







Ethanol Co-Product Research

A checkoff-funded summit titled “Ethanol Co-Products – Beef Product Implications” was held in November 2006 with researchers from around the country to develop a summary of existing research and establish future research needs. In response to these identified needs, The Beef Checkoff funded a total of six research projects to determine the impact of feeding high levels of ethanol co-products (i.e., distiller’s grains) on beef end-product quality and safety. These six projects are summarized below.



Principal Investigator	Institution	Project Title	
<i>Beef Quality Research</i>			
Chris Calkins, Ph.D.	University of Nebraska-Lincoln	Wet Distiller’s Grains – Effect on Beef Quality	
Jim Drouillard, Ph.D.	Kansas State University	Quality and Composition of Beef from Cattle Fed Distiller’s Grains is Similar to Traditional Beef	
Scott Lake, Ph.D.	Purdue University	Effects of Dietary Fat and Crude Protein on Feedlot Performance and Carcass Characteristics in Steers Fed Differing Levels of Distiller’s Dried Grains with Solubles	
Jim MacDonald, Ph.D.	Texas AgriLife Research-Amarillo	Marbling Attributes and Sensory Ratings of Beef Loins Resulting from Dietary Distiller’s Grains Inclusion in Combination with Two Corn Processing Methods	
<i>Beef Safety Research</i>			
Jim Drouillard, Ph.D.	Kansas State University	Distiller’s Grains did not Increase <i>E. coli</i> O157:H7 in Feedlot Steers	
Jim Wells, Ph.D.	USDA-ARS Meat Animal Research Center	Effects of Feeding Distiller’s Grains on Level and Prevalence of <i>Escherichia coli</i> O157:H7 in Feedlot Cattle	

PROJECT OVERVIEWS

Beef Quality

Wet Distiller's Grains - Effect on Beef Quality

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Wet distiller's grains are a by-product of ethanol production. Research indicates these grains are an excellent cattle feed. Most data show an increase in feed efficiency and average daily gain as a consequence of including wet distiller's grains in the diet. However, multiple questions have arisen concerning the impact of wet distiller's grains on beef quality.

Fatty acid content

The fatty acids in corn are predominately unsaturated. When corn is fed to cattle, bacteria in the rumen hydrogenate the fatty acids and cause a high proportion of saturated fatty acids to pass down the intestinal tract for absorption. The overall amounts of saturated and unsaturated fatty acids in beef do not change when wet distiller's grains are fed to cattle. However, there is a significant increase in the amount of polyunsaturated fatty acids (PUFAs) in the lean. Data from this study indicate a 40 to 50% increase in PUFAs.

Relationship between intramuscular fat content and marbling score

Anecdotally, some producers have speculated that changes in fatty acid content have caused a decline in marbling score in cattle fed wet distiller's grains. In three different studies, this lab has investigated the relationship between intramuscular fat content and marbling score. There is no change in this relationship, regardless of the amount of wet distiller's grains in the diet. In fact, this lab's data shows that feeding up to 50% of wet distiller's grains, on a dry matter basis, increases or maintains marbling score.

Oxidation and color

The higher level PUFAs in lean from cattle fed wet distiller's grains results in more rapid oxidation upon retail display. Resulting thiobarbituric acid reactive substance (TBAR) values are significantly elevated. As a result, color stability is compromised and shelf-life is reduced by 10 to 50% depending on the muscle studied and the length of vacuum storage.

Off-flavor ratings

When primals were stored under vacuum, no off-flavors were detected. However, upon retail display there was a significant increase in off-flavor intensity ratings and off-flavor notes in meat from cattle fed wet distiller's grains.

