to change current feeding recommendations with slight modifications to future DGS product. For example, if product contains less oil and less protein, inclusion level could increase to 40-50% of the diet dry matter for finishing cattle. The industry should also consider corn gluten feed, which contains less oil and less protein than DGS. Questions also exist concerning feeding at higher levels (50-75% of dry matter intake).

As a result of the variability of co-product from plant-to-plant, there is also mass confusion in the industry about what is in the co-product. For example, oil content will range from 9-12.5% in dry distillers grains, 10-15% in wet DGS, and will be around 3% in corn gluten feed (CGF). Fiber content, sulfur, moisture, protein, and phosphorus will also vary from co-product to co-product. A diagram of the dry grind and wet milling processes can be found in Figure 3.

More important than, perhaps, what impact does feeding co-products have is the question, are there bad ‘cocktails’ when you combine use of implants, age, genetics, and type of co-product fed that impact tenderness, flavor, and value.

Doud ended with the following points for consideration and questions that need to be answered:

- The need to understand feed and residual need for both corn and ethanol byproducts. Today we need two billion bushels of corn to feed cattle. In the future with more ethanol-based demand for corn, how much corn and/or ethanol by-product can cattle feeders depend on?
What is the impact of feeding co-product on quality grade and other beef quality factors?

- How much co-product can be fed in the ration?
- What is the difference in optimal inclusion rate for stockers, feedlot cattle, heifers, and cows and the differences in performance by feeding those inclusion levels?
- What competition exists for corn and DGS from pork and poultry?
- What competition exists from non-livestock (ex. burning DGS for fuel, etc.) sources?
- How do we address other limitations such as logistics, inventory management, storage, and product availability?

His final point was that there is going to be plenty of DDG, DGS, WDG, etc. around, but the ultimate problem may simply be the logistics of getting it from where it is produced to where it can be utilized by the livestock sector.

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**Research Updates:**

**Product Quality**

**Galen Erickson, Ph.D., University of Nebraska-Lincoln**

Erickson first discussed the efficiency value of wet DGS as part of the diet, replacing dry rolled corn. In the discussion, Erickson concluded that as dry rolled corn is replaced with wet DGS, there is an improvement in average daily gain and feed:gain ratio when feeding up to a 40% inclusion level. The University of Nebraska has developed economic models for wet DGS, dry DGS, wet corn gluten feed, and Dakota Bran based on corn price and level of inclusion. Currently, wet DGS is priced at 95% of the current corn price and return per head increases as inclusion level increased to 30%. However, the main factor influencing return with wet DGS is distance from the plant; as producers move further from the plant, feeding wet DGS becomes less economical.

Erickson also reported a summary of nine research studies conducted at the University of Nebraska from 1990 through 2005 using corn wet DGS, dry rolled corn and/or high moisture corn diets on black crossbred calf-fed and yearling steers (n = 1,257). Inclusion rates in the studies ranged from 0 to 50 percent on a dry matter basis, with 5 to 7.5% roughage in the diet. Data indicated that there was a quadratic response (P < 0.05) with the relation between inclusion level and average daily gain, feed conversion, and 12th rib fat thickness. The same quadratic trend was identified with calculated yield grade (P = 0.06) and marbling score (P = 0.05). Marbling score increased in cattle fed wet DGS up to a 30% inclusion level and decreased when wet DGS was 50% or more of the diet. Erickson concluded that cattle fed intermediate levels of wet DGS (10-40%), in dry rolled corn and high moisture corn diets and fed to an equal days on feed, converted more efficiently, deposited external fat quicker, and had higher marbling scores compared to those fed a control diet. However, it was stated that the effect on marbling is probably not a direct effect of feeding DGS.

