THE EFFECTS OF GRAIN PROCESSING METHOD, WET AND DRY DISTILLER'S GRAINS WITH SOLUBLES AND ROUGHAGE LEVEL ON PERFORMANCE AND CARCASS CHARACTERISTICS OF FINISHING CATTLE

by

MATTHEW LEONARD MAY

B.S., Kansas State University, 2005

A THESIS

Submitted in partial fulfillment of the

Requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2008

Approved by:

Major Professor
J. S. Drouillard

ABSTRACT

A series of five trials were conducted to evaluate grain processing, distiller’s grains inclusion in finishing diets, interactions between distiller’s grains and dry-rolled corn (DRC) or steam-flaked corn (SFC), efficacy of removing roughage in the presence of distiller’s grains and the digestibility of distiller’s grains in steam-flaked and dry-rolled corn diets. The first trial was designed to determine the optimum flake density of SFC in beef finishing diets. Diets consisted of corn flaked to densities of 360, 411, or 462 g/L. Observed improvements in mill production would support increasing flake density; however numerical decreases in animal performance offset economic benefits of increased productivity. The second trial was conducted to evaluate optimum levels of sorghum wet distiller’s grains in finishing diets. Crossbred yearling steers were fed diets containing DRC or SFC and levels of distiller’s grains were 0, 10, 20, or 30% of diet dry matter. Distiller’s grains can effectively replaced a portion of the corn in finishing diets, but their nutritional value was greater in DRC diets than in SFC diets. In trial 3, crossbred heifers were fed diets containing SFC with 0% DDG and 15% corn silage (CS), 25% DDG and 15% CS, or 25% DDG and 5% CS. In trial 4, crossbreed heifers were fed diets similar containing DRC or SFC with 0% DDG and 15% CS, 25% DDG and 15% CS, or 25% DDG and 5% CS. Results indicate that roughage levels can be reduced in feedlot diets containing DDG with no adverse effects on performance or carcass quality. The fifth trial was a metabolism study conducted to evaluate the digestibility of DDG in beef cattle. Treatments consisted of DRC with 0% DDG, DRC with 25% DDG, SFC with 0% DDG, and SFC with 25% DDG. There were no significant grain processing by distiller’s grain interactions observed in main effects. In conclusion optimum flake density was 360 g/L, feeding distiller’s grains has a greater value in DRC diets vs. SFC diets, roughage level and type are important in formulating finishing diets, roughage can be reduced when feeding distiller’s grains, and ruminal ammonia, and pH are decreased and ruminal lactate is increased when feeding DDG and SFC.

TABLE OF CONTENTS

LIST OF FIGURES

Chapter I: A Review of Literature

Chapter III: Optimizing Use of Sorghum Wet Distiller's Grains with Solubles in Beef Finishing Diets

Chapter V: Effect of Dry-Rolled or Steam-Flaked Corn Finishing Diets with or without Distiller's Dried Grains on Ruminal Fermentation and Apparent Total Tract Digestion

LIST OF TABLES

Chapter I: A Review of Literature

Chapter II: Determining Optimum Flake Density in Feedlot Heifers

Chapter III: Optimizing Use of Sorghum Wet Distiller's Grains with Solubles in Beef Finishing Diets

Chapter IV: Dry Distiller's Grains with Solubles with Reduced Roughage Levels in Beef Finishing Diets

Chapter V: Effect of Dry-Rolled or Steam-Flaked Corn Finishing Diets with or without Distiller’s Dried Grains on Ruminal Fermentation and Apparent Total Tract Digestion

ACKNOWLEDGEMENTS

First, I would like to thank my major professor Dr. Jim Drouillard for the opportunity to allow me to complete a master's degree here at Kansas State University. During my time here at Kansas State both as an undergraduate student and a graduate student he has been an advisor, mentor, and friend. His passion and excitement for the industry is something that is contagious, and something I will always remember. I would also like to thank my graduate committee members Dr. Chris Reinhardt and Dr. Ted Schroeder. Their role in my graduate program has made my experiences at Kansas State valuable and I look forward to future interaction with them.

I would also like to thank all of those graduate students and staff who have been an important aspect of my research. They have not only assisted me in my program but have also been teachers and friends who have enhanced my education at Kansas State. I would like to express my appreciation to Matt Quinn, Brandon Depenbusch, Garrett Parsons, Kevin Miller, Callie Walker, Solange Uwituze, Justin Wallace, Marissa Hands, and lab technicians Cheryl Armendariz and Dave Tremble.

Lastly, I wish to thank my family and friends for their encouragement, love, and support during my years at Kansas State. In particular I would like to thank my father, Jim May for his words of encouragement and instilling my love for agriculture and the feedlot industry. I would also like to thank my girlfriend Jennifer Drawbridge, for all of her love and support and assistance in editing my thesis. I would also like to thank Dr. Phillip Phar for his role in my attendance at Kansas State and for encouraging my interest in ruminant nutrition.

1. Chapter I: A REVIEW OF LITERATURE

INTRODUCTION

In most northern states where cattle are fed, grains typically are dry-rolled, ensiled, or left whole. Dry-rolling grain is an effective way to improve efficiencies over whole grain without adding substantial cost. In many of these areas, feedlots take advantage of harvesting grain at higher moisture for ensiling. Ensiled grains provide for improved performance characteristics compared to dry-rolled corn, and also provide more flexibility in harvesting corn. Steam flaking allows for grain to condition in a steam chest for 30 to 45 minutes, during when grain is heated and allowed to absorb water. The starch granules within the grain swell and the starch matrix is disrupted when pressed through rolls, thereby increasing starch availability. Animal efficiency and gains are improved over less extensive processing methods such as dry-rolling, high-moisture ensiling, or whole corn. The cost to produce flaked grain has increased as electrical energy and natural gas costs have increased. Natural gas or propane is used to fire boilers to generate steam. Increasing flake density may be a viable option to increase mill throughput, therefore decreasing energy costs per unit of production.

In recent years, the ethanol industry has grown extensively throughout the Midwest. With the growth of this industry demand for corn has increased, resulting in higher corn prices. Distiller’s grains, a by-product of ethanol production, have become an important ingredient in livestock diets. Many of the nutrients in the by-product are concentrated including: protein, phosphorus, fiber, and fat. Most research that has been conducted with distiller’s grains has pertained to less extensive processing methods, i.e. dry-rolled corn and high-moisture corn. Testing for efficacy in diets containing steam-flaked corn is needed, as most feedlots with flaking infrastructure cannot afford to abandon that investment. Additionally, with decreases in corn availability and increases in cost, finding optimum levels of distiller’s grains in diets comprised of steam-flaked grain is vital to the feedlot industry.

Roughage contributes little to the nutrition of feedlot animals due to its relatively low digestibility. However it is an important ingredient within the diet as a result of its ability to help control digestive disorders and minimize liver abscesses in cattle fed diets of high grain concentration. Distiller’s grains typically are more digestible than common fiber sources such as alfalfa hay, and corn silage. Distiller’s grains have smaller particle size than typical roughages used in finishing diets and therefore may be less effective for preventing digestive disorders. Eliminating a portion of the fiber in finishing diets would, however, be advantageous in finishing cattle diets with less roughage and manure handling.

Grain Processing and Effects on Cattle Performance

With more extensive processing, such as dry-rolling, high moisture grain, and steam-flaking, more starch is made available to the animal. With an increase in starch availability to feedlot animals, this will improve the efficiency of beef cattle production (Theurer, 1986). In a survey of 6 consulting nutritionists, the author noted that the most common grain processing method used in feedlots was steam-flaking grain (Galyean 1996). In feedlot diets, the primary role of processing grain is to increase energy in the diet (Owens et al., 1997). Macken et al. (2006a) evaluated the efficacy of purchasing equipment for dry-rolled corn (DRC), high-moisture corn (HMC), or steam-flaked corn (SFC), based on costs for a 5,000 head feed yard vs. a 20,000 head feed yard. Estimated cost of production in dollars per metric ton for DRC, HMC and SFC for the 5,000 head yard were 1.58, 4.71, and 9.57 and the 20,000 head yard were 0.81, 3.07, and 6.23 respectively. The authors noted that even with high SFC production costs, a 5,000 head yard could justify flaking grain vs. dry-rolling. Feedlots with a capacity of 20,000 head would make a good decision purchasing a flaker mill with improvements in cattle performance. High moisture corn compared to DRC in either yard size is potentially economically viable, but is directly dependant on corn moisture, and corn purchase price. Feeding SFC to finishing cattle was shown to improve the efficiency 16% compared to DRC (Zinn et al., 1998). With improvements in feed efficiency feedlots are able to get more performance out of their grain purchase. In times of high grain prices more extensively processing adds more value to grain.

Theurer (1986) reviewed literature pertaining to steam flaking and concluded that flaking grain increases starch degradation within the rumen 9 to 18% compared to ground or cracked corn. As grain is further processed, the proportion of starch that escapes ruminal degradation is highly digestible in the small intestine and hind gut. Total tract digestion of grain is improved with flaking about 99% vs. rolling (94%) or fine grinding (94%). Owens et al. (1986) observed that as corn is processed more extensively, the proportion of starch digested within the rumen increases. Ruminal degradation of SFC was 82.8% compared to DRC 71.8% and 86.0% for HMC. Small intestinal digestion was 15.6, 16.1, and 5.5% for SFC, DRC and HMC respectively. Large intestinal digestibilities were 1.3, 4.9, and 1.0% for SFC, DRC and HMC, respectively. Total tract starch digestion as a percent of starch within the diet was improved as corn was processed to a greater degree. Total tract digestion percentages were 97.8, 93.2, and 94.6% for SFC, DRC and HMC, respectively. With greater degrees of processing more digestion occurs via fermentation within the rumen, decreasing the amount of starch that reaches the small intestine thus improving feed efficiency in beef. Ørskov et al. (1970) observed that low extent of ruminal digestion decreased microbial growth, thus decreasing the amount of microbial protein available to the animal. Starch digestion that occurs in the large intestine will increase fecal nitrogen loss and decrease apparent protein digestibility.

Zinn et al. (1995) compared DRC vs. SFC at two feed intake levels. Ruminal OM, starch, and N digestion, and total tract OM, starch, N digestion, NEm and NEg were improved with SFC vs. DRC. Microbial efficiency (g/kg OM fermented) and fecal excretion were greater for DRC vs. SFC. Cooper et al. (2002a) compared digestibility and crude protein flow using DRC, HMC, and SFC. Ruminal OM digestion was higher for steers fed HMC compared to DRC, but SFC was not different from the other treatments. Post ruminal starch digestion was greatest for steers fed SFC. Total tract OM and starch digestion were lowest for cattle fed DRC and there were no differences between cattle fed HMC or SFC. Likewise, Huntington (1997) noted total tract OM and starch digestion were greatest for SFC, followed by HMC, than DRC. Zinn and Owens (1983) fed a diet containing DRC at 1.2, 1.5, 1.8, and 2.1% of body weight to evaluate ruminal bypass and site and extent of digestion. As intake level increased, they observed linear increases in flow of N, non ammonia N, microbial N, and feed N to the small intestine. Passage rate was increased with increasing intake percentages. A linear decrease was observed in ruminal degradation as intake level was increased. Microbial efficiency was maximized at the 1.8% feed intake level. Ruminal degradation of OM and ADF decreased linearly as intake level increased. Starch digestion had an opposite trend; more starch was degraded within the rumen as intake increased. The authors noted this was likely due to difference in the amount of fermentable material present as intake levels were increased.

Galyean et al. (1976) compared DRC, SFC, ground high-moisture corn treated with propionic acid and ensiled (PHM), and ground high-moisture corn (GHM). *In vitro* gas production was greatest for SFC and PHM, with lower values for DRC and GHM. Total VFA production was greatest for GHM, followed by SFC, DRC and PHM. Hale (1973) reviewed the effects of processing methods on cattle performance and *in vitro* fermentation of grain. As grain is further processed (i.e., flaked vs. rolled) utilization of non-protein OM, protein, and starch was improved. Corona et al. (2005) compared the effects of whole, ground, DRC, and SFC on digestion and cattle performance. Flaking corn improved gain and efficiency, but decreased DMI. Fecal starch was increased in cattle fed whole corn vs. those fed DRC and ground corn. Fecal starch was lower for SFC than any of the other less extensively processed grains. Total tract digestion of DM, OM, starch, and nitrogen were greatest for cattle fed SFC. Dry-rolling and grinding corn yielded similar values, and whole corn was the least digestible. Similarly, ruminal pH was lowest in flaked diets, while rolled and ground corn produced similar pH. The highest ruminal pH was observed in cattle fed whole corn. Flaking also increased the amount of propionate and decreased acetate and butyrate; thus decreasing AP ratio. Total ruminal volatile fatty acid production was the lowest in cattle fed whole corn, and ground corn produced more total VFA than DRC. Flaking also improved DE versus other processing methods, while whole corn was the least digestible of all grain processing methods.

Owens et al. (1997) compared grain type and processing method on cattle performance. As more extensive processing occurs, cattle consume less feed daily. Flaking grain compared to DRC decreases DMI approximately 12%. Average daily gain was similar for DRC vs. SFC, but lower in HMC cattle. Feed efficiency was improved by 12% for cattle fed SFC compared to DRC and HMC. Feed efficiencies were similar for cattle fed DRC and HMC. Zinn (1990b) evaluated steam conditioning times and effects on digestion vs. DRC. Ruminal digestion of DRC was about 15% lower than SFC. Dry-rolling corn compared to SFC increased starch supply to the small intestine by about 15%. Protein efficiency was improved by approximately 16% when flaking grain compared to DRC. Fecal starch excretion was increased by about 9% in cattle fed DRC compared to SFC. Total tract digestion of starch was improved about 9% in cattle fed

SFC vs. DRC. Organic matter digestion was improved about 5% when flaking corn compared to rolling grain.

Huck et al. (1998) studied associative effects of flaked grain sorghum when combined with SFC, HMC or DRC on cattle performance and carcass characteristics. Steam-flaked corn was mixed with steam-flaked sorghum at 0, 25, 50, and 75%. There were linear decreases in final weight, feed efficiency, and HCW as flaked sorghum replaced SFC. The authors noted an associative effect on ADG with an improvement of 6% when sorghum replaced 25% of SFC. Dry-rolled corn and HMC, when used to replace 33% of steam-flaked sorghum, improved final weight, ADG, feed efficiency, and HCW over the steam-flaked sorghum treatment.

Cooper et al. (2002b) evaluated three corn processing methods with four different DIP levels. Dry-rolled corn, HMC and SFC were the basal grain sources; DIP levels were: 0, 0.5, 1.0, 1.5, and 2.0% (DM basis). Cattle performance for DRC yielded similar estimates in DIP requirements as predicted by the NRC model (NRC, 1996). High-moisture corn evaluated in this study suggested the DIP requirement for cattle fed 90% concentrate was 10.1% DIP, which was lower than NRC predictions. Steam-flaked corn was variable among treatments but 7.1% DIP appeared to be adequate. The authors noted that as corn is more extensively processed DIP requirements are increased due to increase in microbial growth. NRC (1996) dietary DIP requirements for 90% concentrate diets of DRC, SFC and HMC are 6.8, 7.1, and 7.1% respectively. Macken et al. (2006b) compared DRC, fine ground corn (FGC), HMC, ground high-moisture corn (GHM), and SFC with 25% wet corn gluten feed in finishing diets. Average daily gain was similar among treatments. Feed efficiency was improved with cattle fed SFC and HMC. Cattle fed DRC deposited the least amount of external fat; this also corresponded to the lowest yield grade. As the degree of grain processing increased cattle fecal excretions of starch decreased.

Steam-Flaking Grain and Effects on Cattle Performance and Digestion

Steam flaking is the process of allowing grain to steam in a steam chest for 30-45 minutes; usually at a temperature of 95-100° C. The grain is then fed through two corrugated rolls, rotating at the same speed, and setting gap between rolls to obtain desired flake density. Retention time, roll gap, final temperature, and steam pressure entering steam chest all determine the starch gelatinization of the flaked grain. A diagram of steam-flake mill equipment is illustrated in figure 3 (Zinn, et al., 2002).

Hale et al. (1966) compared sorghum and barley dry-rolled and steam-flaked. In both instances, the author noted the importance of steaming time and moisture content for flake quality and animal performance. Feed conversion was improved approximately 6% when flaking compared to rolling milo. Daily gain was also improved when flaked grain was compared to rolled grain, but there were no effects on DMI. Barley as the grain source was had increases in ADG when cattle were fed flaked barley compared to rolled barley. There were similar values for feed conversion between rolled and flaked barley fed cattle. Zinn et al. (2002) stated five factors affect flake quality including: steam chest temperature, steam condition time, rolls corrugation, roll gap, and roll tension. Sindt et al. (2006) evaluated two flake densities 360, and 310 g/L; with three tempering moistures (0, 6, and 12%). Cattle performance was not improved with greater moisture content. Adding moisture and decreasing flake density did not improve total tract digestion of OM, starch, or N. Zinn et al. (1998) evaluated DRC vs. tempered rolled corn at various surfactant concentrations and made the comparison to SFC. When tempering corn prior to rolling, ADG and feed efficiency were improved. Increases in DMI, HCW and final weight were observed when flaking corn vs. rolling. Cattle fed corn tempered prior to rolling did not convert as efficiently as cattle fed SFC. Zinn (1990b) evaluated conditioning time within steam chest and effects on cattle performance. Grain was retained within steam chest for 34, 47 or 67 minutes. Starch leaving the abomasum was greatest for cattle fed SFC conditioned 47 minutes. As tempering time increased, fecal starch and starch leaving the small intestine decreased. Organic matter leaving the small intestine increased as time in the steam chest increased. Total tract digestion of diet was not affected by steaming time. Digestible energy was greatest for cattle fed SFC tempered for 34 minutes. Sindt et al. (2006) compared heifer performance with two moisture contents of SFC. Flaked grain moistures contents were 18 or 36% respectively. Heifers fed 36% moisture flakes consumed less feed, and gained weight at a slower rate than their counterparts fed flaked grain at 18% moisture, with no effect on feed efficiency. Carcass characteristics of heifers were not affected by increasing moisture content. Increasing moisture decreased the amount of particles less than 1,180 µm within the diet; however this had no positive effect on heifer performance.

Johnson et al. (1968) evaluated SFC, DRC, flaked then cracked corn and steam-cracked corn. Flaked-cracked corn was flaked and then re-run through mill with no added steam. Steam-cracked corn was steamed, dried and then cracked. Passage rate was increased with flaking grain versus rolled. Birefringence was used to measure light passing through corn samples. The loss of birefringence was increased for corn that was flaked compared to corn that was rolled. The authors noted that corn that was steamed dried and then rolled had no difference in birefringence loss between cracked corn.

Zinn et al. (2002) describes retrogradation as the re-association of dispersed starch molecules. As grain is processed and allowed to cool, starch hardens, this occurs because porosity of the internal starch availability. Sindt et al. (2006) measured available starch within whole flakes on the day of processing and the day following. Twenty-five g of whole flakes were placed in 100 mL of 2.5% (wt/vol) amyloglucosidase enzyme solution for 15 m and reading soluble percentage on refractometer, available starch percentage decreased from 56.4 to 54.7. This decrease, although small, is likely due to retrogradation.

Optimizing Flake Density in Feedlot Cattle

Flake density (FD) will impact availability of starch as well as digestion. As grain is more extensively processed, decreasing density, more starch is made available to the animal. Sindt et al. (2006) compared corn flaked to 360 and 310 g/L. Available starch percentage was increased when flaking to 310 g/L. The increase in available starch did not improve cattle performance or carcass quality. Zinn, (1990b) evaluated three flake densities 300, 360, and 420 g/L and effects on site and extent of digestion. A linear increase in total tract digestion of OM, starch, and DE Mcal/kg as flake density was decreased. Fecal starch concentration increased as FD increased. Swingle et al. (1999) evaluated four flake densities of sorghum grain and effects on cattle performance fed throughout feeding period. Flake densities were 412, 360, 309, and 257 g/L respectively. The authors observed linear reductions in final weight, DMI, ADG, and HCW as FD was decreased. A quadratic response was observed in HCW, feed conversion, NEm, and NEg. The quadratic response was driven my the 360 g/L treatment improving cattle performance and decreasing processing costs compared to lighter flake densities.

Plascencia and Zinn, (1996) evaluated corn flaked to 390, 320, and 260 g/L vs. DRC in lactating dairy cows. Cows fed steam flaked grain had reductions in acetate and methane production vs. DRC counterparts. However, ruminal propionate production was increased in cattle fed SFC. As flake density increased a linear reduction in acetate, butyrate, and methane production was observed in lactating cows. A linear increase in propionate production was observed in cows as FD was decreased. Milk fat and milk protein were decreased as the flake density decreased.