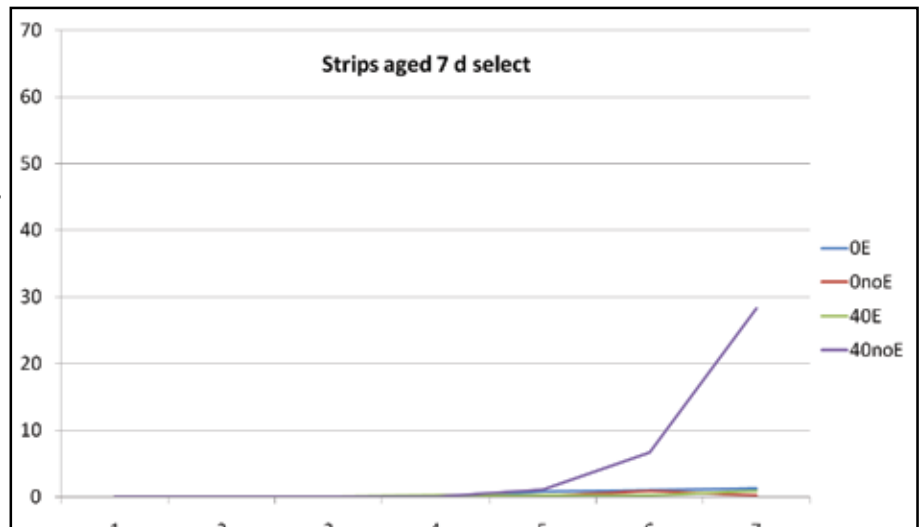


Figure 1. Discoloration of strip steaks from cattle fed 0 or 40% wet distiller's grains plus solubles in the presence or absence of 500 IU/head/day vitamin E for the duration of the finishing period

Benefits of vitamin E

Fortunately, feeding vitamin E at 500 international units (IU)/head/day for the duration of the finishing period has been shown to dramatically reduce the negative effects of feeding wet distiller's grains (Figure 1). Studies are under way to determine the amount of vitamin E necessary to obtain a beneficial effect as well as to evaluate the benefits of vitamin E under different retail packaging systems.

Conclusion

Data from this study demonstrated that feeding wet distiller's grains to cattle improves feed efficiency and is beneficial to marbling score. Negative effects on oxidation, color stability and off-flavor ratings appear to be mitigated through feeding vitamin E.

Quality and Composition of Beef from Cattle Fed Distiller's Grains is Similar to Traditional Beef

J. Drouillard, Kansas State University

The U.S. fuel ethanol industry has undergone massive expansion in recent years, resulting in an abundance of distiller's grains that can be used as a substitute for cereal grains in feedlot cattle diets. In some markets, distiller's grains are priced attractively in comparison to corn, sorghum and other feed grains, providing opportunities for feedlot operators to reduce production costs.

Starch is the primary energy component in corn and other cereal grains. When these grains are used to make ethanol, the starch is almost completely converted to ethanol, resulting in the distiller's grains that contain large amounts of protein, oil and fiber, but little or no starch. Feeding even modest amounts of these distiller's grains represents a significant departure from feeding programs traditionally used in high plains feedyards. Consequently, it is important to verify that replacement of cereal grains with distiller's

grains can be done without compromising the quality, composition and flavor characteristics of beef.

This experiment compared the quality, composition and flavor attributes of beef from cattle fed traditional diets to beef from cattle fed diets containing distiller's grains as a partial substitute for corn grain. The study measured growth efficiency, carcass value, carcass quality grade, carcass yield grade, carcass fatness, the fatty acid composition of carcass fat, the fatty acid composition of lean meat and color shelf-life of steaks during retail display and flavor profiles.

The diets used in this study consisted primarily of steam-flaked corn with alfalfa hay as the roughage source. For test diets, portions of the flaked corn were replaced with 25% dry-rolled corn, 25% distiller's grains, or 50% of a 50:50 combination of dry-rolled corn and distiller's grains. This study compared four different diets: 1) a control diet with steam-flaked corn, 2) a flaked corn diet with 25% distiller's grains, 3) a flaked corn diet with 25% dry-rolled corn, and 4) a flaked corn diet with 25% distiller's grains and 25% dry-rolled corn. The rationale for adding dry-rolled corn was based on results of previous studies that revealed improvements in carcass quality grade when dry-rolled grains were compared to flaked grains. Also, previous studies in this lab have measured increases in carcass fatness (higher yield grades) and less marbling (lower quality grades) when distiller's grains are added to the diets of finishing cattle. Researchers felt it might be possible to overcome these negative effects by adding dry-rolled corn to diets that contain distiller's grains.

In terms of animal performance, rates of gain and efficiencies were very similar for cattle fed the four diets. When 25% dry-rolled corn was added to the diet, dressing percentage increased by 0.9%. This equated to a 7-lb increase in hot carcass weight. Carcass weight and quality grade were similar for cattle fed diets with and without distiller's grains. As seen in previous studies, yield grades increased when distiller's grains were substituted for steam-flaked corn, but this effect was reversed by adding dry-rolled corn to the diet.