Erickson further reported on the impact of feeding wet corn gluten feed based on a series of seven research trials conducted between 1993 and 2005 at the University of Nebraska. Black crossbred calf-fed or yearling steers (n = 880) were fed between 0-38% sweet bran, on a dry matter basis, in a dry rolled corn and/or high moisture corn diet. Results indicated that feeding wet corn gluten feed had a linear increase (P < 0.05) on average daily gain, feed conversion, 12th rib fat thickness, and marbling score as inclusion level increased from 0 to 38% of the diet. While marbling score increased significantly, percentage USDA Choice carcasses was not statistically different between those cattle on a control diet vs. those fed sweet bran during the trials. Erickson also reported similar findings in percentage Choice carcasses when looking at data from 6,000 head of heifers fed wet corn gluten feed in a commercial feedlot.
Three other issues were brought to the table relative to feeding DGS: fat metabolism, storage, and phosphorus:

- **Fat metabolism**: Erickson reported that as you compare corn diets, corn diets with added oil (same oil content as found in DGS) and wet DGS diets, wet DGS diets have a lower acetate:propionate ratio and a lower 18:0 and higher 18:2 fatty acid content ($P < 0.05$) as compared to the corn or corn + oil diets, indicating that there is a potential shift in the fatty acid content.

- **Storage**: Storage of wet DGS is not easy. Erickson reported that double-bagging under pressure (300 PSI) and bunker storage has been evaluated for storage of wet co-products.

- **Phosphorus**: Dietary phosphorus in feedlot diets, according to the National Research Council (NRC), should be below 0.3% of the diet on a dry matter basis. The level of phosphorus in an 85% corn diet plus a supplement is already high at 0.35%, a diet containing an ethanol co-product at 0.52%, and a diet containing a co-product and supplement at 0.59%. Managing phosphorus levels in co-products and managing acres for fertilizer application will become increasingly difficult with the increasing use of co-products in the beef industry.

**Allen Trenkle, Ph.D., Iowa State University**

Trenkle presented data related to four experiments containing DGS, two experiments with CGF and one experiment with DGS fed to Holstein steers.

**DGS**: In the four experiments containing DGS, three of the studies were conducted feeding DGS to steers while the other study fed DGS to heifers. Inclusion levels in the studies were 0, 16, 20 or 28, and 40% wet DGS, which was used to replace corn and protein as compared to the control diet. All cattle weighed 690-910 lbs and were fed for 112 to 186 days on a dry, whole or rolled corn diet where the roughage source varied.

Splitting treatments into a control, medium (16, 20, or 28%) or high level of inclusion for analysis, statistical differences were observed for average daily gain and dressing percentage. However, ribeye area, fat thickness, kidney-pelvic-heart fat, and calculated yield grade were similar among all inclusion levels. Marbling score was significantly lower ($P < 0.05$) for the high inclusion level as compared to the control and medium inclusion groups (Figure 4). There were no statistical differences for carcass value in a grid market or for the marbling score to backfat ratio.

Sensory attributes were evaluated on strip loins from the steers in one of the experiments. Data outlined above for the four experiments was similar to that of the single experiment from which the strip loins were derived. In sensory evaluation, those fed DGS at the medium inclusion level were more tender than those fed at the high inclusion level ($P < 0.05$). Strip loins from cattle fed the control diet were similar in tenderness, juiciness, and flavor intensity to those from the medium and high inclusion treatment groups.

**Corn Gluten Feed (CGF)**: In the CGF experiments, wet CGF was fed at 0, 30 or 40, 50 or 65, and 90% inclusion levels, where CGF replaced corn and roughage in the diet. Steers in the experiments weighed 680-780 lbs and were fed 108 to 215 days on a dry rolled corn, corn silage or ground cob diet.

Feeding wet CGF did not impact ADG, ribeye area, fat thickness, kidney-pelvic-heart fat percentage, marbling score, percentage Choice carcasses, or calculated yield grade in beef steers (Figure 5). However, steers fed wet CGF at a low inclusion level (30-40%) increased dressing percentage as compared to the control, medium inclusion level (50-65%), or the high inclusion level (90%).

Sensory attributes were also evaluated on strip loins from one of the experiments. There were no statistical differences in the evaluation of tenderness, juiciness, flavor, or Warner-Bratzler shear (WBS). Numerically, WBS was 0.8 lbs higher in the low inclusion level as compared to the control, medium inclusion level (50-65%), or the high inclusion level (90%).

**DGS with Holsteins**: In the Holstein experiment, wet or dry DGS was fed at a 0, 10, 20, or 40% inclusion level to replace corn and protein supplement in the diet of Holstein steers. Holstein steers weighed 430 lbs at the beginning of the trial and were fed for 299 days on a dry rolled corn, corn silage, and chopped grass hay diet.
Feeding wet DGS resulted in a lower harvest weight, ADG, and hot carcass weight for the high (40%) inclusion level as compared to the other treatment groups. While the other treatment groups were not different, the trend for decreasing harvest weight, ADG, the trend of decreasing of each trait as inclusion level increased from the control group to 10% to 20% held for both wet and dry DGS. In sensory analysis, evaluation for tenderness, juiciness, flavor, and WBS were not statistically different among treatment groups.