Theurer et al. (1999) evaluated sorghum flaked to 257, 333, and 386 g/L respectively. As FD increased, cattle consumed less feed daily, but there were no differences in cattle ADG or feed efficiency. Plascencia et al. (1996) evaluated corn flaked at 260, 320, and 390 g/L respectivley. Ruminal acetate and butyrate decreased as FD was decreased; but propionate production increased as FD was decreased. Increased propionate production decreased methane production. Reinhardt et al. (1997) steam-flaked sorghum at 283, 322, and 361 g/L, and evaluated flake densities effects on cattle performance, mill production, and subacute acidosis. As FD was ADG, DMI, and dressing percent increased. The authors also noted that feed efficiency and marbling score had a linear tendency to improve as FD increased. As FD was increased mill production rate was improved. Ruminal pH was lower in animals fed flakes that were more extensively processed. Xiong et al. (1991), flaked sorghum at 437, 360 and 283 g/L and evaluated effects on cattle performance in feedlot steers. Average daily gain was not affected by FD. Dry matter intake and feed conversion decreased as grain was processed to lighter flake weights. Animals grading Choice and USDA yield grade decreased as FD decreased. Brown et al. (2000) compared DRC to SFC flaked at 360 or 260 g/L respectively. Total electrical and natural gas costs for DRC, 360 g/L and 260 g/L flakes were 0.46, 4.88, and 6.19 $/metric ton of DM. DMI of cattle decreased as grain was further processed. Cattle fed 360 g/L improved ADG, feed efficiency, and HCW vs. other processing methods.

Use of High-moisture Corn in Feedlot Diets

Mader and Erickson, 2006 describes the process of high moisture corn. Optimum corn moisture for ensiling would be between 28-33%. Ensiling grain at higher moisture content allow producers to harvest corn earlier. If the corn is not properly ensiled spoilage can be problematic. Ensiled HMC is commonly stored in upright storage facilities, anaerobic bags, and covered pits. Grain used for HMC is commonly ensiled whole, ground, or rolled. The fermentation process requires approximately 21 days.

Goodrich et al. (1975) compared high-moisture corn ensiled as whole grain or rolled fed to finishing cattle. Corn moisture at ensiling was also compared at harvest or reconstituting dry grain with water; moisture was added to dry grain at 21.5, 27.5, and 33.1% respectively. Cattle fed rolled HMC had a lower ruminal pH and ethanol production than cattle fed whole HMC. Ruminal acetate, butyrate, and lactate were lower for cattle fed whole grain vs. rolled in ensiled samples. Catle fed corn ensiled at harvest vs. corn reconstituted decreased ruminal pH, increased butyrate and lactate concentrations. As moisture content of grain fed to cattle was increased, ruminal pH decreased. Additionally cattle fed HMC at high moisture content increased ruminal production acetate, butyrate, lactate and ethanol. Mader et al. (1991) evaluated whole dry corn in comparison with high-moisture whole, ground, or rolled in finishing diets. Ensiling methods were evaluated, as well as time of grain processing. Grain processing was done either at ensiling or prior to feeding. Cattle fed dry or high-moisture whole corn increased ADG and DMI compared to ground HMC, rolled HMC, and a mixture of whole and ground HMC. Feed conversion was least efficient when grinding HMC; rolled HMC was more efficient than ground HMC. Cattle consuming ground HMC also yielded lower quality grade than rolled HMC. The cattle fed the mixture of whole and rolled HMC yielded the lowest quality grade among treatments evaluated.

Braman et al. (1973) evaluated HMC in finishing diets containing four CP levels. Crude protein levels were approximately 11, 13, 15, or 17% respectively. Percentage was met using soybean meal or urea. Cattle fed urea had lower ADG compared to those fed soybean meal, but efficiency was similar among treatments. Cattle fed soybean meal had fewer days on feed but similar HCW to cattle fed urea.

Stock et al. (1991) evaluated HMC compared to DRC and mixtures of whole high-moisture corn and ground sorghum in finishing diets. Comparisons were also made regarding the manner in which HMC was ensiled, either in silo bag or bunker, no differences in cattle performance were attributed to the method of ensiling. Stock et al. (1987a) evaluated HMC with several combinations of DRC or dry whole corn in finishing diets. Adding dry whole corn or DRC to HMC up to 67% improved feed efficiency and ADG of cattle. The authors noted that feeding grain ingredients that are rapidly fermented within the rumen with those that are fermented at a slower rate may improve total tract starch digestion. Stock et al. (1987b) evaluated the use of HMC with combinations of DRC and dry-rolled grain sorghum. Cattle had positive associative effects when HMC was fed in combination with dry-rolled sorghum and DRC. These associative effects were evident in feed efficiency of cattle, with no depression in ADG. Archibeque et al. (2006) evaluated the comparison of DRC and HMC in beef finishing diets. There observations yielded no significant differences in the animal's responses to DMI, G:F, or ADG respectively. The authors noted although no significant differences were observed, modest reductions in DMI, feed conversion and daily gain were observed when cattle were fed HMC compared to DRC. Reductions in fecal starch for cattle fed HMC compared to DRC were observed. The authors noted reducing fecal starch in fresh manure in cattle fed HMC reduced VFA concentration in the manure and reduced odorous compounds within the manure compared to cattle fed DRC.

Ethanol Production

Ethanol production has been around for the better part of 100 years. Early automakers like Henry Ford made it possible to use gasoline or ethanol. This was made possible with an adjustment of the cars carburetor. Henry Ford in the 1920's predicted that ethanol production from corn and other plant sources was going to be the future of the fuel industry. During that time, there was an abundance of oil and gasoline production, which was cheaper to produce than ethanol (Kovarick 1998). In the 1970's there was an increase in oil price due to the Middle East disrupting domestic supply. There was also a federal mandate to remove lead from gas during this time period. At that time ethanol plants were not efficient enough in converting corn to ethanol cost effectively. The high energy costs involved with ethanol production ended this short boom in the industry.

In recent years, ethanol production has increased because of many factors. The first being the Unites States dependence on foreign oil; 62% of oil consumed in this country is imported. The U.S. has little control over oil price, and producing ethanol domestically from a renewable source has the potential to lessen our oil dependence. Technological advancements in ethanol production have made the process more efficient. The clean air act of 1990 mandated the use of oxygenated fuels such as ethanol. Using ethanol boosts the octane of gasoline alone and it burns cleaner in combustion engines (Dipardo 2000). The amount of energy needed to produce ethanol today is 50% less than what was required in the late 1970's (Bothast and Schilcher 2005). The Renewable Fuels Association (2007) listed the ethanol plants in current production and those under construction; current ethanol production is 5,912.4 million gallons per year (mgy). Ethanol plants under construction or expansion would add another 6,604.9 mgy, this would be a total U.S. production of 12,517.3 mgy of ethanol. The United States is the number one producer of ethanol worldwide, and ethanol production in the U.S. has increased every year since 1980. (U.S. ethanol production by year is shown in figure 1; ethanol production per country is found in table 1).

Approximately 33% of ethanol production comes by way of the wet milling process. Ethanol production via wet milling is more expensive because more equipment is needed compared to dry milling. Wet milling also requires more energy for the production of ethanol compared to dry milling. The wet milling process first allows corn or blends of grains to steep. After the corn is steeped the grain is separated into starch, fiber, gluten, and germ. The germ is removed from the kernel. The corn germ is then pressed and corn oil is extracted. The remaining germ meal is combined with fiber and the hull to form corn gluten meal. A starch solution is then extracted from the solids and fermentable sugars are produced. These sugars are fermented to form alcohol. The water and alcohol are distilled to remove excess water. Approximately 2.5 gallons of ethanol can be produced from one bushel of corn via the wet milling process. The wet milling production process is further is outlined in figure 2. In either process, the ethanol is added to a gasoline mixture to make the alcohol undrinkable and for use only as a combustible energy source. Because of this, addition of gasoline to the ethanol process does not incur any state or federal alcohol tax (Bothast and Schilcher 2005).

Dry milling is much different than the wet milling process. Today, dry milling is responsible for 67% of ethanol produced in the United Sates. Corn is first ground using a hammer mill and then placed in a jet cooker and cooked. After cooking, enzymes and liquid are added to the product and starch is converted to sugar. Yeast is added to the cooked mash and fermented, expelling CO_2 (48-72 h). After fermentation ethanol and solids are found in the mixture. The mixture is then distilled, separating alcohol from the solid portion of the mash. In both wet milling and dry milling, ethanol that is distilled produces an alcohol that is 95% pure. This liquid is then dehydrated to remove the remaining 5% of water. Dry milling distillation produces a by-product known as distiller's grains (DG). The distiller's grains can be sold as a wet product, i.e. wet distiller's grains (WDG) or dried and sold as dry distiller's grains (DDG). Approximately 2.8 gallons of ethanol can be produced from one bushel of corn via the dry milling process. Ethanol production by dry milling process is outlined in figure 3 (Bothast and Shaver 2005).

Use of Ethanol By-Products in Beef Diets

Variability in ethanol by-products is a concern in formulating beef diets that include distiller's grains wet or dry. Spiehs et al. (2002) evaluated dry distiller's grains with solubles in 10 total plants in MN and SD. Plants were less than 5 year old, and sampled every two months between 1997 and 1999. Means and coefficient of variation were calculated on DM, CP, crude fat, crude fiber, ash, ADF, NDF, Ca, and P; values were: 88.9 and 1.7, 30.2 and 6.4, 10.9 and 7.8, 8.8 and 8.7, 5.8 and 14.7, 16.2 and 28.4, 42.1 and 14.3, 0.06 and 57.2, and 0.89 and 11.7 percent, respectively. The coefficient of variation calculated on the distiller's grains products underscores the large variation with the product from plant to plant.

DePeters et al. (1996) evaluated the composition of several by-products. The by-products evaluated were beet pulp, rice bran, almond hulls, citrus pulp, bakery waste, wheat mill run, brewer's grain, distiller's grain, and soy hulls. The feedstuffs were incubated within the rumen for 72 h within digestion bags. Neutral detergent fiber and crude protein for distiller's grains following incubation were 14.5% higher than any of the other by-product evaluated. Batajoo and Shaver (1998) evaluated ruminal availabilities of DM, CP, and starch for barley, shelled corn, soybean meal, brewers dried grains, corn gluten feed, distiller's dried grains, soybean hulls, and wheat middling's. Dacron bags were used for estimates over a 72 h period. Dry distiller's grains ruminal availability of DM, CP, and starch were 58.3, 39.6 and 85.5% respectively. Their rank among the other feedstuffs evaluated in each the categories of DM, CP and starch were 3rd, 8th, and 2nd respectively.

Corn and sorghum grains are commonly used for the production of ethanol. Lodge et al. (1997a) compared sorghum WDG, sorghum WDG with solubles, sorghum DDG, and sorghum DDG with solubles, (all feedstuffs fed at 40% DM), in diets containing DRC. Dry matter intake and ADG were not different among treatments. Feed efficiencies were similar for cattle not consuming distiller's grains and cattle fed sorghum WDG, sorghum WDG plus solubles. Cattle fed sorghum DDG plus solubles decreased feed efficiency compared to animals not fed distiller's grains. Additionally, the authors completed a metabolism trial comparing corn WDG to sorghum WDG, sorghum DDG plus solubles, and corn DDG with solubles; by-products replaced all grain in diets. Apparent OM digestibility, apparent nitrogen, and true nitrogen were greater for corn WDG vs. sorghum WDG. Apparent OM digestibility, apparent nitrogen, and true nitrogen was greater in cattle fed sorghum DDG was greater than corn DDG. Al-Suwaiegh et al. (2002) fed sorghum WDG to corn WDG in DRC beef diets. Wet distiller's grains of corn or sorghum improved ADG, G:F, HCW, and fat thickness over the 12th rib compared to cattle not consuming distiller's grains. Cattle fed sorghum WDG had higher DMI compared to cattle fed corn WDG.

Comparing wet to dry distiller's grains is important as drying could affect protein availability. Larson et al. (1993) added corn WDG to finishing diets containing DRC. Distiller's grains were fed at 5.2, 12.6, and 40.0% DM respectively. In yearling cattle and calf fed cattle, ADG and G:F were improved as WDG level increased in the diet. In calf fed steers, HCW and quality grade were improved as WDG increased in the diet. Firkins et al. (1985) compared distiller's grains wet and dry in a metabolism study. Evaluations were made on dry matter disappearance, digestion as well as ruminant performance. Dry matter disappearance was not different between wet and dry distiller's grains. Digestion means for N, DM, and NDF were similar between wet and dry distiller's grains. Adding WDG at levels of 0, 25, and 50% to diets containing HMC had a linear improvement ADG and F:G. Adding 17.4% DDG as a replacement of soybean meal in the diet improved ADG and F:G over cattle not fed DDG in finishing cattle.

Lodge et al. (1997b) evaluated DDG, wet corn gluten feed, and a composite feedstuff similar to WDG with a basal grain source of DRC beef and lamb finishing diets. Concentrations of each by-product were 40% diet DM. Average daily gain, G:F, and DMI were similar for lambs not fed by-product compared to DDG and composite treatment groups. In the cattle trial, composite cattle consumed less feed daily, with similar ADG, and improved feed efficiency compared to other treatments. Klopfenstein (1996) compared the use of WDG and DDG both containing solubles in DRC diets in beef finishing diets. Evaluations were made up to 40% diet DM. Average daily gain increased linearly as WDG was increased in the diet. Dry matter intake decreased in cattle fed WDG when compared to cattle not consuming distiller's grains, and cattle fed DDG. Cattle fed distiller's grains wet or dry had improvements in ADG and F:G compared to cattle not fed distiller's grains. Wet distiller's grains fed to cattle had the best feed conversion compared to other treatment groups.

Peter et al. (2000) evaluated the use of DDG, dried corn gluten feed, and modified corn fiber with DRC as grain source in beef diets. Daily gain and feed efficiency were improved with cattle consuming DDG and dried corn gluten feed compared to other treatment groups. Adding DDG to the diet increased ruminal pH compared to cattle not consuming any by-products. Ruminal acetate and butyrate productions were increased in cattle when distiller's grains were included in the diet. Roeber et al. (2005) evaluated the effects of distiller's grains wet or dry and effects on meat quality. Steers were fed 0, 10, 12.5, 20, 25, 40 and 50% DM, of either wet or dry distiller's grains. Meat tenderness was not different among treatments. Cattle fed distiller's grains greater than 40% decreased meat shelf life, and meat color stability of strip loins. Feeding distiller's grains between 10 and 25% did not affect color stability or palatability of steaks.

Reed et al. (2006) evaluated the use of corn DDG with solubles supplemented to calves in creep feeders grazing native pasture. They evaluated the effects on intake, microbial protein synthesis, microbial efficiency, ruminal fermentation, digestion, and performance of nursing calves. Calves that were supplemented corn DDG with solubles had lower AP ratios; additionally more ruminal butyrate was produced. Isobutyrate and isovalerate were decreased when feeding distiller's grains. Calves fed corn DDG with solubles consumed a lower percentage of BW than cattle not fed distiller's grains. Decreases in DMI did not affect cattle performance, as both groups had similar ADG and feed efficiencies. Birkelo et al. (2004) evaluated the use of 30% corn WDG in dairy cattle diets. Body weight, DMI, and milk protein, were decreased with the addition of WDG. Milk fat percent was increased when cows were fed WDG. Nitrogen intake and urine N were increased in cows fed WDG compared to cows not fed WDG. Fecal N, and milk N were lower for cows fed WDG compared to cows not fed WDG. Adding WDG to dairy cow diets increased gross energy, digestible energy, ME and subsequently increased NE_L compared to cows not fed WDG.

Gilbery et al. (2006) evaluated corn condensed distiller's solubles (CCDS) as a protein source to cattle fed poor quality hay; CCDS levels were 0, 5, 10 or 15% diet DM. A linear increase was observed in OM intkae, total duodenal OM flow, microbial, non microbial flow, and fecal OM flow was observed as CCDS was added to the diet. Likewise, a linear increase in duodenal CP flow: microbial, total CP and fecal CP output increased as CCDS increased in dietary percentages. Total tract digestibility was increased as CCDS was added to the diet. Rust et al. (1990) evaluated the use of CCDS as an energy source in feedlot steers. The cattle consumed the CCDS as: grain soaked in

CDDS; CCDS added to water or free choice CCDS (not allowed free choice water). Dry matter intake and ADG were not different among treatment. Feed efficiency was improved in free choice vs. control groups. Metabolizable energy was also increased in free choice supplement of CCDS compared to the control treatment not fed CCDS. Ruminal butyrate concentrations were increased in the cattle fed corn that was soaked in CCDS compared to other treatment groups.

Fron et al. (1996) evaluated the use of CCDS in DRC diets and effects on rumen microbiology and metabolism. They found levels of lactic acid in higher amounts in by-products compared to grain. Adding CCDS to diets increased cultural lactilytic bacteria and amylolytic bacteria. Total protozoa counts decreased with the addition of CCDS. The authors noted that adding CCDS early in the feeding phase may allow bacteria to utilize levels of lactic acid.

Dietary Roughage Level in Beef Finishing Diets

Owens et al. (1998) evaluated the causes and preventions of subacute and acute acidosis in beef animals. Subacute acidosis is described when ruminal pH is between 5.0 and 5.6; acute acidosis is defined when ruminal pH falls below 5.0. Common symptoms of acidosis would include: depression in feed intake, reductions in animal performance, and in severe cases death. Excessive consumption of rapidly fermentable carbohydrates commonly occurs when animals are transitioning from a bulk fill to a chemostatic fill, or in adaptation to high-concentrate diets. Increasing roughage in diets is one method for alleviating acidosis by increasing chewing time and therefore increasing saliva production. With an increase in saliva, buffers within saliva help to maintain ruminal pH. Adding ethanol by-products could conceivably be valuable in high concentrate diets because starch is extracted during fermentation process and the fiber content is increased. Nagaraja and Titgemeyer (2007) discussed the important role protozoa have in acidosis. Protozoa are very sensitive to fluctuations in ruminal pH, and in many cases, in finishing diets low concentrations or complete elimination of protozoa have been observed. Ciliated protozoa are able to metabolize starch as well as lactate, but may not be effective if those populations of protozoa are removed because of low ruminal pH, commonly observed in cattle consuming high concentrate diets. Kreikemeier et al. (1990) evaluated steam-flaked wheat to finishing diets containing 0, 5, 10, or 15% roughage (50:50 blend alfalfa hay and corn silage) in beef finishing diets. Dry matter intake of cattle was increased as roughage level was increased in diet. A quadratic response was observed in ADG, F:G, and HCW of cattle. Roughage in the diet improved cattle performance at 5 and 10% compared to cattle fed 0 and 15% respectively.

Loerch (1991) fed steers diets containing either 85 or 100 percent concentrate. Plastic pot scrubbers were placed in animals as a replacement for roughage. Performance of animals with 100% concentrate and pot scrubbers was similar to animals fed 85% concentrate diet with 15% corn silage. Dry matter intake decreased in animals with pot scrubbers vs. those without scrubbers in one trial, with no difference in the following two trials. Feed conversion was improved in the first trial in animals with pot scrubbers vs. other groups, but was not repeated in subsequent trials. Increasing the number of scrubbers did not increase ruminal pH. Adding scrubbers to the rumen of steers did not decrease the number of animals with liver abscesses.

Zinn et al. (1994) evaluated roughage level and the use of monensin. Cattle were fed 10 or 20% dietary roughage with or without monensin (28 mg/kg). Steers fed 10% roughage improved ADG, feed efficiency, NEm and NEg compared to cattle fed 20% roughage. Dry matter intake decreased in cattle consuming 10% roughage compared to those fed 20% roughage. Increasing roughage level to 20% decreased total tract OM digestion, DE, and ME of cattle. Fecal excretion of ADF and OM were greater when cattle were consuming 20% roughage. Decreasing dietary roughage to 10% increased ruminal production of propionate and valerate and decreased AP ratio. Methane production was also decreased for cattle fed 10% roughage. Stock et al. (1990) evaluated DRC, sorghum, wheat, and HMC with decreasing roughage levels in the diet and interactions with monensin in finishing diets. Reducing dietary roughage levels improved feed efficiency of the cattle. Rapidly fermentable grains (wheat and HMC) decreased ADG of cattle with the reduction of roughage. Grain type did affect intake of animals with similar dietary roughage levels. An increase in liver abscess was not observed as cattle were fed tylosin. The authors stated optimum roughage level in feedlot diets would be between 3 and 7.5 % DM.

Theurer et al. (1999) evaluated roughage type with steam-flaked sorghum in beef finishing diets. Diets all included 6% alfalfa hay, cottonseed hulls and wheat straw were added so that all diets contained 17% NDF. Alfalfa hay diet included an additional 6%, cottonseed hulls diet added 2.8%, and wheat straw diet added 3.7% DM respectively. Cattle fed the all alfalfa hay diet converted more efficiently compared to cattle fed the cottonseed hulls and wheat straw treatments, with no difference on DMI or ADG. Defoor et al. (2002) evaluated alfalfa hay, cottonseed hulls, Sudan hay, wheat straw and Sudan silage in a series of finishing trials; roughage levels varied from 2.5% to 15% in experiments. Their experiments resulted in high concentrate diets containing roughage sources with high NDF values maybe more valuable in finishing diets. More fibrous roughage sources can be fed at lower percentages of the diet, having similar effects on performance. The animal is able to consume more feed; and therefore increase NEg values.

Loerch and Fluharty (1998) compared diets containing HMC as energy source and 0, or 15% corn silage DM, in finishing diets, fed in either the growing phase or finishing phase. Feed efficiency was improved for 0 vs. 15%; NEm and NEg were greater in diets containing no roughage. Condemned livers increased with absence of roughage. Parsons et al. (2007) evaluated the use of corn gluten feed as a partial replacement of roughage. Wet corn gluten feed was included at 40% diet DM, and three levels of roughage: 9, 4.5 and 0 % alfalfa hay. As dietary roughage level was decreased linear reductions were observed in DMI, ADG, HCW and final weight. Feed efficiencies were similar among treatments.