Feeding distiller's grains resulted in several changes in fatty acid composition of lean beef separated from the rib section. Feeding distiller's grains resulted in small but statistically significant decreases in the proportion of palmitic acid, one of the key saturated fats associated with development of heart disease. Additionally, feeding distiller's grains yielded lean with statistically greater concentrations of the trans-10, cis-12 form of conjugated linoleic acid (CLA). The addition of distiller's grains to the diets of beef cattle had little or no impact on perceptions of tenderness, juiciness, or flavor attributes of beef. Vitamin

E concentrations were lower in beef from cattle fed diets containing distiller's grains, but these decreases apparently were insufficient to cause changes in detectable oxidative flavors or in the color stability of beef during a 7-day retail display period (Figure 2).

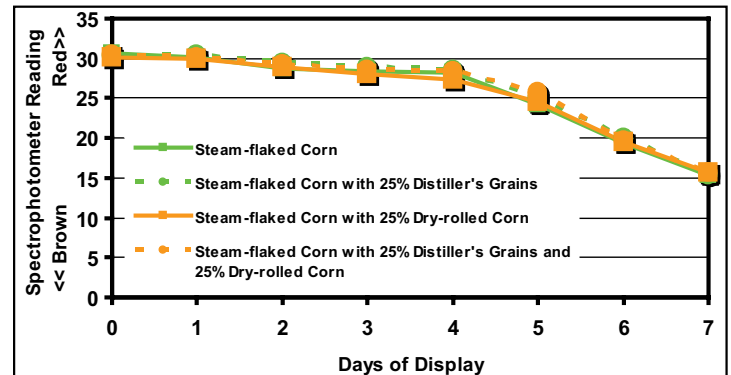


Figure 2. Color Change of Steaks During a 7-day Simulated Retail Display

Based on the conditions evaluated in this experiment, distiller's grains can be used as a substitute for corn grain and still maintain the quality, composition, and desirable flavor attributes of beef that are associated with cattle fed traditional feedlot diets.

Effects of Dietary Fat and Crude Protein on Feedlot Performance and Carcass Characteristics in Steers Fed Differing Levels of Distiller's Dried Grains with Solubles

S. L. Lake, P. Gunn, A. Weaver, D. Gerrard, M. C. Claeys, and R. P. Lemenager, Purdue University

One-hundred and five Angus-cross steers were fed one of five dietary treatments to determine the effects of feeding dried distiller's grains with solubles (DDGS) as an energy source during the last 100 days of feeding. Dietary treatments were: 1) corn-based diet with DDGS included to meet crude protein (CP) requirements (25% of dry matter (DM); 25DDGS), 2) DDGS included at twice the amount of 25DDGS (50% of DM; 50DDGS), 3) 25DDGS with added corn protein (corn gluten meal) to equal the CP in the 50DDGS diet (25DDGS+CP), 4) 25DDGS with added vegetable oil to equal the fat in the 50DDGS diet (25DDGS+vegetable oil (VO)), and 5) 25DDGS with both protein and fat added to equal the CP and fat in the 50DDGS diet (25DDGS+CPVO). Diets containing added protein and fat were used to determine if any performance differences detected with the 50% DDGS inclusion rate were due to excessive fat, protein, or a combination.

Feedlot performance and carcass characteristics

Total number of days needed for calves to reach a common backfat finish of 0.45 inches and total dry matter intake did not differ due to dietary treatment. Average daily gain (ADG) was greater and feed conversion tended to

Table 1. Effects of differing levels of crude protein and fat from distiller's dried grains with solubles on feedlot performance and carcass characteristics in finishing steers