**Summary:** Trenkle concluded feeding wet DGS at high inclusion levels seems to decrease marbling in carcasses. He continued by including that starch intake is likely not a factor, that distribution of fat deposition (marbling/fat thickness ratio) is likely not involved, that cattle fed DGS consume more dietary oils and that other management practices, such as implant program, need to be taken into consideration as conclusions about impact of DGS on marbling deposition are made. Furthermore, feeding wet DGS does not impact the net value of the carcasses nor does it impact the consumer acceptance of beef steaks.

Alfredo DiCostanzo, Ph.D.,
University of Minnesota

Prophetic Statement from the North Central Region research committee relative to dry DGS as an energy source: “if abundant supplies of wet distillers’ grains should become available-as a result, for example, of increased production of fuel alcohol-this by-product could be used as an energy source in livestock feeds” (1984).

In 2006, over 35% of corn will be used for ethanol production, up from just over 25% in 2001. The result of this use is an abundance of ethanol co-products that are being used as feedstuffs that are high in non-digestible fiber (NDF), high in fat, some high in moisture, palatable to cattle, and inexpensive. The question then becomes, based upon these parameters, what is the impact of ethanol co-products on beef quality?

DiCostanzo presented a data set of 106 treatment means from 21 research trials that included 4,752 head of cattle. Trials included the use of condensed corn distillers, corn and sorghum wet DGS, and corn and sorghum dry DGS. Results indicated that when including all co-product types in the analysis, inclusion rate had a quadratic response on yield grade, where the peak (highest numerical) yield grade occurred at 29% co-product on a dry matter basis. Fat thickness resulted in the same trend, where the cattle with the most fat at the 12th/13th rib interface were fed a diet with a 22% inclusion rate of ethanol co-product. The effect of ethanol co-products on ribeye area are dependent on end weight; when considering both inclusion rate and end weight of cattle, effects of the co-products are minimal.

Data also revealed a similar trend for marbling score, with marbling score peaking at 23% inclusion. DiCostanzo noted that marbling score decreased beyond 23% inclusion; however, he also noted that the impact on marbling, and the inclusion level at which marbling began to decrease, differed for every yield grade:

- At a given yield grade end point, effects of co-products are variable.
- At low yield grades (yield grades 1 or 2; lean cattle or lower energy diets), co-products reduce marbling at any inclusion level.
- At a yield grade 3, co-products have no effect on marbling up to 20% inclusion.
- At high yield grades (yield grades 4 or 5; extended days on feed or early maturing cattle), co-products increase marbling at low to intermediate/moderate levels of inclusion.

Determining if this effect is directly from feeding co-products or from an alternative explanation such as dietary fat (ether extract) intake, starch intake, or energy intake is difficult. Percentage of dietary fat in the diet is typically 3.75 in a corn based diet; however, it increases to 5.75 with a 30% inclusion level of co-products. Up to 5.75% dietary fat, there is no impact on marbling. At low metabolizable energy (ME) intake levels, co-product inclusion has a positive impact on marbling; at ME intakes of 30 Mcal/d, co-product inclusion is approximately 50% and is not detrimental to marbling. DiCostanzo concluded that when feeding ethanol co-products, the effect of the inherent increase in dietary fat (ether extract) may be of greater influence on marbling than that of increased ME intake.

DiCostanzo also noted that the impact on fatty acid composition in a study conducted at the University of Minnesota documented that while ethanol co-products increased the omega-6:omega-3 ratio, the ratios were at least three times that recommended by the medical community; so while the increase is seen, it is not of concern.

DiCostanzo concluded with two major research needs: 1) the impact of ether extract in the diet on marbling deposition and 2) impact of overall energy intake on marbling deposition.