CONCLUSION

As corn is more extensively processed, starch availability and digestion are improved. Feeding steam-flaked corn vs. dry-rolled corn to beef animals decreases intake, but improves average daily gain and efficiency. More degradation occurs within the rumen; as more energy is made available within rumen, microbial growth is more efficient, increasing microbial nitrogen flow to the small intestine. Less extensive processing methods will have more starch reach hind gut where microbial growth is increased and subsequent microbial nitrogen is lost. As flakes are processed to lighter densities, less available starch is made available to the animal; most steam-flaked corn studies stated optimum corn flake density to be 360 g/L.

The growth of the ethanol industry has prompted the evaluation as ethanol by-products in livestock diets. Optimum inclusion percentages in DRC diets have been reported from 25-40% diet DM. Decreasing roughage from high concentrate diets will increase energy density within the diet. Increases in liver abscess have been observed with low roughage diets in the absence of tylosin, as a result of more digestive disorders.

LITERATURE CITED

Al-Suwaiegh, S., K. C. Fanning, R. J. Grant, C. T. Milton, and T. J. Klopfenstein. 2002. Utilization of distiller's grains from the fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. J. Anim. Sci. 80:1105-1111.

Archibeque, S. L., D. N. Miller, H. C. Freetly, and C. L. Ferrell. 2006. Feeding high-moisture corn instead of dry-rolled corn reduces odorous compound production in manure of finishing beef cattle without decreasing performance. J. Anim. Sci. 84:1767-1777.

Batajoo, K. K., and R. D. Shaver. 1997. In situ dry matter, crude protein, and starch degradabilities of selected grains and by-product feeds. Anim. Feed Sci. Tech. 71:165-176.

Birkelo, C. P, M. J. Brouk, and D. J. Schingoethe. 2003. The energy content of wet corn distiller's grains for lactating dairy cows. J. Dairy Sci. 87:1815-1819.

Bothast R. J. and M. A. Schilcher. 2005. Biotechnological processes for conversion of corn into ethanol. Appl. Microbiology Biotechnology. 67: 19-25.

Braman, W. L., E. E. Hatfield, F. N. Owens, and J. M. Lewis. 1973. Protein concentrations and sources for finishing ruminants fed high-concentrate diets. 36:782-787.

Brown M. S., C. R. Krehbiel, G. C. Duff, M. L. Galyean, D. M. Hallford, and D. A. Walker. 2000. Effect of degree of corn processing on urinary nitrogen composition, serum metabolite and insulin profiles, and performance by finishing steers. J. Anim. Sci. 78: 2464-2474.

Calderon-Cortes, J. F., and R. A. Zinn. 1996. Influence of dietary forage level and forage coarseness of grind on growth performance and digestive function in feedlot steers. J. Anim. Sci. 74:2310-2316.

Cooper, R. J., C. T. Milton, T. J. Klopfenstein, T. L. Scott, C. B. Wilson and R. A. Mass. 2002a. Effect of corn processing on starch digestion and bacterial crude protein flow in finishing cattle. J. Anim. Sci. 80:797-804.

Cooper, R. J., C. T. Milton, T. J. Klopfenstein, and D. J. Jordon. 2002b. Effect of corn processing on degradable intake protein requirement of finishing cattle. 2002b. J. Anim. Sci. 80:242-247.

Corona, L., S. Rodriguez, R. A. Ware, and R. A. Zinn. 2005. Comparative effects of whole, ground, dry-rolled, and steam-flaked corn on digestion and growth performance in feedlot cattle. Prof. Anim. Sci. 21:200-206.

Defoor, P. J., M. L. Galyean, G. B. Salyer, G. A. Nunnery, and C. H. Parsons. 2002. Effects of roughage source and concentration on intake and performance by finishing heifers. J. Anim. Sci. 80:1295-1404.

DePeters E. J., J. G. Fadel, and A. Arosemena. 1997. Digestion kinetics of neutral detergent fiber and chemical composition with some selected by-product feedstuffs. Anim. Feed Sci. Tech. 67:127-140.

DiPardo J. 2000. Outlook for biomass ethanol production and demand. Energy Information Administration, US Department of Energy, Washington, D.C.

Firkins, J. L., L. L. Berger, and G. C. Fahey, Jr. 1985. Evaluation of wet and dry distiller’s grains and wet and dry gluten feeds for ruminants. J. Anim. Sci. 60:847-860.

Fron, M., H. Madeira, C. Richards, and M. Morrison. 1996. The impact of feeding condensed distiller’s byproducts on rumen microbiology and metabolism. Anim. Feed Sci. Tech. 61:235-245.

Galyean, M. L. 1996. Protein levels in beef cattle finishing diets: industry application, university research, and systems results. 1996. J. Anim. Sci. 74:2860-2870.

Galyean, M. L. and K. S. Eng. 1998. Application of research findings and summary of research needs: Bud Britton memorial symposium on metabolic disorders of feedlot cattle. J. Anim. Sci. 76:323-327.

Galyean, M. L., D. G. Wagner, and R. R. Johnson. 1976. Site and extent of starch digestion in steers fed processed corn rations. J. Anim. Sci. 43:1088-1094.

Gilbery, T. C., G. P. Lardy, S. A. Soto-Navarro, M. L. Bauer, and J. S. Caton. 2006. Effects of corn condensed distiller’s solubles supplementation on ruminal fermentation, digestion, and in situ disappearance in steers consuming low-quality hay. J. Anim. Sci. 84:1468-1480.

Goodrich, R. D., F. M. Byers, and J. C. Meiske. 1975. Influence of moisture content, processing and reconstitution on the fermentation of corn grain. J. Anim. Sci. 1975. 41:876-881.

Hale, W. H. 1973. Influence of processing on the utilization of grains (starch) by ruminants. J. Anim. Sci. 37:1075-1080.

Hale, W. H., L. Cuitin, W. J. Saba, B. Taylor, and B. Theurer. 1966. Effect of steam processing and flaking milo and barley on performance and digestion by steers. J. Anim. Sci. 25:392-396.

Ham, G. A., R. A. Stock, T. J. Klopfenstein, E. M. Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distiller’s byproducts compared with dried corn distiller’s grains with solubles as a source of protein and energy for ruminants. J. Anim. Sci. 72:3246-3257.

Huck, G. L., K. K. Kreikemeier, G. L. Kuhl, T. P. Eck, and K. K. Bolsen. 1998. Effects of feeding combinations of steam-flaked grain sorghum and steam-flaked, high-moisture, or dry-rolled corn on growth performance and carcass characteristics in feedlot cattle. J. Anim. Sci. 76:2984-2990.

Johnson, D. E., J. K. Matsushima, and K. L. Knox. 1968. Utilization of flaked vs. cracked corn by steers with observations on starch modification. J. Anim. Sci. 27:1431-1437.

Klopfenstein, T. J. 1996. Distiller’s grains as energy source and effect of drying on protein availability. Anim. Feed Sci. Tech. 60:201-207.

Kovarik, B. 1998. Henry Ford, Charles F. Kettering and the fuel of the future. Automotive History Review. 32:7-27.

Kreikemeier, K. K., D. L. Harmon, R. T. Brandt, Jr., T. G. Nagaraja, and R. C. Cochran. 1990. Steam-rolled wheat diets for finishing cattle: effects of dietary roughage and feed intake on finishing steer performance and ruminal metabolism. J. Anim. Sci. 68:2130-2141.

Larson, E. M., R. A. Stock, T. J. Klopfenstein, M. H. Sindt, and R. P. Huffman. 1993. Feeding value of wet distiller’s byproducts for finishing ruminants. J. Anim. Sci. 71:2228-2236.

Lodge, S. L., R. A. Stock, T. J. Klopfenstein, D. H. Shain, and D. W. Herold. 1997a. Evaluation of corn and sorghum distiller's byproducts. J. Anim. Sci. 75:37-43.

Lodge, S. L., R. A. Stock, T. J. Klopfenstein, D. H. Shain, and D. W. Herold. 1997b. Evaluation of wet distiller's composite for finishing ruminants. J. Anim. Sci. 75:44-50.

Loerch, S. C. 1991. Efficacy of plastic pot scrubbers as a replacement for roughage in high-concentrate cattle diets. J. Anim. Sci. 69:2231-2328.

Loerch, S. C., and F. L. Fluharty. 1998. Effects of corn processing, dietary roughage level, and timing of roughage inclusion on performance of feedlot steers. J. Anim. Sci. 76:681-685.

Macken, C. N., G. E. Erickson, and T. J. Klopfenstein. 2006a. The cost of corn processing for finishing cattle. Prof. Anim. Sci. 22:23-32.

Macken, C. N., G. E. Erickson, T. J. Klopfenstein, and R. A. Stock. 2006b. Effects of corn processing method and protein concentration in finishing diets containing wet corn gluten feed on cattle performance. Prof. Anim. Sci. 22:14-22.

Mader, T. and G. Erickson. 2006. Feeding high moisture corn. http://extension.unl.edu/publications. retrieved: May 2, 2007.

Mader, T. L., J. M. Dahlquist, R. A. Britton, and V. E. Krause. 1991. Type and mixtures of high-moisture corn in beef cattle finishing diets. J. Anim. Sci. 69:3480-3486.

Nagaraja, T. G., and E. C. Titgemeyer. 2007. Ruminal acidosis in beef cattle: the current microbiological and nutritional outlook. J. Dairy Sci. 90:E17-E38.

NRC, 1996. Nutrient requirements of beef cattle. 7th Revised Edition. National Academy Press. Washington, D.C.

Ørskov, E. R., C. Fraser, V. C. Mason and S. O. Mann. 1970. Influence of starch digestion in the large intestine of sheep on cecal fermentation, cecal microflora and fecal nitrogen excretion. Brit. J. Nutr. 24:671-682.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1997. The effect of grain source and grain processing on performance of feedlot cattle: a review. J. Anim. Sci. 75:868-879.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1998. Acidosis in cattle: a review. J. Anim. Sci. 76:275-286.

Owens, F. F., R. A. Zinn, and Y. K. Kim. 1986. Limits to starch digestion in the ruminant small intestine. J. Anim. Sci. 63:1634-1648.

Parsons, C. H., J. T. Vasconcelos, R. S. Swingle, P. J. Defoor, G. A. Nunnery, G. B. Salyer, and M. L. Galyean. 2007. Effects of wet corn gluten feed and roughage levels on performance, carcass characteristics, and feeding behavior of feedlot cattle. J. Anim Sci. *In Press.* Published online first July 3, 2007 as doi:10.2527/jas.2007-0149.

Plascencia, A., and R. A. Zinn. 1996. Influence of flake density on the feeding value of steam-processed corn in diets for lactating cows. J. Anim. Sci. 74:310-316.

Peter, C. M., D. B. Faulkner, N. R. Merchen, D. F. Parrett, T. G. Nash, and J. M. Dahlquist. 2000. The effects of corn milling co products on growth performance and diet digestibility by beef cattle. J. Anim. Sci. 78:1-6.

Reinhardt, C. D., R. R. Brandt, Jr., K. C. Behnke, A. S. Freeman, and T. P. Eck. 1997. Effect of steam-flaked sorghum grain density on performance, mill production rate, and subacute acidosis in feedlot steers. J. Anim. Sci. 75:2852-2857.

Reed, J. J., G. P. Lardy, M. L. Bauer, M. Gibson, and J. S. Caton. 2006. Effects of season and inclusion of corn distiller's dried grains with solubles in creep feed on intake, microbial protein synthesis and efficiency, ruminal fermentation, digestion, and performance of nursing calves. J. Anim. Sci. 84:2200-2212.

Roeber, D. L., R. K. Gill, and A. DiCostanzo. 2005. Meat quality responses to feeding distiller's grains to finishing Holstein steers. J. Anim. Sci. 83:2455-2460.

Renewable Fuels Association. Ethanol Biorefinery locations. http://www.ethanolrfa.org/industry/locations/. Retrieved: April 27, 2007.

Renewable Fuels Associations. Industry Statistics. http://www.ethanolrfa.org/industry/statistics/. Retrieved: April 27, 2007.

Rust, S. R., J. R. Newbold, and K. W. Mertz. 1990. Evaluation of condensed distiller's' solubles as an energy source in finishing cattle. J. Anim. Sci. 68:186-192.

Sindt, J. J., J. S. Drouillard, E. C. Titgemeyer, S. P. Montgomery, E. R. Loe, B. E. Depenbusch, and P. H. Walz. 2006. Influence of steam-flaked corn moisture level and density on the site and extent of digestibility and feeding value for finishing cattle. J. Anim. Sci. 84:424-432.

Spiehs, M. J., M. H. Whitney, and G. C. Shurson. 2002. Nutrient database for distiller's dried grains with solubles produced from new ethanol plants in Minnesota and South Dakota. J. Anim. Sci. 80:2639-2645.

Stock, R. A., D. R. Brink, R. T. Brandt, J. K. Merrill, and K. K. Smith. 1987a. Feeding combinations of high moisture corn and dry corn in finishing cattle. J. Anim. Sci. 65:282-289.

Stock, R. A., D.R. Brink, R. A. Britton, F. K. Goedeken, M. H. Sindt, K. K. Kreikemeier, M. L. Bauer, and K. K. Smith. 1987b. Feeding combinations of high moisture corn and dry-rolled grain sorghum to finishing steers. J. Anim. Sci. 65:290-302.

Stock, R. A., M. H. Sindt, J. C. Parrott, and F. K. Goedeken. 1990. Effects of grain type, roughage level and monensin level on finishing cattle performance. J. Anim. Sci. 68:3441-3455.

Stock, R. A., M. H. Sindt, R. M. Cleale IV, and R. A. Britton. 1991. High-moisture corn utilization in finishing cattle. J. Anim. Sci. 69:1645-1656.

Swingle, R. S., T. P. Eck, C. B. Theurer, M. De la Llata, M. H. Poore and J. A. Moore. 1999. Flake density of steam-processed sorghum grain alters performance and sites of digestibility by growing-finishing steers. J. Anim. Sci. 77:1055-1065.

Theurer, C. B. 1986. Grain processing effects on starch utilization by ruminants. J. Anim. Sci. 63:1649-1662.

Theurer, C. B., O. Lozano, A. Alio, A. Delgado-Elorduy, M. Sadik, J. T. Huber, and R. A. Zinn. 1999. Steam-processed corn and sorghum grain flaked at different densities alter ruminal, small intestinal, and total tract digestibility of starch by steers. J. Anim. Sci. 77:2824-2831.

Xiong, Y., S. J. Bartle, and R. L. Preston. 1991. Density of steam-flaked sorghum grain, roughage level, and feeding regimen for feedlot steers. J. Anim. Sci. 69:1707-1718.

Zinn, R. A. 1986. Influence of forage level on response of feedlot steers to salinomycin supplementation. J. Anim. Sci. 63:2005-2012.

Zinn, R. A. 1990a. Influence of density of steam-flaked corn on carcass merit and empty body composition of feedlot steers. J. Anim. Sci. 68:767-775.

Zinn, R. A. 1990b. Influence of steaming time on site of digestion of flaked corn in steers. J. Anim. Sci. 68:776-781.

Zinn, R. A., A. Plascencia, and R. Barajas. 1994. Interaction of forage level and monensin in diets for feedlot cattle on growth performance and digestive function. J. Anim. Sci. 72:2209-2215.

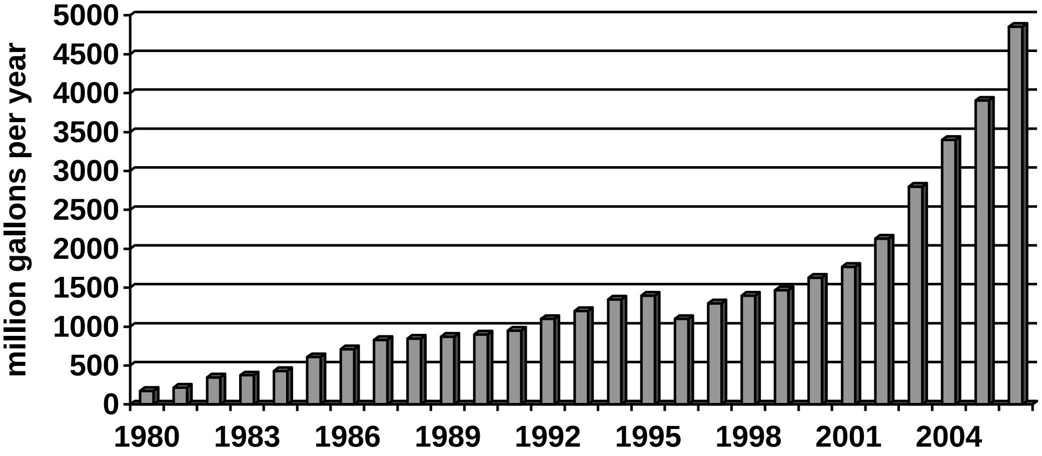
Zinn, R. A., C. F. Adam, and M. S. Tamayo. 1995. Interaction of feed intake level on comparative ruminal and total tract digestion of dry-rolled and steam-flaked corn. J. Anim. Sci. 73:1239-1245.

Zinn, R. A., E. G. Alvarez, M. F. Montaño, A. Plascencia, and J. E. Ramirez. 1998. Influence of tempering on the feeding value of rolled corn in finishing diets for feedlot cattle. J. Anim. Sci. 76:2239-2246.

Zinn, R. A., and F. N. Owens. 1983. Influence of feed intake level on site of digestion in steers fed a high concentrate diet J. Anim. Sci. 56:471-475.

Zinn R. A., F. N. Owens, and R. A. Ware. 2002. Flaking corn: processing mechanics, quality standards, and impacts on energy availability and performance of feedlot cattle. J. Anim. Sci. 80:1145-1156.

Figure 1-1. United States Ethanol Production



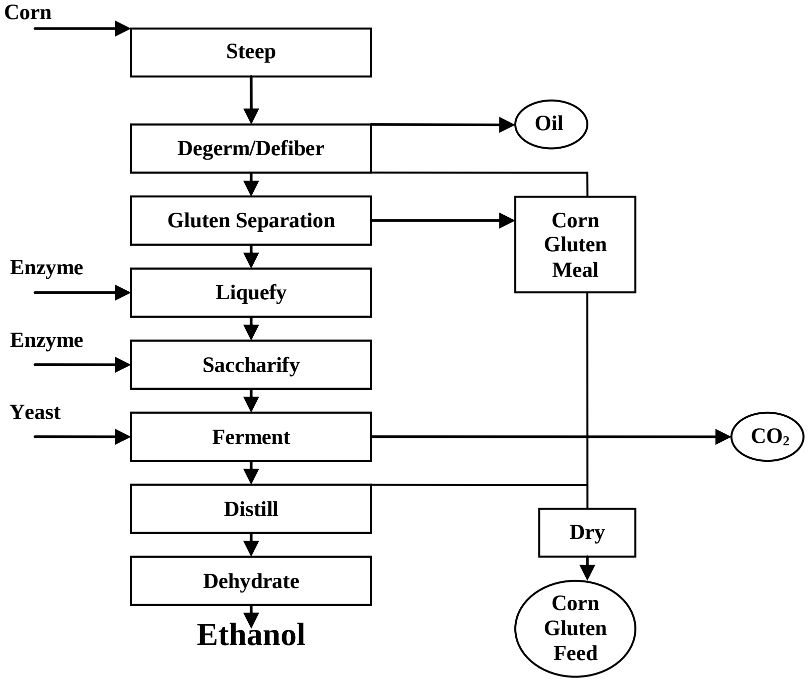
Renewable Fuels Association: http://www.ethanolrfa.org/industry/locations/

Table 1-1.Ethanol Production by Country, million gallons per year

Country	**Year** **2004**	 **2005**	 **2006**
United States	3,535	4,264	4,855
Brazil	3,989	4,227	4,491
China	964	1,004	1,017
India	462	449	502
France	219	240	251
Others	1,601	1,966	2,373
Total	**10,770**	**12,150**	**13,489**

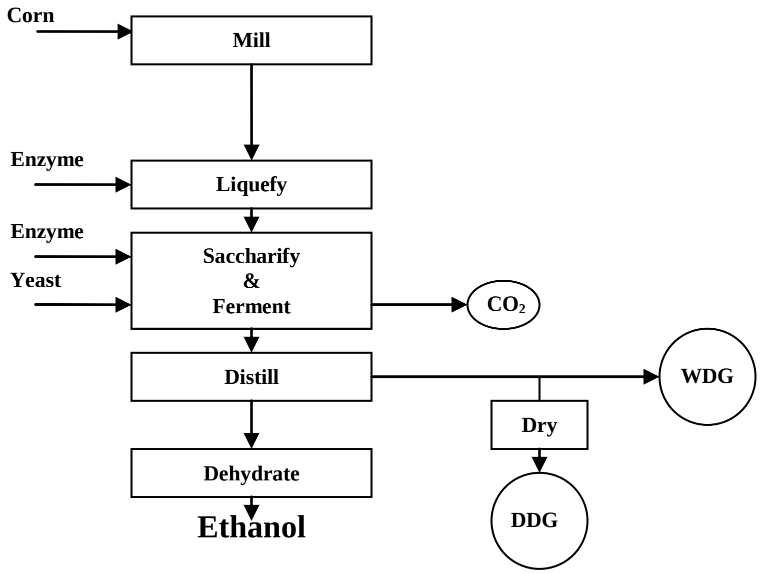
Renewable Fuels Association: http://www.ethanolrfa.org/industry/statistics/

Figure 1-2. Wet Milling Production of Ethanol



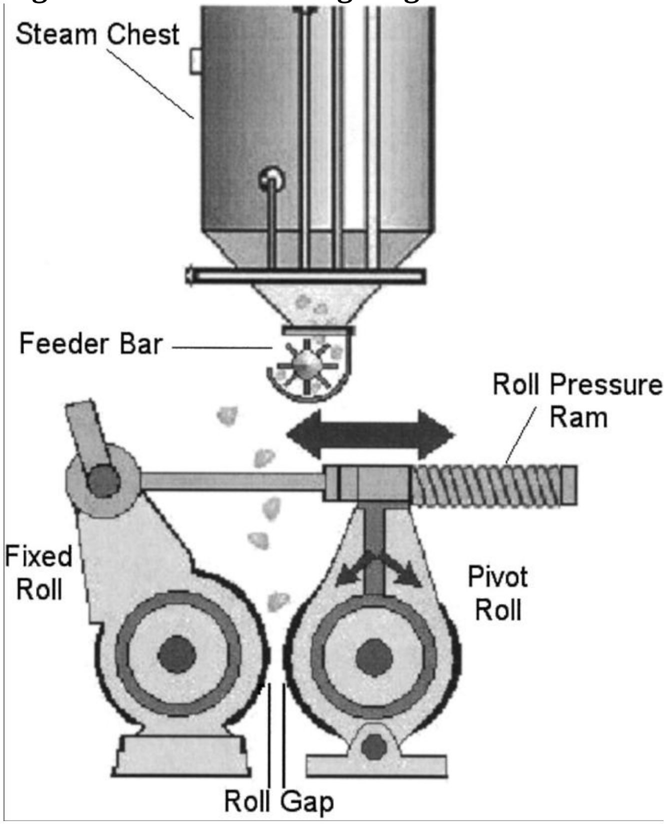
Bothast et al., 2005

Figure 1-3. Dry Milling Production of Ethanol



Bothast et al., 2005

Figure 1-4. Steam-flaking diagram



Zinn et al. (2002)

2. Chapter II: Determining Optimum Flake Density in Feedlot Heifers[1]

M. L. May[2], M. J. Quinn[2], B. E. Depenbusch[2], and J. S. Drouillard[2,3]

Kansas State University
Manhattan, KS 66506

---

[1] This is contribution no. 08-81-J from the Kansas Agricultural Experiment Station, Manhattan, Kansas.