Item	Treatment					SEM	P-value ²		
	CON	50DDGS	CON+CP	CON+VO	CON+CPVO		Treatment	CP	Fat
Feedlot									
Days on feed	95.1	95.5	96.6	98.2	91.3	11.0	0.72	0.87	0.99
Initial BW, lbs	978	978	976	974	977	44.0	0.99	0.96	0.98
Final BW, lbs	1,312 ^a	1,283 ^{ab}	1,286 ^{ab}	1,309 ^a	1,252 ^b	23.0	0.05	0.03	0.09
DMI, lbs/d	22.4	21.8	21.5	20.7	21.2	0.49	0.39	0.14	0.16
ADG, lbs	3.6 ^a	3.2 ^{bc}	3.3 ^{abc}	3.5 ^{ab}	3.1 ^c	0.13	0.04	0.01	0.03
G:F, lbs / lbs	0.160	0.146	0.152	0.159	0.145	0.01	0.11	0.04	0.08
Carcass									
Hot carcass	814 ^d	794.5 ^{de}	799 ^{de}	813 ^d	771 ^e	14	0.08	0.06	0.13
Dressing percent		62.33	62.12	62.10	61.66		0.78	0.93	0.93
Fat thickness, in	0.52	0.48	0.55	0.53	0.47		0.12	0.49	0.09
LM area, in ²		12.5	12.7	12.6	12.6		0.99	0.93	0.97
KPH, %	2.21	2.21	2.19	2.12	2.21		0.87	0.92	0.71
Yield grade	3.33	3.18	3.31	3.11	3.02		0.16	0.20	0.06
Marbling score ³			578.6 ^{ab}	576.9 ^{ab}	517.1 ^b		0.05	0.03	0.03
Quality grade ⁴					16.71 ^b		0.04	0.02	0.02
USDA Choice/Prime		85.7	90.5	85.0	66.7		0.25	0.31	0.22

¹25DDGS = 25% DDGS; 50DDGS = 50% DDGS; 25DDGS +CP = control + corn protein; 25DDGS +VO = control + vegetable oil; 25DDGS +CPVO = control + both corn protein and vegetable oil.

²Probabilities for overall treatment *F*-test and for pre-planned orthogonal contrasts between both CON vs. elevated CP diets and 25DDGS vs. elevated fat diets.

³Marbling score: 400 = Slight 0, 450 = Slight 50, 500 = Small 0, etc.

⁴Quality grade: 15 = Select⁻, 16 = Select⁺, 17 = Choice⁻, 18 = Choice⁰, 19 = Choice⁺, etc.

^{a,b}Means within a row lacking a common superscript differ ($P \leq 0.05$).

^{d,e}Means within a row lacking a common superscript tend to differ ($P \leq 0.10$).

be better for steers finished on the 25% DDGS treatment. Due to the differences in ADG and feed efficiency and the similar days on feed, final body weight and hot carcass weight were greater in the cattle fed 25% DDGS compared with cattle fed 50% DDGS. The reduction in feedlot performance associated with elevated levels of DDGS in the diet appears to be primarily due to excessive levels of dietary CP, as it is generally accepted that excessive dietary protein does not have a stimulatory effect on protein deposition, is energetically inefficient for energy utilization and requires additional energy to excrete excess nitrogen as waste. In addition, these data also suggest that diets containing elevated fat tend to reduce performance during the finishing phase. This may be due in part to a negative associative effect of fat on fiber digestion.

No differences were detected in the percentage of cattle obtaining a quality grade of USDA Choice or Prime. However, steers fed the 25DDGS diet had both greater marbling scores and quality grade scores compared with steers fed either the elevated CP or fat diets (Table 1). Steers fed 25DDGS graded exceptionally well,

averaging modest levels of marbling (score of 612.9) and 90.5% of the carcasses grading either Choice or Prime. However, contrasts show elevated CP and fat levels in the diet reduced marbling scores by 8.5% (52 points) and quality grade scores by over 0.5 units, but did not reduce the percentage of carcasses grading Choice or Prime when compared with 25DDGS fed steers. This is of particular interest because over 1/3 of all carcasses reported in the 2000 National Beef Quality Audit received a marbling score of Small with over 63% of those carcasses having a marbling score of less than Small50. Therefore, a 52 point decrease in marbling score, similar to that associated with added CP and fat diets in the current study, would have reduced the percent of carcasses grading USDA Choice or better in the 2000 National Beef Quality Audit from nearly 53% to only approximately 32%. Consequently, the negative economic impact for producers feeding finishing steers diets containing 50% DDGS could be severe based solely on carcass merit if the cattle represent the industry average for marbling and respond to elevated DDGS similarly to cattle in the current study.