Mark McCully,
Certified Angus Beef LLC

McCully shared that based on the results from the 2005 National Beef Quality Audit, purveyors, restaurateurs, and retailers ranked insufficient marbling as their leading beef quality concern and reminded participants that the lost opportunity relative to meeting the ideal quality grade consist for end users costs the beef industry $26.81 for every steer and heifer harvested in the U.S. McCully then presented data that indicated that the percentage of carcasses grading Choice has been decreasing, while at the same time, the percentage of carcasses with a yield grade 4 or 5 is increasing. As such, during this same time frame, the percentage of eligible cattle earning the Certified Angus Beef (CAB) brand has decreased to 14% in 2006. Of those eligible cattle that are rejected from CAB, 85% of them are rejected for inadequate marbling vs. 16% rejected for not meeting the yield grade requirement. Among certified carcasses, 50% of carcasses have marbling scores between Modest 0 and Modest 30 and 75% between Modest 0 and Modest 70. As such, CAB has grave concern over management factors that might impact marbling score, even to the slightest degree, for fear of decreasing the acceptance percentage below the current level of 14%.
In a white paper written by Larry Corah and McCully in 2006, the primary factors responsible for the declining quality grade in the cattle population are:

- Increasing health problems in the beef cattle industry – increase in morbidity and mortality;
- Increased use of ethanol co-products by feedlots;
- Structural and management changes in the feeding industry such as more steam flaking of grain;
- Marbling development as a lifetime event; and
- Timing, number, and potency of implant regimes.

This paper attributes secondary factors to genetics, disposition, vitamin A levels, gender, and the lack of effective sorting. While it is recognized that there is not one single factor responsible, it is also recognized that there is not one silver bullet for solving the problem and as such a combination of things will be needed to improve the percentage of Prime and Choice carcasses in the industry.

McCully challenged participants with a review of current thinking on marbling deposition in feedlot cattle. Current thinking indicates that weaning is a critical window in determining later marbling potential. Marbling is dependent upon number and size of fat cells and preadipocyte differentiation happens early in an animal’s life. As such, early management may have an impact on marbling deposition and marbling score at harvest. Examples of early management effects presented were prefinishing nutritional plane (high vs. low), implant strategy (no implant vs. delayed implant vs. early implant), age at weaning (early weaning vs. traditional weaning), and health of calves (no hospital visits vs. 1 hospital visit vs. 2 or more hospital visits).

McCully also presented reviews from Reinhardt (2006) and Owens (2006) on the impact of ethanol co-products on beef quality. Data from Reinhardt (2006) included control, low (1-15%) inclusion, medium (16-29%) inclusion, and high (over 29%) inclusion. Reinhardt concluded that marbling decreased 20 points from the control to the high inclusion group \( P < 0.05 \) and 14 points from the low to high inclusion group \( P < 0.05 \).

Data from Owens (2006) included 3 trials using condensed solubles (0-20% inclusion), 11 trials using dried grains and solubles (0-75% inclusion), and 15 trials using wet grains and solubles (0-50% inclusion). Feeding condensed distillers grains and wet DGS did not change marbling \( P > 0.05 \). Feeding dried DGS resulted in a quadratic decline \( P < 0.01 \) of marbling as the inclusion rate increased; however, data is lacking for high inclusion levels.

McCully pointed out that there are other quality considerations beyond marbling. Data is limited on sensory attributes, tenderness and color stability. However, work currently available from the University of Minnesota and the University of Nebraska indicate that there is no effect on flavor profile or tenderness when feeding up to 50% distillers grain (DG). Work from the University of Wisconsin and the University of Minnesota indicate that DG can influence color of fat in milk and color stability of beef steaks, respectively.

**Summary:** McCully summarized by indicating that there are several considerations beyond inclusion rate when determining the proper use for DG in diets. These considerations include calf-feds vs. yearlings; previous plane of nutrition; high vs. low marbling genetics; DG variability between plants; DG variability between corn varieties; proper classification of different types of DG; improvements in the distilling process and oil removal from the product; sulfur levels; copper absorption, and, perhaps, the price of corn, co-products, cattle, and carcasses.

In baseball, the rule is 3 strikes and you are out. If we work on the same philosophy in the beef industry, strikes could include stress of transport, illness, implant regime, genetics, and many others. However, it may not be this simple. This industry may have to include the severity of each strike with the strike count to determine the impact on quality.
Research Updates: Safety

Jim Drouillard, Ph.D.,
Kansas State University

Drouillard indicated that Kansas State University has been engaged in research to evaluate food safety related aspects of distiller’s grains utilization in cattle feeding. Results of this research indicate that there may be important food safety implications associated with the use of distiller’s grains, and that further studies are necessary to define the extent of these effects, as well as the conditions under which they occur.