[2] Kansas State University, Department of Animal Science and Industry

[3] Corresponding author: jdrouill@ksu.edu; Phone: (785) 532-1204; Fax: (785) 532-5681

ABSTRACT

The purpose of the experiment was to determine optimum flake density (FD) of steam-flaked corn in beef finishing diets. Diets consisted of corn flaked to densities of 360, 411, or 462 g/L (i.e., 28, 32 or 36 lb/bu, respectively). Cattle were randomly allotted to 48 feedlot pens (16 pens per treatment) with 6 to 8 animals in each pen (n=358; initial BW = 337 ± 1.22 kg). Heifers were fed once daily for 115 d. There were no significant differences DMI, ADG, efficiency, carcass weight, dressing percent, quality grade, average yield grade, fat over the 12th rib, and kidney pelvic and heart fat ($P > 0.10$). Cattle performance was numerically decreased when FD was increased above 360 g/L. Mill efficiency was improved as density of flaked grain increased ($P < 0.01$), and was driven primarily by increases in mill throughput. Particle size of processed corn and the complete diet particle size increased as FD increased above 360 g/L ($P < 0.01$). Percentage of available starch of flakes was decreased as flake density increased ($P < 0.01$). The increase in mill production would support increasing FD; however decreases in animal performance, though small, may offset economic benefits attributed to greater mill capacity.

Key Words: Steam-flaked corn, Flake Density, Feedlot

INTRODUCTION

As energy costs increase, especially natural gas, the cost to produce steam-flaked grain has increased. Flaking grain to higher densities can increase mill throughput, and in so doing so use less energy. Reinhardt et al. (1997) found when increasing steam-flaked sorghum from 283, 322 and 361 g/L (i.e., 22, 25, and 28 lb/bu) that cattle fed the 361 g/L flake diet had the greatest ADG and feed efficiency. Production of the 361 g/L also improved mill efficiency linearly. Production rate was improved increasing flake production per unit of time, therefore decreasing overall cost of production. Xiong et al. (1991) saw that as sorghum flake density (FD) was increased from 283, 360, and 437 g/L (i.e., 22, 28, and 34 lb/bu) the amount of starch found in feces increased as FD increased. Likewise fecal pH was higher for cattle fed grain processed to heavier flake weights. Electrical expenditure, kwh per 1,000 kg for each density 283, 360 and 437 g/L were 4.4, 7.5, and 11.0 respectively. Sindt et al. (2006) flaked two densities 360 or 310 (i.e., 28 or 24 lb/bu) and added 0, 6, or 12% moisture. This study showed no advantage to lower flake density or increasing pre-conditioning time. A survey including 3.6 million cattle consulted by 6 feedlot nutritionists, Galyean, (1996) stated steam-flaking grain was the most common grain processing method U.S. feedlots employ. Production of steam-flaked to higher density can be economical if satisfactory cattle performance can be maintained with less extensive grain processing, it would be possible to reduce overall cost of production.

MATERIALS AND METHODS

The study was conducted in accordance with procedures approved by the Kansas State University Institutional Animal Care and Use Committee Protocol No.2315. Three-hundred fifty-eight crossbred-yearling heifers (initial BW = 337 ± 1.22 kg) were obtained and used in a randomized complete block design finishing study. Heifers were fed a common diet 14 d prior to initiation of study. Heifers were fed a similar diet differing only in steam-flaked corn density; corn was flaked to 360 (SF28), 411 (SF32), 462 (SF36) g/L respectively. Finishing diets are further described in Table 1. Upon arrival heifers were processed, identified with uniquely numbered tags in both ears, received injections of Bovishield-4 and Fortress-7 vaccines, (Pfizer Animal Health, Exton, PA), administered Phoenectin pour-on, (Phoenix Scientific Inc., St. Joseph, MO). Heifers were implanted with 20 mg estradiol and 200 mg trenbolone acetate implant 91 d prior to slaughter (Revalor 200, Intervet Inc., Millsboro, DE). Heifers were housed in concrete-surfaced pens (36 m^2) with automatic water fountains and 4.2 m of bunk space. Pens contained 6 to 8 heifers, with 48 pens used for evaluation. Pen weight of animals were determined immediately prior to shipping to a commercial abattoir. Heifers were offered *ad libitum* access to diets delivered once daily for 115 d. Dietary NE_m and NE_g values were calculated based on heifer performance (NRC 1984).

Cattle were harvested on d 115 at a commercial abattoir in Emporia, KS, at which time carcass data were collected. Hot carcass weight and liver abscess scores were obtained at the time of harvest. Longissimus muscle area, subcutaneous fat thickness over 12th rib, KPH fat, marbling score, USDA quality grades, and USDA yield grades were measured following a 24-h chill. Final BW were calculated by dividing carcass weight by a common dressing percent of 63.5%.

Corn was flaked daily to provide fresh flakes with adequate amounts to meet the days feed requirements. Corn was conditioned with steam for approximately 45 minutes to a final temperature of 100° C. Peg feeder and roll setting were adjusted throughout flaking process to meet desired density and quality.

Flaked-corn samples were collected weekly throughout the trial and analyzed for DM (forced air oven set at 105° C). Starch availability was determined daily using 25 g of SFC with 25 mL of amyloglucosidase (Validase GA, Valley Research, South Bend, IN; 300 enzyme units per mL) at each FD as described by Sindt (2004). Particle size distribution was measured on flake samples taken daily, and total diet samples taken weekly throughout experiment (ASAE, 1983) using a Ro-Tap (W. S. Tyler, Mentor, OH) and seven sieves ranging from 9,500 to 1,180µm. Mill throughput was calculated by measuring the amount of time needed to fill one plastic tote, (1.10 m^3, 3028 EXT, Bonar Plastics, Inc., Littleton, CO) and then weighing tote, full and empty, for each flake density.

Statistical Analysis

Growth performance, carcass characteristics, mill efficiency, flake particle size and available starch were analyzed statistically using the Proc GLM procedure of SAS

(SAS Inst., 2002, Cary NC). The model statement included the effects of treatment. Pen was the experimental unit. Linear and quadratic contrasts were used to determine optimum flak density fed to heifers.

RESULTS AND DISCUSSION

Corn flaked to 360 g/L had a higher percentage of flakes remaining on the 9,500 µm sieve plate when compared to the other two densities linear ($P < 0.01$). The corn flaked to 360 g/L had more surface area than the other two densities. On the second sieve plate of 6,700 µm there was a linear increase in the percentage flakes remaining on the screen from SF28 to SF36 ($P < 0.01$). The remaining six sieve plates measuring from 4,750 µm to less than 1,180 µm, had a linear decrease in the percentage of flakes remaining on each of the plate from SF28 to SF36 ($P < 0.01$). There was a linear reduction in the percent of particles less than 1,180 µm present in the flake samples ($P < 0.01$). The geometric mean diameter was linearly increased from SF28 to SF36 ($P < 0.01$). The geometric standard deviation was also the lowest for the SF36, stating it had the least amount of variation when compared to the other densities ($P < 0.01$). The differences in particle size distribution observed, state the higher densities have a higher percentage of remaining at the desired density and remaining intact.

When the total mixed diet was placed onto the same sieve plate, there were similarities to the flake particle size distribution. On the 9,500 and 6,700 µm sieve plates, there was a linear increase in the percentages of the diet remaining on each plate from 360 g/L to 462 g/L ($P < 0.01$). The remaining sieve plate distribution from 4,750 to less than 1,180 µm had more particles on diets containing 360 g/L than the other two densities (linear $P < 0.01$). The 360 g/L flake did not have a high percentage of particles remaining on the 9,500 µm when the diet was mixed, which was contrary to the flake samples. As each flake density increased, the durability throughout the mixing process was increased. There was a linear reduction in the percent of particles less than 1,180 µm remaining in the pan for the total mixed diet ($P < 0.01$). The highest geometric mean diameter was highest for the 462 g/L and there was a linear decrease as FD decreased ($P < 0.01$). Similar to the flake samples, the diet with the least amount of variation was the SF36 diet (linear $P < 0.01$).

Increasing flake density improved flake durability, as well as durability throughout the mixing process; this however did not positively influence cattle performance. Contrary to Sindt et al. (2006), where mixing times for 360 g/L flakes reduced flake and diet particle size, had no significant difference on cattle performance, but had numerical decreases in animal performance as particle size decreased. Our data suggests fewer particles less than 1,180 μm did not positively improve cattle performance. Sindt et al. (2006) would have sourced corn flaked at similar densities only changing mixing times. In our experiment, we were not using similar flakes which affected physical and chemical properties of the grain. As corn was more extensively processed starch availability increased (linear $P < 0.01$). Xiong et al. (1991) saw an increase in fecal starch, and a decrease in fecal pH as FD increased. Our experiment did not analyze fecal starch or pH, but with a decrease in flake surface area and decreases in starch availability, more starch would escape ruminal fermentation, subsequently decreasing ruminal digestibility and total tract digestion and increase starch content in the feces, decreasing fecal pH.

The appearance of the SF36 flake was similar to steam-rolled corn. There was little cracking of the pericarp of the kernel, and a slight indentation made by the roll corrugation. The starch matrix was much less affected with SF36 than the other densities. At SF36, the kernel was heated and able to absorb water. The starch within the kernel swelled, but with less extensive gain processing when compared to SF28 and SF32, the potential to disrupt starch matrix was decreased, as was available starch availability to the animal. Starch availability percentages within our data set were lower than what is normally observed within the industry. This study took place in summer months with abnormally high ambient temperature; higher grain temperatures entered the steam chamber, which decreased the amount of moisture the grain was able to absorb. With decreases in grain moisture starch gelatinization was compromised, our flakes had similar moisture content among treatments 84.38 ± 0.27 %.

Increasing FD improved mill production at rates by 14.8% when flaking to SF32 and 52.8% for production of SF36, compared to SF28 as baseline; linear effect ($P < 0.01$). Similar to Reinhardt et al. (1997) and Brown et al. (2000) stated as flake density increased mill throughput was increased, and starch availability was decreased. Final temperature within the steam chest did not change, and steam rate would have been similar from day-to-day for each density. Increasing mill throughput with similar steam pressure would decrease natural gas costs per unit of production. Energy costs would also be less because the electrical load is decreased as the friction on the rolls is decreased, as rolls gap is increased to produce higher flake densities.

There were no significant differences in cattle performance when increasing FD above SF28. There were, however, numerical improvements in ADG, G:F, DMI, final weight, and HCW as FD decreased ($P > 0.13$). Although not significant our results would be similar to those observed by Zinn (1990), Swingle et al. (1999) and Xiong et al. (1991) that as grain was processed to a lower degree cattle performance was hindered. Theurer et al., (1999), increased FD from 283, 360, and 437 g/L, and observed linear decreases in starch digestion within the rumen as FD was increased. This shifted the sight and extent of digestion from the rumen to the small intestine. Total tract starch digestion was increased as grain was more extensively processed. The performance differences in our trial, though small, were probably due to the fact that sight and extent of digestion were shifted to the small intestine, and hind gut when FD was increased above SF28.

There was a linear reduction in longissimuss muscle as flake weight increased ($P = 0.01$). Cattle fed SF28 had numerically higher carcass weights than their trial counterparts. Average yield grade was not affected by increasing flake density. A linear increase was observed for percentage of animal with a yield grade 3 from SF28 to SF36 ($P < 0.05$). This linear response was driven by the increase in animals with a yield grade 3 in the SF36 treatment. Similarly a tendency for a linear increase in heifers fed SF28 to SF36 was observed in animal with a yield grade 4 ($P = 0.06$). Heifers fed SF28 had higher values grading 4 than their trial cohorts. These results would state that animals fed the 360 g/L flake were slightly fatter cattle fed the SF32 and SF36 treatments. This difference, however, could be driven by the changes in HCW; cattle fed SF28 had numerically higher carcass weights than did SF32 and SF36 heifers. These differences are possible driven by different physiological end points.

Implications:

The cost to produce a higher flake density takes less energy and decreases the production costs of steam-flaked corn, but the decrease in cattle efficiency and average daily gain are not enough to increase flake density above SF28. Numerical differences in DMI, ADG, G:F, final weight, and HCW, though small, would significantly impact the monetary value of beef animals associated with increasing FD above SF28. A model estimating the motor efficiency for the peg feeder and mill, steam usage based on steam chest size, and with these estimated parameters determine flaking costs.

LITERATURE CITED

Brown, M. S., C. R. Krehbiel, G. C. Duff, M. L. Galyean, D. M. Hallford, and D. A. Walker. 2000. Effect of degree of corn processing on urinary nitrogen composition, serum metabolite and insulin profiles, and performance by finishing steers. J. Anim. Sci. 78:2464-2474.

Cooper, R. J., C. T. Milton, T. J. Klopfenstein, T. L. Scott, C. B. Wilson, and R. A. Mass. 2002. Effect of corn processing method on starch digestion and bacterial crude protein flow in finishing cattle. J. Anim. Sci. 80:797-804.

Cooper, R. J., C. T. Milton, T. J. Klopfenstein, and D. J. Jordon. 2002. Effect of corn processing on degradable intake protein requirement of finishing cattle. 2002. J. Anim. Sci. 80:242-247.

Galyean, M. L. 1996. Protein levels in beef cattle finishing diets: industry application, university research, and systems results. 1996. J. Anim. Sci. 74:2860-2870.

NRC, 1984. Nutrient requirements of beef cattle. 6th Revised Edition. National Academy Press. Washington, D.C.

NRC, 1996. Nutrient requirements of beef cattle. 7th Revised Edition. National Academy Press. Washington, D.C.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1997. The effect of grain source and grain processing on performance of feedlot cattle: a review. J. Anim. Sci. 75:868-879.

Reinhardt, C. D., R. R. Brandt, Jr., K. C. Behnke, A. S. Freeman, and T. P. Eck. 1997. Effect of steam-flaked sorghum grain density on performance, mill production rate, and subacute acidosis in feedlot steers. J. Anim. Sci. 75:2852-2857.

Sindt, J. J. 2004. Factors influencing the utilization of steam-flaked corn. Ph. D. Diss., Kansas State Univ., Manhattan.

Sindt, J. J., J. S. Drouillard, S. P. Montgomery, and E. R. Loe. 2006. Factor influencing characteristics of steam-flaked corn and utilization by finishing cattle. J. Anim. Sci. 84:154-161.

Sindt, J. J., J. S. Drouillard, E. C. Titgemeyer, S. P. Montgomery, E. R. Loe, B. E. Depenbusch, and P. H. Walz. 2006. Influence of steam-flaked corn moisture level and density on the site and extent of digestibility and feeding value for finishing cattle. J. Anim. Sci. 84:424-432.

Swingle, R. S., T. P. Eck, C. B. Theurer, M. De la Llata, M. H. Poore and J. A. Moore. 1999. Flake density of steam-processed sorghum grain alters performance and sites of digestibility by growing-finishing steers. J. Anim. Sci. 77:1055-1065.

Theurer C. B., O. Lozano, A. Alio, A. Delgado-Elorduy, M. Sadik, J. T. Huber, and R. A. Zinn. 1999. Steam-processed corn and sorghum grain flaked at different densities alter ruminal, small intestine, and total tract digestibility or starch by steers. J. Anim. Sci. 77:2824-2831.

Ward, C. F., and M. L. Galyean. 1999. The relationship between retrograde starch as measured by starch availability measurements and in vitro dry matter disappearance of steam-flaked corn. Burnett Ctr. Internet Prog. Rep. Available at http://www.asft.ttu.edu/burnett_center/progress_reports/bc2.pdf. Accessed April 24, 2007.

Xiong, Y., S. J. Bartle, and R. L. Preston. 1991. Density of steam-flaked sorghum grain, roughage level, and feeding regimen for feedlot steers. J. Anim. Sci. 69:1707-1718.

Zinn, R. A. 1990. Influence of flake density on the comparative feeding value of steam-flaked corn for feedlot cattle. J. Anim. Sci. 1990 68:767-775.

Zinn R. A., F. N. Owens, and R. A. Ware. 2002. Flaking corn: processing mechanics, quality standards, and impacts on energy availability and performance of feedlot cattle. J. Anim. Sci. 80:1145-1156

Table 2-1. Composition of steam-flaked corn based finishing diets containing different flaked densities fed to yearling heifers.

	Flake Density, g/L		
Item, % dry matter	**360**	**411**	**462**
Steam-flaked corn	83.0	83.1	83.0
Alfalfa hay	6.4	6.3	6.4
Corn steep	3.9	3.9	3.9
Limestone	1.9	1.8	1.9
Urea	1.4	1.4	1.4
Supplement[ab]	3.4	3.5	3.4
Nutrients			
Crude protein	13.86	13.80	13.85
Calcium	0.81	0.80	0.81
Phosphorus	0.25	0.25	0.25
Potassium	0.30	0.29	0.30
NE, Mcal/kg			
Maintenance	2.45	2.42	2.37
Gain	1.75	1.72	1.67

[a] Formulated to provide the following per kilogram of total diet DM: 0.1 mg of Co; 10 mg of Cu; 0.6 mg of I; 60 mg of Mn; 0.2 mg of Se; 60 mg of Zn; and 1,200 IU of vitamin A.

[b] Fed at 0.23 kg·heifer^{-1}·d^{-1} (DM basis) to provide 300 mg monensin, 90 mg tylosin per heifer, and 0.5 mg of melengestrol acetate.

Table 2-2. Growth performance for yearling heifers fed steam-flaked corn based finishing diets containing different flake densities.

	Flake Density, g/L					
Item	**360**	**411**	**462**	**SEM**	**Lin**	**Quad**
No. pens (heifers)	16 (116)	16 (118)	16 (121)	-	-	-
Initial weight, kg	336	337	338	5.36	0.51	0.85
Final weight, kg[1]	485	483	481	3.58	0.43	0.92
DMI, kg	7.63	7.67	7.70	0.08	0.52	0.95
ADG, kg[1]	1.29	1.27	1.24	0.08	0.29	0.85
G:F[1]	0.169	0.166	0.161	0.004	0.13	0.83

[1] Calculated using carcass adjusted weights, using hot carcass weight and dividing by common dressing percent of 63.5 %

Table 2-3. Carcass characteristics for yearling heifers fed steam-flaked corn based finishing diets containing different flake densities.