Impacts of Distiller's Grains and Corn Processing Method on Fatty Acid Profile, Palatability Attribute, and Shelf-Life of Beef Loins

J. C. MacDonald, S. Smith, T. McCollum III, R. Miller, T. Lawrence, Texas AgriLife Research and West Texas A&M University

Feeding wet distiller's grains to feedlot cattle may impact shelf-life of beef, but likely has minimal impacts on beef taste and quality. Research conducted by Texas AgriLife Research investigated the effects of feeding 35% distiller's grains to steers consuming diets made up of steam-flaked or dry-rolled corn. This project was funded in part by The Beef Checkoff. The study was developed to address concerns that feedlot diets that replace corn, which is primarily starch, with wet distiller's grains, which contains essentially no starch, would negatively affect marbling and consumer acceptance of beef. Two corn processing methods were evaluated because steam-flaked corn has greater starch availability in the rumen, which presumably reduces the amount of starch entering the small intestine and may negatively affect marbling. Additionally, dry-rolling and steam-flaking are the two primary corn processing methods utilized in feedlot diets in the United States. The study utilized 54 individually fed steers (3/4 Angus, 1/4 Hereford) which were on feed for 174 days. Loins and subcutaneous fat samples were collected at harvest and transported to Texas A&M University where they were evaluated for fatty acid composition, palatability attributes, shelf-life and activity of key enzymes.

Steers consuming steam-flaked corn-based diets had increased activity of the enzyme malate dehydrogenase, which is a key enzyme in fat deposition. This difference is likely explained by the fact that steam-flaking corn increases the energetic density of corn. Greater energy intake results in more carbon units available for fat deposition which increases the activity of malate dehydrogenase. The addition of distiller's grains may have decreased the activity of Δ -9 desaturase enzyme which is responsible for desaturating fatty acids. As a result, beef from cattle fed distiller's grains was higher in saturated and lower in monounsaturated fatty acids, relative to cattle fed diets without distiller's grains.

A major objective of the study was to determine the effects of distiller's grains inclusion on marbling. The study utilized four indices to ascertain impacts on marbling including marbling scores, total fat content of the loin, ultrasound estimates of marbling collected every 56 days while the steers were on feed and Δ -9 desaturase enzyme activity. There were no differences in marbling scores due to distiller's grains inclusion. Ultrasound estimates of marbling suggest distiller's grains reduced intramuscular fat deposition late in the feeding period. The reduced Δ -9

desaturase enzyme activity from feeding distiller's grains supports the ultrasound data. However, the best indicator of intramuscular fat deposition is the total fat content of the loins, and loins resulting from steers fed distiller's grains had greater total fat content compared to loins resulting from steers consuming no distiller's grains. While these indices are unclear, the researchers found no clear evidence to suggest that distiller's grains negatively impacts marbling.

Palatability attributes evaluated by a trained taste panel resulted in subtle differences due to dietary treatment. Steaks from steers fed dry-rolled corn were juicier and more tender compared to steaks from steers fed steam-flaked corn when there were no distiller's grains in the diet. However, when distiller's grains were added to the diet, the differences in tenderness and juiciness tended to go away. Therefore, it is unlikely that consumers could detect differences in palatability attributes due to distiller's grains inclusion in the finishing diet.

A clear finding of the study was that steaks from steers fed distiller's grains were darker in color and were more susceptible to lipid oxidation after 5 days of storage. This difference is demonstrated in Figure 3. This will likely have little impact on consumers but may affect retailers because it may limit the amount of time beef resulting from cattle fed high levels of distiller's grains can be displayed in a retail case.

These results indicate that the inclusion of distiller's grains may have little impact on marbling, but may alter the fatty acid composition and length of time beef is displayed in the retail case. However, consumers should not expect feeding distiller's grains to change the eating quality of their beef.