Kenneth Bischoff, Ph.D.,
USDA-ARS-NCAUR

Following an introduction to the National Center for Agricultural Utilization Research (NCAUR), Bischoff provided an overview of the Energy Policy Act of 2005, Renewable Fuels Standard. The Standard calls for doubling the current production of renewable fuels by 2012, establishes a renewable fuels standard that starts at 4 billion gallons in 2006 and increases to 7.5 billion gallons in 2012, calls for a minimum production of 250 million gallons per year of cellulosic derived ethanol by 2013, and promotes research on alternative feedstocks and biomass to ethanol. He also presented the current and proposed locations for ethanol production (Fig. 1). Based on plants in production and proposed plants, the percent of corn harvest going to ethanol production should reach 20% by 2012, producing 7.5 billion gallons which would be 5% of the transportation fuel used in the U.S. market. There is potential for cellulosic substrates to be used in ethanol production to take some of the pressure off of the U.S. corn supply. These substrates include cottonwoods, switchgrass, wood chips, paper, cornstover, bagasse, and corn fiber. Corn fiber, as an example, would provide a more homogeneous feedstock that is already at the wet mill as compared to using corn stover as the feedstock. Although the price of such materials is cheaper than current products used for ethanol production, the challenge with cellulosic materials is the increased technical complexity of utilization.

Current research priorities at NCAUR include feedstock/energy crop development; pretreatment strategies; conversion of biomass polysaccharides to fermentable sugars-discovery of new enzymes and enzyme expression systems; new biocatalysts for ethanol production – yeast strain improvement, recombinant bacterial strains, and novel microorganisms; and bioprocess engineering.

Bischoff stated that continued research should include the composition and nutrition of cellulosic ethanol co-products and the acceptability of recombinant organisms in such products.

Breakout Group Reports

Product Quality

Research Needs

- What is the ultimate effect of increasing levels (> 30%) of ethanol co-products as part of the diet on end product quality?
- Based on the level of inclusion of ethanol co-products and the associated effects on fat, sulfur, phosphorus, nitrogen, etc, what is the effect on end product quality?
- Are there environment and health effects with feeding?
- The breakout group defines product quality to include, but not be limited to, marbling, flavor, shelf-life, color, sensory, and fatty acid composition.

Product Safety

Research Needs

- Pathogen prevalence in cattle
- Do different diets result in a higher or lower prevalence of E. coli and Salmonella?
- Are different effects of diets seen in market cows and bulls as compared to steers and heifers?
- Environmental effects
- Are there transportation and distribution issues with co-products based on their phosphorus content?
- Does there need to be a phosphorus education program to educate producers, industry professionals, etc. on regional vs. regulatory differences?
- What is the variability in sulfur content in co-products?
- Can the ethanol industry address sulfur content during the ethanol production process?
- The breakout group stressed the importance of making feeding trials last long enough to allow cattle to adjust to the diets before taking samples and drawing conclusions.

Next Steps

Next steps may include providing funding for projects to answer product quality and safety concerns. This could include individual, regionalized proposals to address short-term needs, as well as a future large-scale, collaborative project to address long-term needs.
References:


Contributors:
Gregg Doud, Chief Economist, National Cattlemen’s Beef Association

Galen Erickson, Ph.D.
University of Nebraska-Lincoln

Allen Trenkle, Ph.D.
Iowa State University

Alfredo DiCostanzo, Ph.D.
University of Minnesota

Mark McCully
Certified Angus Beef LLC

Jim Drouillard, Ph.D.
Kansas State University

Kenneth Bischoff, Ph.D.
USDA-ARS-NCAUR

Abbreviation Guide
ADG  average daily gain
CAB  Certified Angus Beef
CGF  corn gluten feed
CRP  Conservation Reserve Program
DDG  dried distillers grains
DG  distillers grains
DGS  distillers grains with solubles
ME  metabolizable energy
NCAUR  National Center for Agricultural Utilization Research
NCBA  National Cattlemen’s Beef Association
NDF  non-digestible fiber
NRC  National Research Council
WBS  Warner-Bratzler shear
WDG  wet distillers grains