	Flake Density, g/L					
Item	**360**	**411**	**462**	**SEM**	**Lin**	**Quad**
Hot carcass weight, kg	308	307	305	2.27	0.43	0.92
USDA Quality Grade						
Prime, %	3.7	1.7	3.3	1.80	0.88	0.40
Upper 2/3rds Choice, %	21.1	18.0	22.6	3.11	0.73	0.33
Choice, %	61.0	54.5	58.2	4.98	0.69	0.41
Select, %	33.3	42.2	37.6	4.74	0.53	0.25
No roll, %	1.0	0.8	0.9	0.91	0.91	0.87
Dark cutter, %	0.9	0.9	0.0	0.73	0.39	0.62
Marbling score[1]	536	516	536	11.57	0.99	0.17
USDA Yield grade	2.69	2.62	2.75	0.06	0.50	0.16
Yield grade 1, %	5.98	2.45	4.02	2.12	0.51	0.33
Yield grade 2, %	31.0	39.8	24.2	3.98	0.24	0.02
Yield grade 3, %	51.4	51.2	65.2	4.54	0.04	0.21
Yield grade 4 %	11.7	6.6	5.8	2.09	0.06	0.40
Liver Abscess, %	3.6	4.9	5.0	1.89	0.62	0.79
LM area, square cm	83.61	83.16	78.97	1.05	0.01	0.15
Kidney, pelvic, heart fat, %	2.33	2.40	2.39	0.04	0.26	0.40
Back fat 12th rib, mm	14.48	14.73	14.98	0.51	0.57	0.80

[1] Marbling score 500 = Small

Table 2-4. Influence of steam-flaked corn density on dry matter, available starch, and mill efficiency.

	Flake Density, g/L					
Item	**360**	**411**	**462**	**SEM**	**Lin**	**Quad**
Dry Matter, %	84.54	84.39	84.22	0.27	0.39	0.99
Starch Availability, %[1]	46.73	39.27	34.87	0.32	<0.0001	0.0001
Rate, ton/h	2.22	2.45	3.40	0.13	<0.001	0.13
Mill efficiency, %	-	14.0	52.8	---	---	---

[1] Measured by incubating 25 g of whole flake in 100 mL of a 2.5% (wt/vol) amyloglucosidase enzyme solution for 15 min and reading the percentage of solubles on a refractometer.

Table 2-5. Particle size distribution, geometric mean diameter, and geometric standard deviation of steam-flaked corn where flakes densities were 360, 411, or 462 g/L.

	Flake Density, g/L					
Item	**360**	**411**	**462**	**SEM**	**Lin**	**Quad**
Screen size, µm	**Particle size distribution, %[a]**					
9,500	52.15	43.54	24.40	12.57	<0.0001	0.04
6,700	32.97	45.80	64.61	15.92	<0.0001	0.12
4,750	6.63	4.79	3.77	1.45	<0.0001	0.52
3,350	2.94	2.23	1.98	0.50	<0.0001	0.56
2,360	1.51	1.01	0.58	0.47	<0.0001	0.82
1,700	0.76	0.48	0.22	0.27	<0.0001	0.98
1,180	0.62	0.36	0.19	0.22	<0.0001	0.40
< 1,180	2.41	1.79	1.25	0.58	<0.0001	0.82
GMD, µm[b]	6,163	6,565	7,000	55.23	<0.0001	0.81
GSD[c]	3.47	2.90	2.75	0.11	<0.0001	0.13

[a] Percentage of sample remaining on screen

[b] GMD = geometric mean diameter

[c] GSD = geometric standard deviation

Table 2-6. Particle size distribution, geometric mean diameter, and geometric mean diameter standard deviation of complete diets where flakes densities were increased from 360, 411, or 462 g/L.

	Flake Density, g/L					
Item	**360**	**411**	**462**	**SEM**	**Lin**	**Quad**
Screen size, µm	**Particle size distribution, %[a]**					
9,500	4.56	12.15	12.34	4.44	<0.0001	0.004
6,700	22.87	36.01	45.71	11.46	<0.0001	0.41
4,750	22.21	16.47	12.70	4.79	<0.0001	0.37
3,350	15.07	11.26	9.61	2.80	<0.0001	0.16
2,360	9.26	6.12	5.38	2.06	<0.0001	0.01
1,700	6.04	4.19	3.50	1.32	<0.0001	0.14
1,180	14.58	9.98	7.75	3.48	<0.0001	0.24
< 1,180	5.41	3.82	3.01	1.22	<0.0001	0.33
GMD, µm[b]	2,990	4,420	4,565	284.47	0.0004	0.07
GSD[c]	1.80	1.66	1.53	0.03	<0.0001	0.78

[a] Percentage of sample remaining on screen.

[b] GMD = geometric mean diameter.

[c] GSD = geometric standard deviation.

3. Chapter III: Optimizing Use of Sorghum Wet Distiller's Grains with Solubles in Beef Finishing Diets[1]

M. L. May[2], B. E. Depenbusch[2], E. R. Loe[3], M. J. Quinn[2], R. W. Daubert[5], J. J. Sindt[6], J. J. Higgins[4] and J. S. Drouillard[1,7]

Kansas State University
Manhattan, KS 66506

---

[1] This is contribution no. 08-80-J from the Kansas Agricultural Experiment Station, Manhattan, Kansas.

[2] Kansas State University, Department of Animal Science and Industry
[3] South Dakota State University, Department of Animal and Range Sciences
[4] Kansas State University, Department of Statistics
[5] Current Address: 524 N 8th St., Wakeeney, KS 67672
[6] Current Address: 1435 Avenue N, Lyons, KS 67554
[7] Corresponding author: jdrouill@ksu.edu; Phone: (785) 532-1204; Fax: (785) 532-5681

ABSTRACT

Two trials were conducted to determine the optimum level of sorghum wet distiller's grains with solubles (SWDG) in beef finishing diets. In trial 1 crossbreed yearling heifers (n=583; initial BW 385 ± 4 kg) were used in a randomized complete block design with 6 treatments. Treatments consisted of steam-flaked corn (SFC) with SWDG at 0, 8, 16, 24, 32, and 48% on DM basis. A total of 24 pens were used, each containing 23 to 25 animals. Increasing dietary levels of SWDG from 0 to 40% on a DM basis resulted in a linear decrease ($P = 0.01$) in DMI and a quadratic effect ($P = 0.01$) on ADG and feed efficiency. In trial 2, crossbreed yearling steers (n=624; initial BW = 453 ± 0.37 kg), were blocked by weight and randomly allocated, within block, to each of 8 treatment groups in a 2 x 4 factorial arrangement. Factors consisted of grain source dry-rolled corn (DRC) or SFC and level of sorghum wet distiller's grains (0, 10, 20, or 30% of diet dry matter). Total of 24 pens were used, each containing 25 to 26 animals. The DRC diet containing 20% SWDG was mis-formulated, and therefore was not included in the final analysis. Steers fed SFC diets were more efficient ($P < 0.05$) than cattle fed DRC diets. Dry matter intake and ADG were improved by adding SWDG to DRC diets, but resulted in poorer performance when added to SFC diets (interaction, $P < 0.10$). Average daily gain and HCW increased in DRC and decreased in SFC as SWDG levels increased in the diets (interaction, $P < 0.10$). SWDG can effectively replace a portion of the corn in finishing diets, but their nutritional value is greater in DRC diets than in SFC diets.

KEY WORDS: Steam-flaked Corn, Dry-rolled Corn, Distiller's Grains

INTRODUCTION

With the continued expansion of the ethanol industry production of distiller's grains wet and dry have also increased. Energy costs have also increased, increasing the cost to dry wet distiller's grains (WDG). Many plants with close proximity to livestock operations have decided to sell the WDG to producers to decrease drying costs. Transporting the WDG is more expensive than dry distiller's grains because of the difference in moisture. Economic analysis estimated by Vander Pol et al., 2006 would suggest feedlots adjacent to plants have a greater incentive to feed higher levels of WDG up to 40% (dry basis) in dry-rolled corn (DRC) diets, optimizing ADG, and decreasing days needed for finishing and overall production costs. When comparing dry distiller's grains to WDG Ham et al. (1994) observed an increase in DMI, and improvements in feed efficiency when feeding WDG compared to DDG, with no effect on ADG.

Steam-flaked corn (SFC) improves ruminally available starch compared to DRC and by making more starch ruminally available, improving ADG, decreasing DMI and improving feed efficiency, and shifting site and extent of digestion (Barajas and Zinn 1998 and Zinn et al., 1998). Comparing the two grain sources with varying levels of sorghum wet distiller's grains with solubles (SWDG) is important, as a large number of feedlots in the High-Plains commonly flake grain. Lodge et al. (1997) observed WDG at 40% (dry basis) in DRC diets had no effect on DMI, ADG, or feed efficiency. Larson et al. (1993) replaced DRC with WDG at levels of 5.2, 12.6 and 40% diet DM. Daily gain and feed efficiency were improved as WDG percentage increased. Therefore experiments were conducted to establish optimum SWDG levels in beef finishing diets with SFC as the basal grain source, and comparing DRC and SFC with the addition of SWDG.

MATERIALS AND METHODS

Trial 1

The study also was conducted in accordance with procedures approved by the Kansas State University Institutional Animal Care and Use Committee Protocol No. 2315. Five hundred and eighty-three crossbred-yearling heifers (initial BW 385 ± 4 kg) were obtained and used in a randomized complete block design finishing study. Heifers were fed steam-flaked corn (360 g/L) based finishing diets with varying levels of SWDG (0, 8, 16, 24, 32, and 48% on DM basis). Finishing diets are further described in Table 1.

Upon arrival heifers were processed, identified with uniquely numbered tags in both ears, received injections of Bovishield-4 and Fortress-7 vaccines (Pfizer Animal Health, Exton, PA), administered Phoenectin pour-on (Phoenix Scientific Inc., St. Joseph, MO), and implanted with estradiol/trenbolone acetate implant (Revalor 200, Intervet Inc., Millsboro, DE). Heifers were fed a common diet for 136 d prior to initiation of study. Heifers were housed in 24 dirt-surfaced pens (432 m^2) with automatic water fountains and 9.4 m of bunk space. Pens contained 23 to 25 heifers, with 24 pens used for evaluation. Heifers were offered *ad libitum* access to diets delivered once daily for 58 d. Dietary NE_m and NE_g values were calculated based on heifer performance (NRC 1984).

Pen weight of animals were determined immediately prior to shipping to a commercial abattoir. Cattle were harvested on d 58 at a commercial abattoir in Emporia, KS, at which time carcass data were collected. Hot carcass weight and liver abscess scores were obtained at the time of harvest. Longissimuss muscle area, subcutaneous fat thickness over 12th rib, KPH fat, marbling score, USDA quality grades, and USDA yield grades were measured following a 24-h chill. Final BW was calculated by dividing carcass weight by a common dressing percent of 63.5%.

Statistical analysis

Growth performance and carcass characteristics were analyzed statistically using the Proc GLM procedure of (SAS Inst., Cary NC, 2002). Pen was the experimental unit and block was used as a random effect. Effects of diet were determined using linear, quadratic, and cubic contrast.

Trial 2

The study was conducted in accordance with procedures approved by the Kansas State University Institutional Animal Care and Use Committee Protocol No. 2315. Six-hundred twenty-one crossbreed steers (initial BW = 424 ± 1 kg) were used randomized complete block design finishing study. Steers were fed DRC or SFC (360 g/L) based finishing diets with varying levels of SWDG (0, 10, 20, and 30% on DM basis). The

DRC diet containing 20% SWDG was mis-formulated, and therefore is not included in final analysis. Finishing diets are further described in Table 2.

Upon arrival steers were processed, identified with uniquely numbered tags in both ears, injected with a 7-way clostridial bacterin; 4-way viral vaccine;(Fortress-7 vaccines; Bovishield-4; Pfizer Animal Health, Exton, PA), and administered topical parasiticide (Phoenectin pour-on, Phoenix Scientific Inc., St. Joseph, MO), implanted with 24 mg of estradiol and 120 mg of trenbolone acetate (Revalor-S Intervet Inc., Millsboro, DE). Animals were fed a common diet before initiation of study 14 d to minimize differences in gastrointestinal fill. Steers were housed in 24 dirt-surfaced pens (432 m^2) with automatic water fountains and 9.4 m of bunk space. On d -1 cattle were individually weighed on scales to the nearest 0.454 kg. On d 0 animals were allocated to block by initial weight, randomly assigned to pen within each block and pens were stratified to treatments so that differences and variances in initial BW among treatments groups were minimized. Pens contained 24 to 26 steers, with 24 pens used for evaluation. Steers were offered *ad libitum* access to diets delivered once daily for 69, 96 and 119 d, within block respectively. Dietary NE_m and NE_g values were calculated based on heifer performance (NRC 1984).

Pen weight of animals were determined immediately prior to shipping to a commercial abattoir. Cattle were harvested by block on d 69, 96 and 119 respectively, at a commercial abattoir in Emporia, KS, at which time carcass data were collected. Hot carcass weight and liver abscess scores were obtained at the time of harvest. Longissimuss muscle area, subcutaneous fat thickness over 12th rib, KPH fat, marbling score, USDA quality grades, and USDA yield grades were measured following a 24-h chill. Final BW were calculated by dividing carcass weight by a common dressing percent of 63.5%. Each load of SWDG was sampled when the load arrived. Sulfur concentrations for each weekly sample are shown in figure 1.

Statistical analysis

Growth performance and carcass characteristics were analyzed statistically using the Proc Mixed procedure of SAS (2002). Pen was the experimental unit and random effect included block. The effects of grain processing method, distiller's grains and the interaction of grain by distiller's grain were tested.

RESULTS AND DISCUSSION

Trial 1

Increasing dietary levels of SWDG from 0 to 40% on a DM basis resulted in a linear decrease ($P = 0.01$) in DMI and a quadratic effect ($P = 0.01$) on ADG and feed efficiency. Using the first derivative of the quadratic equation and solving for zero indicated that ADG and feed efficiency reached an asymptote with 14.3 and 15.4% SWDG respectively. Larson et al. (1993) observed similar results in that DMI was decreased as corn wet distiller's grains increased from 0 to 40% (DM basis). However, they also reported that ADG and feed efficiency increased with increasing levels of corn WDG. Likewise, Farlin (1981) reported reduced DMI and increased ADG and feed efficiency when corn wet distiller's grains were included into the diet at 43 and 64% of the diet DM, respectively. Firkins et al. (1985) did not see a difference in DMI, but did observe an increase ($P < 0.10$) for ADG and feed efficiency with increasing levels of corn WDG up to 50% on DM basis.

Conflicting results between our data and that of Farlin (1981), Firkins (1985), and Larson et al. (1993) may be explained by the different corn processing methods used in the studies. In our study, we used SFC based finishing diets, whereas Farlin (1981) and Larson et al. (1993) used DRC based finishing diets, and Firkins (1985) used high-moisture corn based finishing diets. Optimal level of distiller's grains (DG) appears to be related to energy density of the ingredient it is replacing. Based on the NRC (1984 and 1996) SFC has a 6% and 4% relative advantage, respectively, for NE_m over DRC. Research from Barajas and Zinn (1998) and Zinn et al. (1998) would suggest that the feeding value of SFC is 10 – 16% higher than that of DRC. Distiller's grains contain the protein, fat, and fiber components of the cereal seed stock used in the ethanol process. Replacing a highly digestible starch product such as SFC with DG leads to a lower energy density of the diet which yielded lower optimal distiller's grain inclusion levels based on G:F. Dry-rolled corn is not as readily digested within the rumen therefore, higher levels of DG can be added without negatively affecting feed conversions. Secondly, DG contains high levels of crude protein (30-34%) of which 30% (NRC 1996) is considered DIP. Finishing diets containing DG may be sufficient in metabolizable protein, but may lack adequate DIP for ruminal fermentation. Research by Cooper et al. (2002) suggests that DIP requirements are higher for SFC diets than for DRC diets, due to greater ruminal starch digestion and microbial growth. Our diets were well in excess of NRC requirements for finishing animals but available ruminal nitrogen may be limiting ruminal fermentation in diets containing SFC and DG.

Trial 2

When comparing DRC to SFC, cattle performance yielded typical results. Dry matter intake was not affected by grain processing method ($P > 0.10$). Average daily gain and final BW had tendencies to be higher for cattle fed DRC compared to SFC counterparts ($P = 0.13$). Feed efficiency was improved for cattle fed SFC vs. DRC cohorts ($P < 0.05$). Corona et al., 2005, Owens 1997, and Zinn 1998 found similar results with improvements in feed efficiency, decreases in DMI, and either no change or an improvement in ADG. There was a tendency to increase dark cutting beef when flaking grain ($P = 0.09$). This was due to the fact that two animals were dark cutters in the SFC treatment groups, and no animals were dark cutters in DRC cattle.

In figures 1 and 2, DMI and G:F are shown. The DRC 20% SWDG treatment was estimated based on the responses in the other 3 treatments. These curves show the effects of DG on the two grain processing methods. Distiller's grains had an effect on DMI ($P < 0.05$). Intake was increased when DG were replacing a portion of the DRC in diets, and intake decreased when DG replaced SFC. The response to DG in the two grain processing methods did have a tendency for an interaction with the addition of DG ($P = 0.08$). Dry matter intake was not different between grain processing methods when DG was not included in the diet. At 10% SWDG those intakes were improved for cattle fed DRC vs. SFC. The two curves only are further separated as dietary percentages of DG increased ($P < 0.05$). Feed efficiency also had a similar response to DG. When DG were not present in the diet, SFC had about a 13% improvement in efficiency ($P < 0.05$). As DG were added to the diet, feed efficiency estimated lines came closer together. As SWDG was increased in the diet to 10, 20, and 30% dietary DM, the efficiencies were not different from one another.

There was a tendency for an interaction in ADG when including DG in SFC and DRC diets (P = 0.07). Daily gain was improved when increasing DG in DRC diets, and decreased in SFC diets. There was a tendency for an interaction between grain processing method and the addition of SWDG in final weight, improving final weight in DRC cattle and decreasing final weight in SFC fed cattle as SWDG increased in the diet (P = 0.13). There was also a tendency for a grain type by SWDG interaction in HCW where cattle fed DRC compared to SFC increased carcass weight as DG increased (P = 0.07).

Marbling score had a tendency to improve when adding DG to diets comprised of either grain source (P = 0.09). Marbling score would also follow observations made in average yield grade. As DG increased in the diet, yield grade was also increased numerically. This would be similar to results observed in trial 1. There was a grain processing method by SWDG interaction in the percentage of yield grade 5 steers (P < 0.05). This interaction was driven by a larger percentage of animals with a yield grade 5 occurring in cattle fed SFC vs. DRC.

Using the first derivative of the quadratic equation and solving for zero indicated that DMI, ADG and G:F reached an asymptote in DRC diets of 21.7, 18.8 and 17.1% SWDG, respectively. Similarly, solving for optimum levels in SFC diets optimum levels for DMI, ADG, and G:F were 4.7, 0, and 0% respectively. Our DRC diets would approach optimum levels observed by Firkins et al., 1985 and Ham et al., 1994; which suggest optimum levels of DG between 25 and 50% diet DM. Not having the DRC 20% SWDG treatment is unfortunate in that it could have shifted the optimum levels of DG higher or lower. Differences in optimum levels may be different because of the grain used for ethanol production. All of the studies used corn DG vs. our sorghum DG product. However observations made by Al-Suwaiegh et al. (2002) suggested that sorghum DG did not affect cattle performance when compared to corn DG.

A possible explanation as to why optimum inclusion levels were different between trial 1 and trial 2, is that cattle fed SFC diets had different roughage levels. The roughage level in experiment 1 was slightly higher (7% DM), while experiment 2 had roughage at about 6% DM. The higher roughage level could possibly have a higher buffering capacity increasing ruminal pH and possibly improving the ruminal environment, and improving fiber digestion. Another explanation could be in trial 1 no added liquid was added to the diet. In trial 2 corn steep liquor was added to the diet. Trial 1 may have been dryer than the other treatments and that could explain why we saw the quadratic response in DMI, ADG, and G:F up to 16%.

Zinn et al (1995) compared DRC diets to SFC diets on total tract digestibility and two intake levels. Ruminal pH for the DRC was higher than cattle fed SFC, 6.07 and 5.67, respectively. With readily fermentable carbohydrates that are present in cattle fed SFC, this gives rise to rapidly growing microbes that can handle a high percentage of carbohydrates and grow at a pH lower than where fiber digestion is optimized. May et al. (2007), were able to feed 25% dry corn distiller's grains in SFC or DRC diets with no deleterious effects on cattle performance. Roughage levels in their trials were about 9% of the diet. The difference in roughage level may be important when including DG in SFC diets.

One animal at initiation of study did show signs of polioencephalomalcia (PEM) 12 h after assigned to treatment of DRC containing 10% SWDG. Animal was dosed with thiamine and allowed feed and water. Animal had full recovery and was placed back in pen. In most cases of PEM animals showing clinical signs do so after 10-14 days, as stated by Gould (1998). Diagnosis of this animal was believed to be PEM and treated as such, but because the animal had a full recovery we can only speculate as to causes for the clinical signs of PEM.

After looking at sulfur samples of each load, the sulfur content of the first load was 0.86%. Although the animal was only fed 10% SWDG, if the animal consumed a high percentage of the SWDG this could have possibly have caused sulfur toxicity. Animals were not fed SWDG prior to study, so no adaptation to the by-product existed. Niles et al. (2000) had three cases where corn gluten feed, or corn distiller's solubles, were fed to growing beef animals that caused PEM. Once these feeds were pulled from the animals, the cases ceased, and if the animals were treated early enough had a full recovery. The animals in these cases all occurred 2-3 w after by-products were fed. Gould (1998) sulfate reduction within the rumen could potentially be harmful to beef animals due to the increase production of sulfides. There were no other PEM cases throughout the duration of the trial. Sulfur concentration between loads had an average value of 0.79 ± 0.07%.

In areas of high ethanol production and an abundance of DG, it may be economically feasible to include a portion of the diet with DG. Grain processing method has an impact on expected cattle performance. Wet distiller's grains can effectively replace a portion of the corn in finishing diets, but their nutritional value is greater in DRC diets compared to SFC diets. More extensive research needs to be done to compare differences between grain processing method and level of distiller's grain. Additionally digestion of distiller's grains between processing methods may help us understand why responses have been different between DRC and SFC.