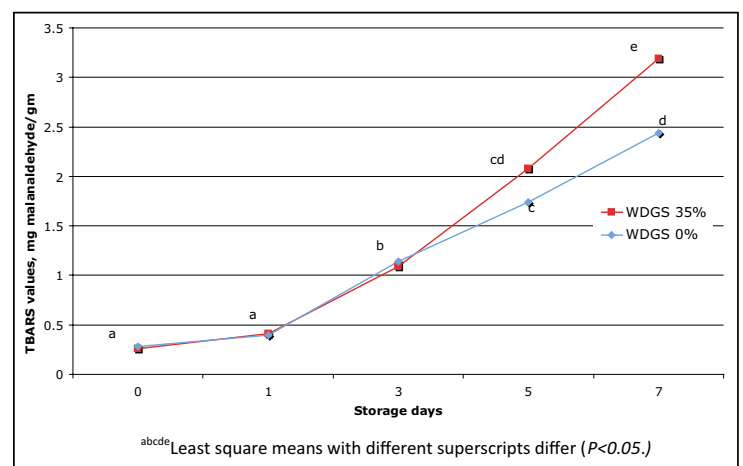


Figure 3. Lipid oxidation as measured by TBARS values of steaks stored in refrigerated aerobic storage from 0 to 7 days from cattle fed 0 or 35% of dietary wet distiller's grains plus solubles (WDGS) ($P=0.013$)

Beef Safety

Distiller's Grains did not Increase *E. coli* O157:H7 in Feedlot Steers

J. Drouillard, Kansas State University

E. coli is a normal inhabitant of the gastrointestinal tract occurring in humans and virtually all animals, including dogs, cats, cattle, pigs and poultry. However, some strains of *E. coli*, including the O157:H7 strain, are known to cause serious illnesses in humans. Consequently, the beef industry has been vigilant in its support of research efforts aimed at eliminating this organism from food.

Dozens of experiments have focused on reducing numbers of this organism in all phases of the beef supply chain, including experiments such as this which have the specific objective of determining the relationships between animal production practices and *E. coli* O157:H7 levels in food animals.

Recent expansion of the ethanol industry has created an abundance of distiller's grains, which are becoming increasingly important as a source of energy and protein for livestock production. Some research have revealed a possible link between *E. coli* O157:H7 and feeding of distiller's grains. The present study was conducted under controlled experimental conditions to determine if feeding distiller's grains to cattle somehow alters the gut environment to create conditions that are more favorable to the survival of *E. coli* O157:H7.

This study evaluated the relationship between diet and *E. coli* levels using feedlot steers that were experimentally inoculated with pathogenic strains of *E. coli* O157:H7. The research was conducted in a secure biocontainment facility, and no animal products from the experiment were permitted to enter the food chain. All animals were sacrificed at the conclusion of the experiment, and carcasses were destroyed by incineration.

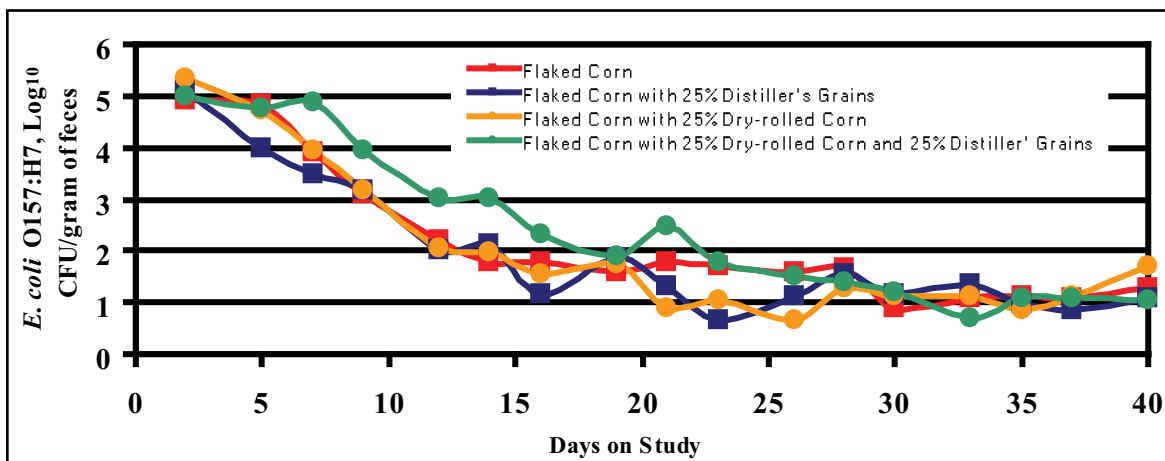


Figure 4. Concentrations of *E. coli* O157:H7 in Feces of Cattle Fed Combinations of Steam-flaked Corn, Dry-rolled Corn, and Dried Distiller's Grains

Diets consisted primarily of steam-flaked corn with alfalfa hay as the roughage source. For test diets, portions of the flaked corn were replaced with dry-rolled corn, distiller's grains, or a combination of dry-rolled corn and distiller's grains. The rationale for adding dry-rolled corn was based on results of previous studies in which *E. coli* O157 levels were decreased by feeding dry-rolled wheat or sorghum grains. The steers were adapted to their diets for several weeks, and each was then given an oral dose consisting of approximately 3 billion live *E. coli* O157:H7 organisms. Concentrations of *E. coli* O157:H7 in feces of each animal were then measured 3 times per week for 6 weeks. At the end of the 6-week period, cattle were sacrificed and concentrations of the pathogen were measured in various compartments of the gastrointestinal tract.

The results of this experiment are shown in Figure 4. Essentially, feeding distiller's grains had no impact on the fecal shedding of *E. coli* O157:H7. Likewise, adding dry-rolled corn to the diet had no impact on the numbers of *E. coli* O157:H7 organisms in feces. When the contents of the stomach and large intestine were examined, the study found that composition of the diet had no effect on numbers of *E. coli* O157:H7.

Based on the results of our experiment, we have concluded that distiller's grains can be safely fed to cattle without increasing the prevalence of *E. coli* O157:H7.

The Effects of Feeding Distiller's Grains on Level and Prevalence of *Escherichia coli* O157:H7 in Feedlot Cattle

J. Wells, S. Shackelford, T. Wheeler, M. Koohmaraie, USDA, ARS U.S. Meat Animal Research Center

Escherichia coli O157:H7 is a pathogen associated with many foods including undercooked ground beef, and in humans can cause illness and, in some cases, death. This pathogen colonizes the digestive tract of cattle, is shed in the feces and contaminates the hides. During hide removal,

some pathogens may be transferred to the carcass and post-harvest interventions have been implemented to reduce this contamination.

Beef cattle historically have been fed corn grain to improve quality and gain, but other feedstuffs such as

wet distiller's grains with solubles (WDGS) may be fed with little detriment to growth. WDGS is a co-product from grain-based ethanol production, and in recent years ethanol production has competed for corn supplies and the use of WDGS as feed has increased. Recent studies have examined the effect of feeding WDGS to cattle on *E. coli* O157:H7, but these reports differ in their results and the effect on *E. coli* O157:H7 is unclear. The objective of this study was to determine if feeding WDGS to feedlot cattle affects *E. coli* O157:H7 levels and prevalence in feces and on hides.

The study was conducted at the U. S. Meat Animal Research Center with 600 steers in a feedlot environment, and the naturally-occurring level and prevalence for *E. coli* O157:H7 on hides and in feces were monitored for 245-days through the growing and finishing phases of production. The study was initiated in October 2007 and completed in June 2008 (Table 2). In the growing phase, animals were fed diets with 0 or 14% WDGS (on a dry matter basis) and sampled three times from November to January. Animals that received 14% WDGS had higher fecal prevalence for *E. coli* O157:H7 than did cattle fed control diets, but no other measure for *E. coli* O157:H7 was significantly different.

In the finishing phase, animals were fed diets with 0 or 40% WDGS (on a dry matter basis) and sampled six times from February to the end of June. Animals that received 40% WDGS in their diet had greater prevalence of the pathogen on hides and in feces compared to control animals fed corn grain only. However, the magnitude of the differences in *E. coli* O157:H7 observed between the two finishing phase diets may have been inflated by the unexpectedly low prevalence in the pens of animals fed corn and the large variation in the pathogen across the pens of animals fed 40% WDGS. The complete results will soon be published in the Journal of Food Protection. Additional studies with feedlot animals in the summer months are needed to determine if high levels of WDGS in the finishing diet affect pathogen load in the summer when *E. coli* O157:H7 prevalence is highest.

Table 2. Distribution of *E. coli* O157:H7 for all animals in the 245-day experiment

Month of Sampling	Sample Day	Sample Type	
		Hide (% positive)	Fecal (% positive)
October	0	54.7	6.0
November	28	71.0	28.4
December	49	36.5	5.8
January	77	44.5	5.3
February	105	0.2	0.3
March	133	18.4	6.5
April	151	31.3	4.2
May	189	17.9	3.8
June	217	24.3	10.2
June	245	26.7	22.7

For more information contact:

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