LITERATURE CITED

Al-Suwaiegh, S., K. C. Fanning, R. J. Grant, C. T. Milton, and T. J. Klopfenstein. 2002. Utilization of distiller's grains from the fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. J. Anim. Sci. 80:1105-1111.

Barajas, R. and R. A. Zinn. 1998. The feeding value of dry-rolled and steam-flaked corn in finishing diets for feedlot cattle: influence of protein supplementation. J. Anim. Sci. 76: 1744-1752.

Cooper, R. J., C. T. Milton, T. J. Klopfenstein, and D. J. Jordon. 2002. Effect of corn processing on degradable intake protein requirement on finishing cattle. J. Anim. Sci. 80:242-247.

Farlin, S. D. 1981. Wet distiller's grains an excellent substitute for corn in cattle finishing diets. Anim. Nutr. Health 35:36.

Firkins, J. L., L. L. Berger, and G. C. Fahey, Jr. 1985. Evaluation of wet and dry distiller's grains and wet and dry gluten feeds for ruminants. J. Anim. Sci. 60:847-860.

Ham, G. A., R.A. Stock, T. J. Klopfenstein, E. M. Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distiller's byproducts compared with dried corn distiller's grains with solubles as a source of protein and energy for ruminants. J. Anim. Sci. 72:3246-3257.

Hover, W. H. 1986. Chemical factors Involved in ruminal fiber digestion. J. Dairy Sci. 69:2755-2766.

Larson, E. M., R. A. Stock, T. J. Klopfenstein, M. H. Sindt, and R. P. Huffman. 1993. Feeding value of wet distiller's byproducts for finishing ruminants. J. Anim. Sci 71:2228-2236.

Lodge, S. L, R. A. Stock, T. J. Klopfenstein, D. H. Shain, and D. W. Herold. 1997. Evaluation of corn and sorghum distiller's byproducts. J. Anim. Sci. 75:37-43.

May, M. L., M. L. Hands, M. J. Quinn, B. E. Depenbusch, J. O. Wallace, C. D. Reinhardt, and J. S Drouillard. 2007. Dry distiller's grains with solubles in steam-flaked corn or dry-rolled corn diets with reduced roughage levels. J. Anim. Sci. 85 (Supp 1):528 (Abstr.).

Niles G.A., S.E. Morgan, and W.C. Edwards. 2000. Sulfur-induced polioencephalomolacia in stocker calves. J. Vet Hum. Toxicology. 42:290-291.

NRC, 1984. Nutrient requirements of beef cattle. 6th Revised Edition. National Academy Press. Washington, D.C.

NRC, 1996. Nutrient requirements of beef cattle. 7th Revised Edition. National Academy Press. Washington, D.C.

Vander Pol, K. J., G. E. Erickson, T. J. Klopfenstein, and D. R. Mark. 2006. Economic optimum use of wet distiller's grains in feedlots. Nebraska Beef Report. pp. 54-56.

Zinn, R. A., C. F. Adam, and M. S. Tamayo. 1995. Interaction of Feed Intake Level on Comparative Ruminal and Total Tract Digestion of Dry-Rolled and Steam-Flaked Corn. J. Anim. Sci. 73:1239-1245.

Zinn, R. A., E. G. Alvarez, M. F. Montaño, A. Plascencia, and J. E. Ramirez. 1998. Influence of tempering on the feeding value of rolled corn in finishing diets for feedlot cattle. J. Anim. Sci. 76:2239-2246.

Table 3-1. Composition of steam-flaked corn based finishing diets containing different levels of sorghum wet distiller's grains with solubles fed to yearling heifers.

	Sorghum wet distiller's grains, %					
Ingredient, %	0	8	16	24	32	40
Steam-flaked corn	83.6	76.9	70.3	63.6	56.1	48.1
Sorghum wet distiller's grain with solubles	---	8.0	16.0	24.0	32.0	40.0
Alfalfa hay	7.0	7.0	7.0	7.0	7.0	7.0
Soybean meal	3.4	2.4	1.3	0.7	---	---
Limestone	1.5	1.5	1.5	1.5	1.5	1.5
Urea	1.2	0.8	0.5	0.1	---	---
Vitamin/mineral premix[a]	0.9	0.9	1.0	1.0	1.0	1.0
Supplement[b]	2.5	2.5	2.5	2.5	2.5	2.5
Chemical composition %						
Diet DM	81.5	73.3	66.6	61.1	56.5	52.6
Crude Protein	15.3	15.6	16.0	16.3	17.6	19.5
Crude Fat	3.9	4.5	5.0	5.6	6.1	6.5
Calcium	0.70	0.70	0.70	0.71	0.71	0.71
Phosphorus	0.29	0.34	0.40	0.45	0.50	0.55
NE, Mcal/kg						
Maintenance	2.22	2.27	2.37	2.25	2.20	2.17
Gain	1.54	1.58	1.67	1.57	1.52	1.49

[a] Formulated to provide the following per kilogram of total diet DM: 0.1 mg of Co; 10 mg of Cu; 0.6 mg of I; 60 mg of Mn; 0.2 mg of Se; 60 mg of Zn; and 1,200 IU of vitamin A.

[b] Fed at 0.23 kg·heifer^{-1}·d^{-1} (DM basis) to provide 300 mg monensin, 90 mg tylosin per heifer, and 0.5 mg of melengestrol acetate.

Table 3-2. Composition of dry-rolled or steam-flaked corn based finishing diets containing different levels of sorghum wet distiller's grains with solubles fed to yearling steers.

	Dry-rolled corn				**Steam-flaked corn**			
	SWDG[a]				**SWDG[a]**			
Ingredient, %	**0**	**10**	**20**	**30**	**0**	**10**	**20**	**30**
Dry-rolled corn	83.45	78.70	---	59.32	---	---	---	---
Steam-flaked corn	---	---	---	---	83.26	78.45	69.17	58.99
Sorghum wet distiller's grains with solubles	---	10.33	---	30.77	---	10.45	20.79	31.03
Alfalfa hay	5.98	5.96	---	5.92	6.06	6.03	6.00	5.96
Corn Steep	5.06	---	---	---	5.12	---	---	---
Soybean meal	---	1.39	---	---	---	1.41	---	---
Limestone	1.53	0.91	---	1.48	1.54	0.91	1.51	1.50
Urea	1.17	0.25	---	---	1.18	0.25	---	---
Vitamin/mineral premix[b]	0.65	0.33	---	0.37	0.66	0.33	0.37	0.37
Supplement[c]	2.16	2.15	---	2.13	2.18	2.17	2.17	2.15
Chemical composition %								
Diet Dry Matter %	83.06	74.94	---	59.56	77.65	70.66	63.28	57.40
Crude Protein	14.77	14.68	---	16.62	14.77	14.68	14.29	16.62
Crude Fat								
Calcium	0.69	0.68	---	0.69	0.69	0.69	0.70	0.70
Phosphorus	0.28	0.34	---	0.50	0.28	0.34	0.42	0.50
NE, Mcal/kg								
Maintenance	2.25	2.32	---	2.27	2.48	2.43	2.40	2.34
Gain	1.56	1.62	---	1.58	1.76	1.72	1.69	1.64

[a] Sorghum wet distiller's grains with solubles

[b] Formulated to provide 0.1 ppm cobalt, 8 ppm copper, 0.5 ppm iodine, 48 ppm manganese, 0.25 ppm selenium, 48 ppm zinc, and 1000 IU/lb vitamin A in the diet dry matter.

[c] Fed at 0.23 $kg \cdot steer^{-1} \cdot d^{-1}$ (DM basis) to provide 300 mg monensin and 90 mg tylosin per steer.

Table 3-3. Heifer growth performance for yearling heifers fed steam-flaked corn based finishing diets containing different levels of sorghum wet distiller's grains with solubles.

	Sorghum wet distiller's grains, %								
Item	**0**	**8**	**16**	**24**	**32**	**40**	**SEM**	**Lin**	**Quad**
No. of pens (heifers)	4 (99)	4 (93)	4 (92)	4 (98)	4 (102)	4 (99)	-	-	-
Days on feed	58	58	58	58	58	58	-	-	-
Initial BW, kg	385	385	385	385	385	385	3.81	0.61	0.09
Final BW, kg[1]	459	467	465	461	456	452	5.22	0.14	0.20
DMI, kg/d	8.6	9.2	8.6	8.7	8.5	8.3	0.13	0.01	0.37
ADG, kg/d[1]	1.27	1.41	1.38	1.31	1.22	1.16	0.004	0.01	0.01
G:F	0.147	0.154	0.161	0.150	0.144	0.139	0.0043	0.04	0.01

[1] Calculated using carcass adjusted weights, using hot carcass weight and dividing by common dressing percent of 63.5 %

Table 3-4. Carcass characteristics for yearling heifers fed steam-flaked corn based finishing diets containing different levels of sorghum wet distiller's grains with solubles.

	Sorghum wet distiller’s grains, %								
Item	**0**	**8**	**16**	**24**	**32**	**40**	**SEM**	**Lin**	**Quad**
HCW, kg	291	296	295	293	289	287	3.31	0.15	0.20
Dressing percent	63.7	62.7	63.2	62.7	62.9	62.4	0.32	0.02	0.82
LM area, cm^2	81.3	78.7	80.7	79.4	77.4	75.5	1.35	0.01	0.15
KPH fat, %	2.1	2.2	2.2	2.2	2.2	2.2	0.04	0.41	0.81
12th –rib fat, cm	0.89	0.99	0.94	0.97	0.94	1.02	0.04	0.14	0.70
USDA yield grade	1.76	2.06	1.87	2.15	2.01	2.13	0.09	0.02	0.43
Yield grade 1, %	32.8	15.5	33.2	11.8	25.8	13.4	4.8	0.04	0.99
Yield grade 2, %	57.8	63.0	46.7	63.2	47.4	61.6	4.5	0.77	0.38
Yield grade 3, %	9.2	21.4	19.9	22.7	26.7	23.7	5.4	0.06	0.55
Yield grade 4, %	---	---	---	2.17	---	---	1.0	0.36	0.47
USDA quality grade, %									
Prime, %	---	1.1	---	---	---	---	0.46	0.39	0.74
Choice, %	33.9	47.5	33.9	56.4	34.9	53.4	5.7	0.10	0.68
Select, %	57.7	46.2	63.7	38.4	59.4	44.2	5.1	0.23	0.95
No roll, %	5.2	4.0	2.2	3.0	4.7	1.1	2.2	0.34	0.68
Marbling score[a]	486	507	482	524	500	509	9.1	0.08	0.64
Liver abscess, %	1.9	3.2	2.2	2.0	2.0	2.2	1.6	0.85	0.96

[a] Marbling score 400 = Slight, 500 = Small

Table 3-5. Steer performance and carcass characteristics of steers dry-rolled or steam-flaked corn based finishing diets containing different levels of sorghum wet distiller's grains with solubles.

	Dry-Rolled Corn				Steam-Flaked Corn							
	SWDG[a]				SWDG					P-Values		
Item	**0**	**10**	**20**	**30**	**0**	**10**	**20**	**30**	**SEM**	**SWDG**	**Grain**	**SWDG*Grain**
No. of pens (steers)	8 (77)	8 (77)	---	8 (78)	8 (78)	8 (78)	8 (78)	8 (78)	---	---	---	---

Initial BW, kg	453	453	---	452	452	453	452	452	0.40	0.51	0.76	0.78
Final BW, kg[1]	563	574	---	573	572	570	565	559	7.01	0.24	0.13	0.13
ADG, kg/d[1]	1.14	1.30	---	1.28	1.29	1.24	1.18	1.15	0.21	0.30	0.07	0.07
HCW, kg	357	365	---	364	363	362	359	355	4.45	0.57	0.46	0.07
Dressing percent	64.3	64.1	---	64.6	63.9	63.8	63.4	63.9	0.01	0.20	0.41	0.64
LM area, cm^2	86.7	88.90	---	87.5	87.5	88.5	85.9	87.0	1.48	0.40	0.53	0.27
KPH fat, %	2.51	2.47	---	2.47	2.44	2.37	2.48	2.36	0.04	0.86	0.22	0.56
12th –rib fat, cm	0.96	1.03	---	1.06	1.03	1.01	1.10	0.97	0.05	0.15	0.34	0.20
USDA yield grade	1.98	2.05	---	2.22	2.03	2.00	2.15	1.98	0.09	0.56	0.63	0.96
Yield grade 1, %	28.48	23.29	---	17.95	24.61	29.48	18.00	24.36	3.75	0.32	0.38	0.37
Yield grade 2, %	43.73	52.67	---	44.87	50.67	42.31	49.38	56.41	6.78	0.85	0.42	0.11
Yield grade 3, %	24.10	21.37	---	32.05	18.21	26.92	27.38	12.82	6.71	0.48	0.56	0.17
Yield grade 4, %	2.47	1.28	---	3.85	3.90	1.28	3.95	3.85	1.74	0.42	0.72	0.90
Yield grade 5, %	0.00	1.39	---	0.00	1.33	0.00	0.00	1.28	0.84	0.97	0.19	0.04
USDA Quality Grade												
Choice %	26.85	32.69	---	30.97	28.61	21.79	31.33	15.38	5.45	0.43	0.88	0.84
Select %	66.78	64.74	---	64.08	67.44	73.08	64.82	78.21	6.02	0.73	0.68	0.87
No roll, %	6.37	2.56	---	5.28	3.95	2.13	2.56	6.41	2.82	0.32	0.58	0.54
Dark cutter, %	0.00	0.00	---	0.00	1.28	0.00	1.28	0.00	0.66	0.28	0.09	0.28
Marbling score[b]	358	381	---	379	353	362	362	357	8.86	0.09	0.68	0.38
Liver abscess, %	8.99	6.41	---	10.36	3.90	10.25	9.13	8.97	3.14	0.77	0.23	0.15

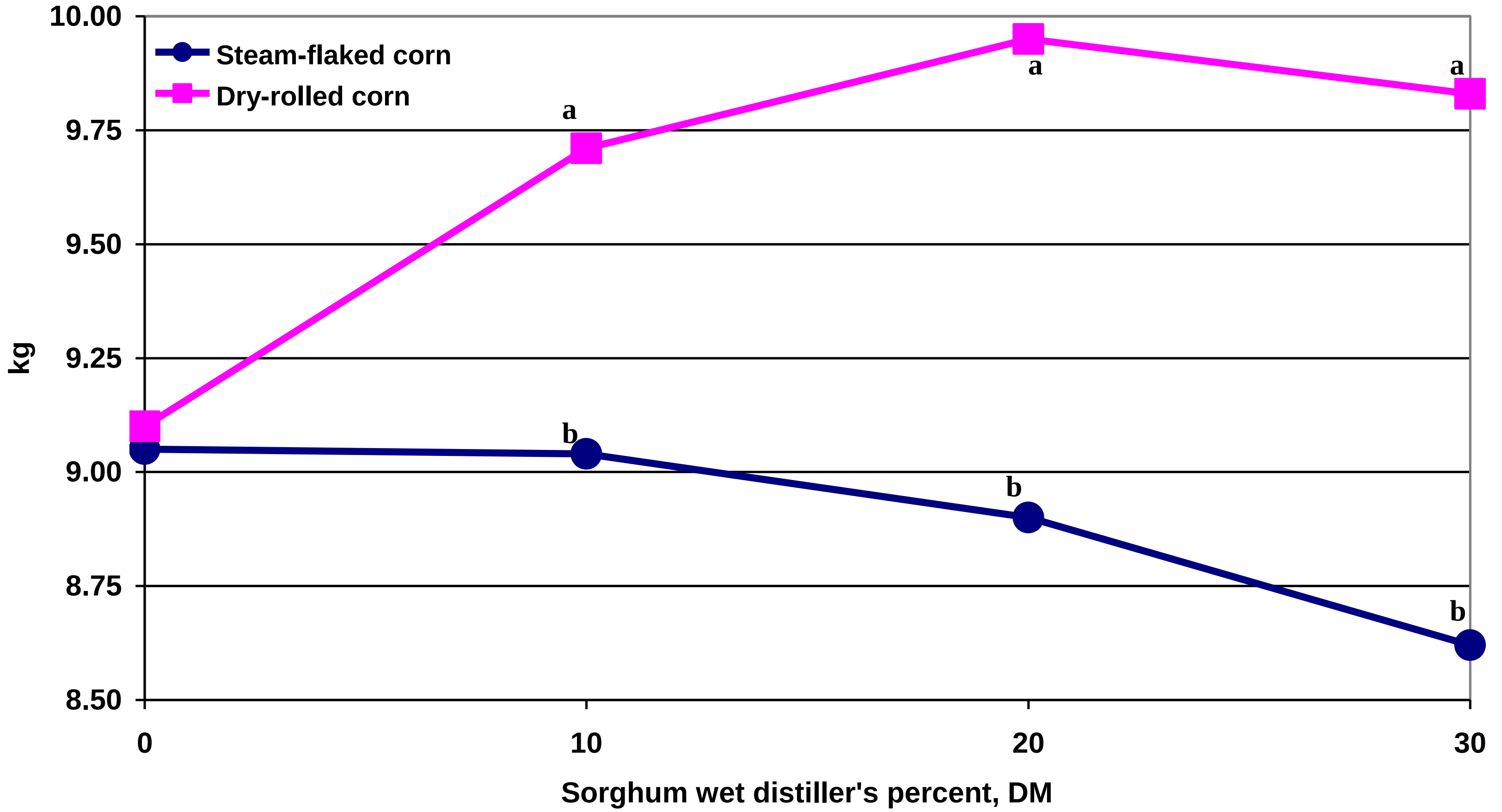
---

[1] Calculated using carcass adjusted weights, using hot carcass weight divided by common dressing percent of 63.5%.

[a] SWDG = Sorghum wet distiller's grains

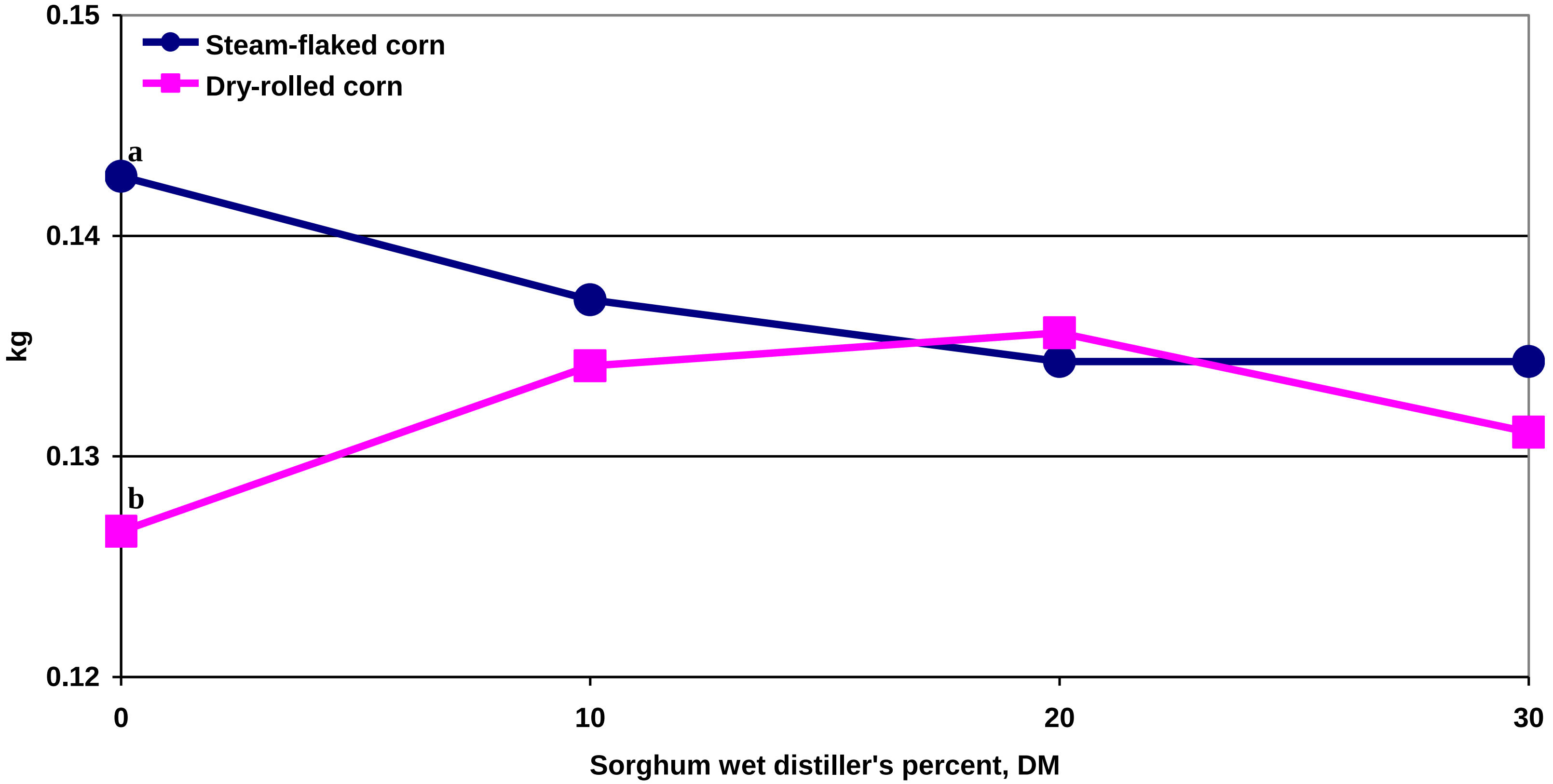
[b] Marbling score 300 = Traces

Figure 3-1. Dry matter intake for yearling steers fed dry-rolled or steam-flaked corn based finishing diets containing different levels of sorghum wet distiller's grains with solubles.



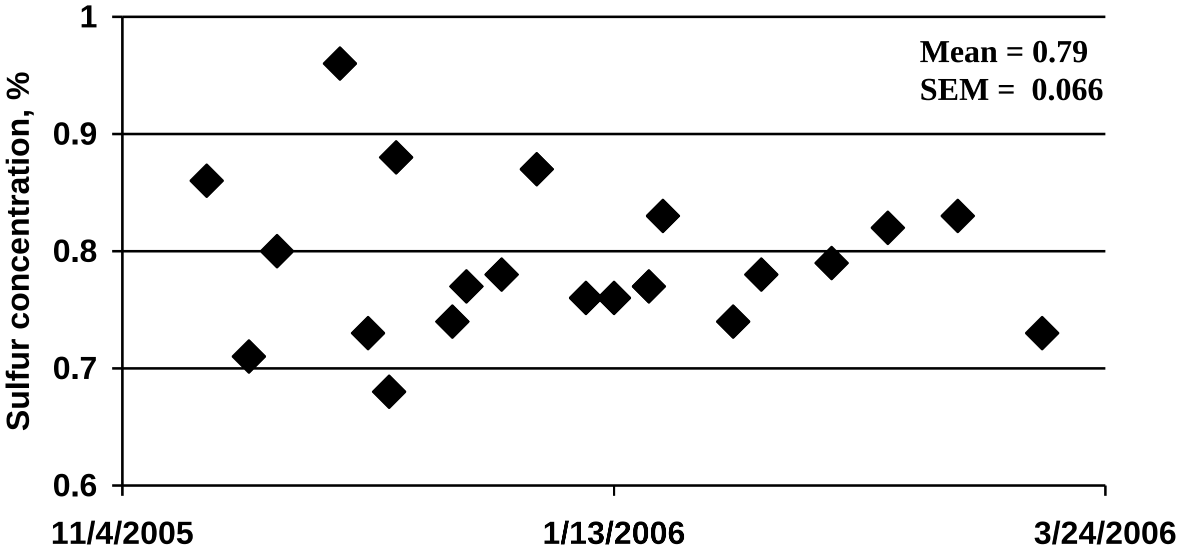
^{a,b} Within diet percentage, means that do not have a common superscript differ ($P < 0.05$).
Grain effect ($P = 0.78$)
Distiller's grain effect ($P = 0.04$)
Grain by distiller's grain interaction ($P = 0.08$)
Pooled SEM = 0.22

Figure 3-2. Feed efficiency for yearling steers fed dry-rolled or steam-flaked corn based finishing diets containing different levels of sorghum wet distiller's grains with solubles.



^{a,b} Within diet percentage, means that do not have a common superscript differ ($P < 0.05$).
Grain effect ($P < 0.05$)
Distiller’s effect ($P = 0.78$)
Grain by distiller’s grain interaction $P = 0.18$
Pooled SEM = 0.005

Figure 3-3. Sulfur concentration of sorghum wet distiller's grains with solubles between loads throughout trial.



4. Chapter IV: Dry Distiller's Grains with Solubles with Reduced Roughage Levels in Beef Finishing Diets[1]

M. L. May[2], M. J. Hands[2], M. J. Quinn[2], B. E. Depenbusch[2], J. O. Wallace[1], C. D. Reinhardt[2] and J. S. Drouillard[2,3]

Kansas State University
Manhattan, KS 66506

---

[1] This is contribution no. 08-79-J from the Kansas Agricultural Experiment Station, Manhattan, Kansas.
[2] Kansas State University, Department of Animal Science and Industry
[3] Corresponding author: jdrouill@ksu.edu; Phone: (785) 532-1204; Fax: (785) 532-5681

ABSTRACT

Two finishing trials were conducted to evaluate the use of dry corn distiller's grains with solubles (DDG) in beef finishing diets. Trial 1, crossbred heifers (n = 377; BW 378 ± 1.4 kg) were fed diets consisting of steam-flaked corn (SFC) with 0% DDG and 15% corn silage (CS), 25% DDG and 15% CS, or 25% DDG and 5% CS. Heifers fed the 0% DDG diet vs. heifers fed 25% DDG and 5% CS had decreased DMI 9.01 vs. 8.52 kg/d and higher dressing percentage 63.23 vs. 63.73% ($P < 0.05$). Inclusion of DDG with 15% CS reduced LMA when compared to 0% DDG and 15% CS ($P < 0.05$). There was a tendency to increase yield grade 4 and 5 in heifers consuming DDG ($P < 0.10$). Trial 2, crossbreed heifers (n = 582; BW 377 ± 0.4 kg) were fed diets similar to experiment 1, but utilized SFC or dry-rolled corn (DRC) as the basal grain. Treatments contained DRC with no DDG and 15% CS, DRC with 25% DDG and 15% CS, and DRC with 25% DDG and 5% CS. Feeding SFC compared to DRC improved G:F ($P < 0.05$). Average USDA yield grade was higher for cattle fed DRC compared to SFC ($P < 0.05$), but when calculating yield grade there were no differences among treatments. The 5% CS groups in both grain sources consumed less feed daily and were also were more efficient than their counterparts fed 15% CS ($P < 0.05$). Average yield grade and carcass quality were not affected by inclusion of DDG. Results indicate that roughage levels can be reduced in feedlot diets containing DDG with no adverse effects on performance, or carcass quality.

KEY WORDS: Steam-flaked corn, Dry-rolled corn, distiller's grains, feedlot

INTRODUCTION

Roughages are perceived as being an essential component of feedlot diets in order to reduce the incidence of digestive disturbances. Generally speaking, roughages are relatively expensive in relation to their nutritional value and digestibility. Loerch et al., 1998 evaluated diets containing high-moisture corn with 0, or 15% corn silage (DM basis) and found that feed efficiency was improved for 0 vs. 15% corn silage. Loerch et al., 1998 Kreikemeier et al., 1990 and Firkins et al., 1985 observed increases in condemned livers with the absence of roughage. Stock et al., 1990 evaluated interactions between in roughage level and monensin and observed improvements in feed efficiency were observed with variable results on ADG. Defoor et al., 2002 evaluated different roughage types and found more fibrous roughage sources can be fed at lower percentages of the diet; allowing the animal to consume a more energy dense diet.

Ham et al. (1994) suggested that feeding distiller's grains (wet or dry) in dry-rolled corn diets increases digestibility. Expansion of the ethanol industry into the Southern Plains has prompted research for their value in beef finishing diets containing dry-rolled corn (DRC) and steam-flaked corn (SFC). In making ethanol from grains, most of the starch is fermented, thus yielding a residue in which the fiber, protein, and mineral fractions of the grain are concentrated along with yeast cells. DDG is more digestible and could be a possible replacement for a portion of the roughage in finishing beef diets.

MATERIALS AND METHODS

Trial 1

The study was conducted in accordance with procedures approved by the Kansas State University Institutional Animal Care and Use Committee (protocol no. 2315). Three hundred eighty four crossbred heifers (BW 378 ± 1.4 kg) were used in a randomized complete block design finishing study. Dietary treatments were steam-flaked corn (360 g/L) with no DDG and 15% corn silage (CON), SFC with 25% DG and 15% corn silage (HI), and SFC with 25% DG and 5% corn silage (LO). Finishing diets are further described in Table 1.

Upon arrival heifers were processed by identifying with uniquely numbered tags in both ears, injected with a 7-way clostridial bacterin; 4-way viral vaccine; (Fortress-7 vaccines; Bovishield-4; Pfizer Animal Health, Exton, PA), and administered topical parasiticide (Phoenectin pour-on; Phoenix Scientific Inc., St. Joseph, MO), implanted with estradiol/trenbolone acetate implant (Revalor 200, Intervet Inc., Millsboro, DE). Animals were fed a common diet for 14 d before initiation of study to minimize differences in gastrointestinal fill. Heifers were housed in 24 dirt-surfaced pens (245 m^2) with automatic water fountains and 9.4 m of bunk space. On d 0 cattle were individually weighed, stratified from lightest to heaviest BW, and randomly assigned within strata to 24 pens. Pens contained 15 to 16 heifers, with 24 pens used for evaluation. Heifers were offered *ad libitum* access to diets delivered twice daily for 85 d. Dietary NE_m and NE_g values were calculated based on heifer performance (NRC 1984).

Pen weights were determined immediately prior to shipping to a commercial abattoir. Cattle were harvested by block on d 85, at a commercial abattoir in Emporia, KS, at which time carcass data were collected. Hot carcass weight and liver abscess scores were obtained at the time of harvest. Longissimuss muscle area, subcutaneous fat thickness over 12th rib, kidney pelvic and heart fat percentage, marbling score, USDA quality grade, and USDA yield grade were measured following a 24-h chill. Final BW was calculated by dividing carcass weight by a common dressing percent of 63.5%.

Statistical analysis

Growth performance and carcass characteristics were analyzed as a randomized complete block using the Proc GLM procedure of SAS version 8.1 (SAS Inst., Cary NC, 2002). The model statement included the effect of dietary treatment. Treatment averages were calculated using LSMEANS option and separated using the protected *F*-test.

Trial 2

The study was conducted in accordance with procedures approved by the Kansas State University Institutional Animal Care and Use Committee Protocol No. 2315. Five hundred eighty-two crossbred heifers (BW 377 ± 0.4 kg) were used in a randomized complete block design finishing study. Heifers were fed SFC (360 g/L) with no DG and 15% corn silage , SFC with 25% DG and 15% corn silage , SFC with 25% DG and 5%

corn silage, dry-rolled corn with no DG and 15% corn silage, DRC with 25% DG and 15% corn silage, and DRC with 25% DG and 5% corn silage. Finishing diets are further described in Table 2.

Upon arrival heifers were processed by identifying with uniquely numbered tags in both ears, injected with a 7-way clostridial bacterin; 4-way viral vaccine; (Fortress-7 vaccines; Bovishield-4; Pfizer Animal Health, Exton, PA), and administered topical parasiticide (Phoenectin pour-on; Phoenix Scientific Inc., St. Joseph, MO), and implanted with estradiol/trenbolone acetate implant (Revalor 200, Intervet Inc., Millsboro, DE). Animals were fed a common for diet 14 d before initiation of the study to minimize differences in gastrointestinal fill. Heifers were housed in 24 dirt-surfaced pens (432 m^2) with automatic water fountains and 9.4 m of bunk space. On d 0 cattle were individually weighed, on scales to the nearest 0.454 kg and heifers were allocated to block by initial weight, and randomly assigned to pen within each block. Pens were stratified to treatments so that differences and variances in initial BW among treatments groups were minimized. Each pen contained 21 to 24 heifers. Heifers were offered *ad libitum* access to diets delivered once daily for 110 d. Dietary NE_m and NE_g values were calculated based on heifer performance (NRC 1984).

Pen weights were determined immediately prior to shipping to a commercial abattoir. Cattle were harvested on 110 d at a commercial abattoir in Emporia, KS, at which time carcass data were collected. Hot carcass weight and liver abscess scores were obtained at the time of harvest. Longissimuss muscle area, subcutaneous fat thickness over 12th rib, kidney pelvic and heart fat percentage, marbling score, USDA quality grade, and USDA yield grade were measured following a 24-h chill. Final BW was calculated by dividing carcass weight by a common dressing percent of 63.5%.

Statistical analysis

Growth performance and carcass characteristics were analyzed statistically using the Proc GLM procedure of SAS version 8.1 (SAS Inst., Cary NC, 2002). Pen was the experimental unit. Model statement included the effects of dietary treatment, block, grain processing method, DDG and interactions between grain processing and DDG. Treatment averages calculated using LSMEANS option and separated using the protected *F*-test.

RESULTS AND DISCUSSION

Trial 1

Reducing roughage levels from 15% to 5% resulted in lower DMI. When comparing the cattle fed the CON and LO treatment groups (P = 0.05). Reductions in DMI likely are due to the fact that energy density is increased in low roughage diets. Loerch (1991) and Loerch, Fluharty (1998) and Stock et al. (1990) observed decreases in DMI, and improvements in feed efficiency when decreasing a portion or all of the dietary roughage in finishing diets. Contrary to their observations, our results did not yield a significant improvement in feed efficiency, but there were numerical improvement in feed efficiency. Owens et al. (1998) described when animals are fed diets with higher percentages of grain excessive consumption of rapidly fermentable carbohydrates commonly occur, during this period animals are transitioning from a bulk fill to a chemostatic fill within the rumen. In our trial cattle fed the low roughage diet would have consumed a higher energy diet possibly decreasing intake because of chemostatic fill.

Average daily gain and G:F were not affected by including DDG in the diet. Ham et al. (1994) and Firkins et al. (1985) observed improvements in cattle performance when including DDG in finishing diets consisting of DRC. Contrary to their experiments, we used SFC as the basal grain source. Zinn et al. (1995) compared DRC diets to SRC and observed ruminal pH for the DRC was higher than cattle fed SFC (6.07 vs. 5.67, respectively). This environment within the rumen in the presence of flaked grain may not be an ideal environment for digestion of fiber in distiller's grains.

Dressing percent were 63.73 and 63.23 for LO vs. CON respectively (P = 0.05). Differences in dressing percentage are most likely due to differences in gut fill. Longissimuss muscle area was higher for CON cattle compared to HI cattle (P < 0.05). The LM area values mirror the results observed in HCW, where both DDG treatment groups had numerically lower values than CON heifers (P > 0.53). Average USDA yield grade was not different between treatments. When calculating average yield grade we observed a tendency to increase average yield grade (P < 0.10). Heifers with a yield grade 4 and 5 had a tendency to be higher for HI treatment groups vs. CON groups (P = 0.08). There was also a tendency to increase liver abscess percentage in LO treatment groups vs. CON counterparts ($P = 0.08$). Our results although not significant were similar to Kreikemeier et al., (1990) and Loerch and Fluharty (1998), who observed higher percentage of condemned livers when reducing roughage in finishing diets. Marbling score, USDA quality grade, subcutaneous fat over the 12th rib, and KPH fat percentage were not affected by decreasing roughage or by adding DDG to finishing diets ($P > 0.14$).

Trial 2

In trial 2 when comparing DRC to SFC typical results were observed. There was a decrease in DMI when feeding flaked grain vs. dry-rolling corn 7.76 and 8.23 kg respectively ($P < 0.01$). Steam-flaked compared to dry-rolled corn produced a non-significant improvement in ADG 1.22 vs. 1.16 kg respectively ($P = 0.13$); and an improvement in G:F 0.142 and 0.158 ($P < 0.01$). Steam-flaked corn had a numerically higher value for HCW and final weight (carcass adjusted 63.5% dressed yield) than did DRC counterparts 321 vs. 325 kg respectively ($P = 0.08$). Corona et al., 2005, Owens 1997, and Zinn 1998 found similar results with improvements in feed efficiency, decreases in DMI and either no change or an improvement in ADG.

Average yield grade was higher for DRC vs. SFC 2.62 and 2.51 respectively ($P < 0.05$). Although, when calculating average yield grade there were no differences between grain processing methods ($P = 0.71$). There was also a tendency for cattle fed SFC to have a higher marbling score than their DRC counterparts, 529 vs. 519 respectively ($P = 0.11$). Huck et al. (1998) observed similar results with SFC fed cattle having a higher marbling score than their DRC counterparts. Cattle fed SFC had tendencies to increase the number of animals grading USDA Choice and decreasing animals grading USDA Select vs. DRC counterparts ($P \leq 0.13$).

Dry matter intake was decreased when removing a portion of the silage in DRC diets as well as SFC diets ($P < 0.05$). These results were similar to trial 1 and could be also be due to the fact that heifers were consuming a more energy dense diet. Feed efficiency was improved when removing a portion of the roughage in diet in either grain processing method compared to other treatment groups ($P < 0.05$). There were no differences among treatments in ADG ($P > 0.46$). Loerch (1991) and Loerch, Fluharty

(1998) and Stock et al. (1990) observed reductions in DMI, and improvements in feed efficiency when removing a portion or all of the dietary roughage in finishing diets.

When adding DDG to diets increased dressing percent vs. both control groups ($P < 0.05$). At the low roughage level, dressing percentage was the greatest in both grain sources vs. other treatments ($P < 0.01$). Similar to trial 1 when removing a portion of the roughage dressing percent increased; these differences are probably due to differences in gut fill of those animals. Both control groups containing no DDG had higher percentages of low grade animals vs. DDG counterparts ($P < 0.05$). These differences were driven by both control groups containing a small percentage of low grade animals and no low grade animals in DDG treatments. There were no differences among treatments in animal grading Prime, Choice, Select, marbling score, kidney pelvic heart fat percentage, back fat over the 12th rib, or LM area ($P > 0.22$). Trial 2 heifer performance and carcass characteristics are further described in tables 4 and 6.

In comparing both trials when SFC was used as the basal grain source similar results were observed. When the concentration of corn silage was decreased DMI was decreased in both experiments. In both studies there was a non significant reduction in ADG when DDG were added to the diet. Feed efficiency also was improved in both trials when corn silage was decreased (non significant improvement in trial 1). Carcass characteristics of both trials also mirrored one another as there were no major differences in terms of quality grade. Our results were similar to those found by (Roeber et al., 2005) who noted that feeding distiller’s grains up to 25% diet DM did not affect carcass quality grade. In trial 2 treatment percentages for yield grade 4 or 5 were not increased as was observed in trial 1.

Defoor et al. (2002) observed more fibrous roughage sources fed at lower levels having no effect on performance but increasing NEg values. In both trials cattle performance responses was similar. Removing a portion of the roughage and replacing it with a higher energy more digestible feedstuff i.e., DRC or SFC may explain for the improvements in performance. Parsons et al., 2007 observed small improvements or no differences in cattle performance when adding wet corn gluten feed as a partial replacement of roughage. Wet corn gluten feed is produced via wet milling process vs. distiller’s grains produced via dry milling. Both by-products distiller’s grains and wet corn gluten feed would both have similar fiber contents but different nutrient compositions.

When corn silage is used as the roughage source 25% DDG DM is an effective replacement for SFC or DRC in feedlot diets with no deleterious affects on animal performance. Additionally decreasing corn silage levels in finishing diets containing 25% dry distiller's grains may be a feasible way to decrease ration costs with no deleterious affects on cattle performance.

LITERATURE CITED

Corona, L., S. Rodriguez, R. A. Ware, and R. A. Zinn. 2005. Comparative effects of whole, ground, dry-rolled, and steam-flaked corn on digestion and growth performance in feedlot cattle. Prof. Anim. Sci. 21:200-206.

Defoor, P. J., M. L. Galyean, G. B. Salyer, G. A. Nunnery, and C. H. Parsons. 2002. Effects of roughage source and concentration on intake and performance by finishing heifers. J. Anim. Sci. 80:1295-1404.

Firkins, J. L., L. L. Berger, and G. C. Fahey, Jr. 1985. Evaluation of wet and dry distiller's grains and wet and dry gluten feeds for ruminants. J. Anim. Sci. 60:847-860.

Ham, G. A., R. A. Stock, T. J. Klopfenstein, E. M. Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distiller's byproducts compared with dried corn distiller's grains with solubles as a source of protein and energy for ruminants. J. Anim. Sci. 72:3246-3257.

Hover, W. H. 1986. Chemical factors Involved in ruminal fiber digestion. J. Dairy Sci. 69:2755-2766.

Huck, G. L., K. K. Kreikemeier, G. L. Kuhl, T. P. Eck, and K. K. Bolsen. 1998. Effects of feeding combinations of steam-flaked grain sorghum and steam-flaked, high-moisture, or dry-rolled corn on growth performance and carcass characteristics in feedlot cattle. J. Anim. Sci. 76:2984-2990.

Kreikemeier, K. K., D. L. Harmon, R. T. Brandt, Jr., T. G. Nagaraja, and R. C. Cochran. 1990. Steam-rolled wheat diets for finishing cattle: effects of dietary roughage and feed intake on finishing steer performance and ruminal metabolism. J. Anim. Sci. 68:2130-2141.

Loerch, S. C. 1991. Efficacy of plastic pot scrubbers as a replacement for roughage in high-concentrate cattle diets. J. Anim. Sci. 69:2231-2328.

Loerch, S. C., and F. L. Fluharty. 1998. Effects of corn processing, dietary roughage level, and timing of roughage inclusion on performance of feedlot steers. J. Anim. Sci. 76:681-685.

NRC, 1984. Nutrient Requirements of Beef Cattle. 6th Revised Edition. National Academy Press. Washington, D.C.

NRC, 1996. Nutrient Requirements of Beef Cattle. 7th Revised Edition. National Academy Press. Washington, D.C.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1997. The effect of grain source and grain processing on performance of feedlot cattle: a review. J. Anim. Sci. 75:868-879.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1998. Acidosis in cattle: a review. J. Anim. Sci. 76:275-286.

Parsons, C. H., J. T. Vasconcelos, R. S. Swingle, P. J. Defoor, G. A. Nunnery, G. B. Salyer, and M. L. Galyean. 2007. Effects of wet corn gluten feed and roughage levels on performance, carcass characteristics, and feeding behavior of feedlot cattle. J. Anim Sci. *In Press.* Published online first July 3, 2007 as doi:10.2527/jas.2007-0149.

Roeber, D. L., R. K. Gill, and A. DiCostanzo. 2005. Meat quality responses to feeding distiller’s grains to finishing Holstein steers. J. Anim. Sci. 83:2455-2460.

Stock, R. A., M. H. Sindt, J. C. Parrott, and F. K. Goedeken. 1990. Effects of grain type, roughage level and monensin level on finishing cattle performance. J. Anim. Sci. 68:3441-3455.

Zinn, R. A., C. F. Adam, and M. S. Tamayo. 1995. Interaction of Feed Intake Level on Comparative Ruminal and Total Tract Digestion of Dry-Rolled and Steam-Flaked Corn. J. Anim. Sci. 73:1239-1245.

Zinn, R. A., E. G. Alvarez, M. F. Montaño, A. Plascencia, and J. E. Ramirez. 1998. Influence of tempering on the feeding value of rolled corn in finishing diets for feedlot cattle. J. Anim. Sci. 76:2239-2246.

Table 4-1. Composition of steam-flaked corn based finishing diets with reduced corn silage levels and 25% corn dry distiller's grains with solubles.

	Steam-flaked corn		
Item, % dry matter	0% DDG 15% Silage	25% DDG 15% Silage	25% DDG 5% Silage
Steam Flaked Corn	75.31	55.73	65.56
Corn silage	14.81	4.94	14.85
DDG	-	24.67	24.72
Soybean meal	4.32	-	-
Urea	1.17	0.33	0.16
Limestone	1.58	1.85	1.81
Supplement[a]	0.68	0.58	0.51
Feed additive premix[b]	2.14	2.15	2.15
Nutrients			
Crude Protein	13.90	14.27	14.02
Calcium	0.76	0.73	0.70
Phosphorus	0.23	0.39	0.37
Ether extract	3.24	4.81	5.23
NDF	9.75	18.35	11.80
NE Maintenance, Mcal/kg	2.24	2.25	2.30
NE Gain, Mcal/kg	1.55	1.56	1.60

[a] Minerals and Vitamins, %. Formulated to provide 2650 IU/kg Vitamin A, 0.15 mg Co, 10 mg Cu, 0.5 mg I, 50 mg Mn and 50 mg Zn per kg DM.

[b] Feed additive premix provided 300 mg monensin, 90 mg tylosin, and 0.5 mg melengestrol-acetate per animal daily in a ground corn carrier.

Table 4-2. Composition of steam-flaked or dry-rolled corn based finishing diets with reduced corn silage levels and 25% corn dry distiller's grains with solubles.

	Dry-rolled corn			Steam-flaked corn		
Item, % dry matter	0% DDG 15% Silage	25% DDG 15% Silage	25% DDG 5% Silage	0% DDG 15% Silage	25% DDG 15% Silage	25% DDG 5% Silage
Steam-flaked corn	-	-	-	74.06	56.51	65.72
Dry-rolled corn	74.25	56.75	65.91	-	-	-
Corn silage	13.31	13.32	4.37	13.41	13.40	4.41
DDG	-	25.40	25.05	-	25.54	25.22
Vegetable oil	2.20	-	-	2.22	-	-
Soybean meal	4.49	-	-	4.52	-	-
Urea	1.22	0.15	0.30	1.22	0.15	0.30
Limestone	1.64	1.66	1.72	1.65	1.67	1.72
Supplement[a]	0.68	0.52	0.51	0.68	0.52	0.47
Feed additive premix, %[b]	2.19	2.20	2.17	2.20	2.20	2.18
Nutrients						
Crude Protein	15.37	15.34	15.51	14.72	14.85	14.93
Calcium	0.75	0.67	0.65	0.75	0.66	0.65
Phosphorus	0.29	0.40	0.40	0.29	0.40	0.40
Ether extract	5.82	5.31	5.39	5.84	5.32	5.40
NDF	10.98	19.28	13.54	11.05	19.37	13.62
NE Maintenance, Mcal/kg	2.22	2.24	2.39	2.43	2.44	2.62
NE Gain, Mcal/kg	1.53	1.56	1.68	1.72	1.72	1.73

[a] Minerals and Vitamins, %. Formulated to provide 2650 IU/kg Vitamin A, 0.15 mg Co, 10 mg Cu, 0.5 mg I, 50 mg Mn and 50 mg Zn per kg DM.

[b] Feed additive premix provided 300 mg monensin, 90 mg tylosin, and 0.5 mg melengestrol-acetate per animal daily in a ground corn carrier.

Table 4-3. Performance of yearling heifers fed steam-flaked corn based finishing diets containing corn dry distiller's grains with solubles.

Item	0% DDG 15% Silage	25% DDG 15% Silage	25% DDG 5% Silage	SEM
No. of pens (heifers)	8 (127)	8 (124)	8 (126)	-
Initial weight, kg	378	377	377	4.07
Final weight, kg[1]	491	487	486	5.02
Dry matter intake, kg	9.01[a]	8.77[ab]	8.52[b]	0.16
Average daily gain, kg[1]	1.32	1.29	1.28	0.04
Gain:feed[1]	0.146	0.148	0.151	0.003

[1] Final weight, average daily gain, and efficiency were computed by using carcass-adjusted final weights. Final live weight = hot carcass weight divided by a dressing percent of 0.635.

[a,b] Within a row, means that do not have a common superscript differ ($P < 0.05$).

Table 4-4. Performance of yearling heifers fed steam-flaked or dry-rolled corn based finishing diets containing corn dry distiller's grains with solubles.

	Dry-rolled corn			Steam-flaked corn				Contrasts[2]				
Item	0% DDG 15% Silage	25% DDG 15% Silage	25% DDG 5% Silage	0% DDG 15% Silage	25% DDG 15% Silage	25% DDG 5% Silage	SEM	1	2	3	4	5
No. of pens (heifers)	4 (93)	4 (95)	4 (94)	4 (94)	4 (91)	4 (94)	-	-	-	-	-	
Initial weight, kg	377	377	377	377	378	378	0.43	0.11	0.09	0.36	0.62	0.44
Final weight, kg[1]	503	507	505	515	508	508	3.72	0.08	0.64	0.82	0.20	0.94
Dry matter intake, kg	8.37^{a}	8.38^{a}	7.78^{bc}	8.08^{ab}	7.70^{bc}	7.06^{d}	0.15	<0.01	0.19	<0.01	0.18	0.88
Average daily gain, kg[1]	1.15	1.17	1.17	1.26	1.19	1.18	0.08	0.13	0.52	0.92	0.19	1.00
Gain:feed[1]	0.138^{a}	0.141^{ab}	0.151^{bc}	0.156^{cd}	0.155^{cd}	0.166^{d}	0.004	<0.01	0.88	0.02	0.62	0.90

[1] Final weight, average daily gain and efficiency were computed by using carcass-adjusted final weights. Final live weight = hot carcass weight divided by a common dressing percent of 0.635.

[2] ontrast 1: Mean of dry-rolled corn diets vs. mean of steam-flaked corn diets

Contrast 2: Mean of diets with 0% dry distiller’s grains and 15% silage vs. mean of diets containing 25% dry distiller’s grains and 15% silage

Contrast 3: Mean of dry distiller’s grains diets with 15% silage vs. mean of dry distiller’s grains diets with 5% silage

Contrast 4: Grain by dry distiller’s grains interaction with 15% silage

Contrast 5: Grain by roughage level interaction with diets containing dry distiller’s grains

[a,b,c,d] Within a row, means that do not have a common superscript differ ($P < 0.05$).

Table 4-5. Carcass characteristics for yearling heifers fed steam-flaked corn based finishing diets containing corn dry distiller's grains with solubles.

Item	0% DDG 15% Silage	25% DDG 15% Silage	25% DDG 5% Silage	SEM
Hot carcass weight, kg	312	309	309	3.18
Dressed yield, %	63.23^{a}	63.46^{ab}	63.73^{b}	0.16
USDA quality grade				
Prime, %	0.78	0.00	0.00	0.45
Choice, %	55.11	62.24	61.93	4.29
Upper 2/3 Choice or greater, %	15.26	12.55	9.53	2.59
Select, %	40.10	37.76	36.46	3.61
Low grade, %	2.39	0.00	0.78	1.12
Dark cutter, %	0.83	0.00	0.83	0.68
USDA yield grade	2.62	2.74	2.66	0.07
Calculated yield grade	2.67^{c}	2.90^{d}	2.72^{cd}	0.09
Yield grade 1, %	2.40	1.56	1.62	1.02
Yield grade 2, %	39.27	36.35	39.11	4.86
Yield grade 3, %	53.49	47.92	48.12	5.32
Yield grade 4 & 5, %	5.68^{c}	14.12^{d}	11.09^{cd}	3.13
Marbling score[1]	517	505	503	8.95
Kidney pelvic heart fat, %	2.24	2.28	2.27	0.04
Back fat over 12th rib, mm	13.97	14.73	14.22	0.51
LM area, square cm	86.13^{a}	82.52^{b}	84.84^{ab}	1.03
Liver abscess, %	1.62^{c}	3.96^{cd}	6.30^{d}	1.75

[1] Marbling score 500 = Small

[a,b] Within a row, means that do not have a common superscript differ ($P < 0.05$).

[c,d] Within a row, means that do not have a common superscript differ ($P < 0.10$).

Table 4-6. Carcass characteristics of yearling heifers fed steam-flaked or dry-rolled corn based finishing diets containing corn dry distiller's grains with solubles.

	Dry-rolled corn			Steam-flaked corn								
	0% DDG	25% DDG	25% DDG	0% DDG	25% DDG	25% DDG		Contrasts[b]				
Item	15% Silage	15% Silage	5% Silage	15% Silage	15% Silage	5% Silage	SEM	1	2	3	4	5
Hot carcass weight, kg	320	321	321	327	323	323	2.39	0.08	0.64	0.78	0.22	0.96
Dressed yield, %	63.30^{a}	64.28^{abd}	65.00^{bcd}	63.27^{ab}	63.90^{ab}	65.27^{bcd}	0.36	0.89	0.04	<0.01	0.63	0.38
USDA quality grade												
Prime, %	1.04	0.00	1.00	0.00	1.04	2.23	0.92	0.59	1.00	0.25	0.27	0.92
Choice, %	56.89	62.86	61.11	66.94	67.98	61.64	3.80	0.11	0.37	0.30	0.52	0.55
Upper 2/3 Choice or greater, %	18.13	13.77	15.52	22.15	16.94	19.84	3.77	0.24	0.22	0.52	0.91	0.91
Select, %	39.99	37.14	34.77	32.02	30.98	34.00	3.78	0.13	0.61	0.93	0.81	0.49
Low grade, %	2.09	0.00	0.00	1.04	0.00	0.00	0.66	0.53	0.03	1.00	0.44	1.00
Dark cutter, %	1.04	0.00	2.08	0.00	0.00	2.13	1.10	0.72	0.64	0.07	0.64	0.98
USDA yield grade	2.59	2.65	2.66	2.54	2.42	2.54	0.06	0.02	0.64	0.30	0.16	0.34
Calculated yield grade	2.90	2.83	2.89	2.94	2.86	2.88	0.07	0.71	0.31	0.57	0.91	0.83
Yield grade 1, %	6.53	4.17	7.43	8.47	11.82	5.64	2.47	0.21	0.84	0.56	0.26	0.07
Yield grade 2, %	36.68	39.49	35.60	39.27	39.31	42.81	4.75	0.42	0.77	0.97	0.77	0.45
Yield grade 3, %	48.23	45.70	41.89	43.70	41.44	42.78	4.26	0.46	0.58	0.78	0.98	0.55
Yield grade 4 and 5, %	8.56	9.60	14.00	8.56	6.38	8.77	3.42	0.33	0.87	0.34	0.64	0.77
Marbling score[a]	519	517	522	528	531	530	7.33	0.11	0.92	0.80	0.74	0.65
Kidney pelvic heart fat, %	2.34	2.37	2.34	2.36	2.35	2.40	0.05	0.57	0.84	0.98	0.58	0.33
Back fat over 12th rib, mm	1.37	1.40	1.47	1.47	1.45	1.40	0.05	0.58	0.84	0.73	0.73	0.21
LM area, square cm	82.8	84.8	84.7	84.8	85.3	84.0	0.97	0.44	0.24	0.52	0.45	0.53
Liver abscess, %	2.17	2.17	1.00	2.13	2.08	4.64	1.73	0.44	0.99	0.73	0.99	0.32

[a] Marbling score 500 = Small

[b] Contrast 1: Mean of dry-rolled corn diets vs. mean of steam-flaked corn diets

Contrast 2: Mean of diets with 0% dry distiller’s grains and 15% silage vs. mean of diets containing 25% dry distiller’s grains and 15% silage

Contrast 3: Mean of dry distiller’s grains diets with 15% silage vs. mean of dry distiller’s grains diets with 5% silage

Contrast 4: Grain by dry distiller’s grains interaction with 15% silage

Contrast 5: Grain by roughage level interaction with diets containing dry distiller’s grains

[a,b,c,d] Within a row, means that do not have a common superscript differ ($P < 0.05$).

5. Chapter V: Effect of Dry-Rolled or Steam-Flaked Corn Finishing Diets with or without Distiller's Dried Grains on Ruminal Fermentation and Apparent Total Tract Digestion[1]

M. L. May[2], M. J. Hands[2], M. J. Quinn[2], J. O. Wallace[2], C. D. Reinhardt[2], L. Murray[3], and J. S. Drouillard[2,4]

Kansas State University
Manhattan, KS 66506

---

[1] This is contribution no. 08-82-J from the Kansas Agricultural Experiment Station, Manhattan, Kansas.

[2] Kansas State University, Department of Animal Science and Industry

[3] Kansas State University, Department of Statistics

[4] Corresponding author: jdrouill@ksu.edu; Phone: (785) 532-1204; Fax: (785) 532-5681

ABSTRACT

A metabolism study was conducted to evaluate the use of dried corn distiller's grains with solubles (DDG) in beef finishing diets. Holstein steers (n = 16, 351 kg BW) with ruminal cannulas were fed diets consisting of dry-rolled corn (DRC) with no DDG, DRC with 25% DDG, steam-flaked corn (SFC) with no DDG, and SFC with 25% DDG. Feeding SFC vs. DRC decreased intake of DM, OM, NDF and ether extract ($P < 0.01$). Steers fed SFC had less fecal excretion of DM, OM, starch, NDF and ether extract ($P < 0.01$). Feeding DRC compared to SFC decreased acetate, butyrate, AP ratio, isobutyrate, 2-methyl isovalerate and 3-methyl isovalerate ($P < 0.01$). Compared to SFC, DRC decreased ruminal propionate, valerate, and lactate ($P < 0.01$). Ruminal pH compared to cattle fed SFC, DRC was lower at 0 h and higher at 6 h post-feeding ($P < 0.01$). Ruminal ammonia concentrations were higher for DRC vs. SFC at h 0, 6, 10, 12, 14, 16, 18, 20, and 22 post-feeding ($P < 0.05$). Cattle fed DDG diets consumed less starch, and ether extract, but more NDF ($P < 0.01$). DDG yielded decreases in consumption of starch, and ether extract, with an increase in NDF ($P < 0.01$). Fecal excretion of ether extract was increased by adding DDG compared to diets without DDG ($P < 0.05$). Apparent total tract digestibility of ether extract was lower for cattle consuming DDG compared to cattle without DDG ($P < 0.01$). Ruminal lactate production was increased with addition of DDG compared to diets without DDG ($P = 0.01$). Ruminal pH were different between 25% DDG and 0% DDG at h 2, 6, 20 and 22, pH values were: 5.55 and 5.87, 5.32 and 5.57, 5.88 and 5.66, and 6.04 and 5.71 respectively ($P < 0.05$). Ruminal ammonia concentrations were lower for steers fed 25% DDG vs. 0% DDG at 2, 4, 6, 8, and 10 h post-feeding ($P < 0.05$). Feeding DDG in diets with DRC as basal grain source had a lower magnitude of change in digestibility than SFC counterparts. Feeding DDG increased ruminal lactate production. Feeding DDG in SFC diets yielded low ruminal ammonia concentrations.

Keywords: Steam-flaked corn, Dry-rolled corn, Distiller's grains, Digestibility

INTRODUCTION

Ham et al. (1994) suggested that feeding distiller's grains (wet or dry) in dry-rolled corn diets improves cattle performance and diet digestibility. Expansion of the ethanol industry into the Southern Plains where grain is more commonly steam-flaked has prompted research to investigate value of DDG in beef finishing diets. Distiller's grains are the primary by-product of the fuel ethanol industry. As the ethanol industry expands, distiller's grains become more prevalent and it is important to establish means for optimal use in beef finishing diets. When grain is used for ethanol production the starch in the grain is fermented. The by-product produced from ethanol production concentrates CP, fat, fiber, and phosphorus of the grain and may be valuable for use in beef finishing diets.

Differences between dry-rolled corn (DRC) and steam-flaked corn (SFC) in terms of cattle performance and site and extent of digestion have been well documented by Barajas and Zinn (1998), Corona et al., 2006, and Theurer (1986). Digestion characteristics of the two grain processing methods and the addition of distiller's grains is an important area to research with the recent growth of the ethanol industry. May et al. (2007a) compared the two grain types with the addition of sorghum wet distiller's grains in large pen study. Average daily gain, DMI, and HCW had tendencies to have a grain processing by wet distiller's grains interaction. Adding wet distiller's grains to DRC diets increased ADG and DMI vs. SFC counterparts. Evaluating DDG in diets comprised of SFC or DRC in a metabolism study may identify why these interactions with distiller's grains and grain processing method have been observed.

MATERIALS AND METHODS

The study was conducted in accordance with procedures approved by the Kansas State University Institutional Animal Care and Use Committee Protocol No. 2315. Holstein steers (n = 16; 351 kg) fitted with ruminal cannulas (Bar Diamond Inc., Parma, ID; dorsal sac) and were allowed *ad libitum* access to diets fed once daily. Both of the two experimental periods consisted of 15 d, with 12 d for adaptation and 3 d for sample collections. Treatments were SFC with 0% DDG, SFC with 25% DDG, DRC with 0% DDG and DRC with 25% DDG. Diets are presented in table 3.

Chromic oxide (10 g) in a gelatin capsule (Torpac Inc., Fairfield, NJ) was placed into the rumen prior to feeding each day to estimate total fecal output. Ruminal digesta was collected at the following times relative to feeding each day: d 1 at 0, 6, 12, 18 h; d 2 at 2, 8, 14, 20 h; d 3 at 4, 10, 16 and 22 h. Ruminal digesta was strained through 4 layers of cheesecloth; 4 mL of strained ruminal fluid was added to 1 mL of 25% (wt/vol) metaphosphoric acid and then frozen at -20°C. A portable pH meter was used to measure ruminal pH of strained ruminal fluid at time of each sampling. Acidified ruminal fluid samples were thawed and centrifuged at 15,000 x. g for 15 min, and a portion of the supernatant fluid was analyzed for VFA and lactate by gas chromatography (Hewlett-Packard 5890A, Palo Alto, CA; 2m x 2mm column; Supelco column packing, Bellefonte, PA), with N_2 as the carrier gas, a flow rate of 24 mL/min, and the column temperature of 175°C. A portion of the supernatant fluid was analyzed for NH_3 concentration using a Technicon Autoanalyzer III (Bran and Luebbe, Elmsford, NY) in accordance with Broderick and Kang (1980).

Fecal samples were taken from each steer coinciding with ruminal fluid sample. Diet samples and each fecal sample was oven dried at 55°C for 4 d. Dried fecal samples and diet samples were ground through a Wiley mill (Thomas Scientific, Swedesboro, NJ) to pass a 1-mm screen. Approximately 3 grams of each dry ground fecal sample were pooled within each collection period for each animal for chemical composition.

Diet samples and fecal samples were dried at 105° C to determine DM, and ashed at 600° C for 2 h to determine OM. Starch content of diets and fecal samples were determined in accordance with Herrera-Saldana and Huber (1989) using a Technicon Autoanalyzer III to measure free glucose (Gochman and Schmitz, 1972). Determination of NDF was conducted using an ANKOM 200 Fiber Analyzer (ANKOM Technologies, Macedon, NY) in accordance with Van Soest et al. (1991). When determining NDF in diet samples heat stable α-amylase (ANKOM Technologies) was added to remove starch. Ether extract of diets and fecal samples were done in accordance with AOAC official method 920.39 (AOAC, 1995). Fecal output was estimated using chromic oxide concentration of fecal samples which were determined by atomic absorption spectrophotometry with an acetylene/air flame (Perkin Elmer 3110, Norwalk, CT) in accordance with Williams et al. (1962). One animal was not properly adapted to a new diet during period two, therefore the animal was eliminated from the study.

Calculations and Statistical Analyses:

Fecal output for each steer within each period was determined by taking chromic oxide dosed ruminally (g/d) dived by chromic oxide concentration in the feces (g/g DM). Apparent total tract digestibilities of DM, OM, starch, NDF, and ether extract were calculated by the following formula: [(intake of nutrient – fecal output of nutrient) / intake of nutrient] x 100.

Volatile fatty acid profiles, pH, ammonia concentration, and digestibility characteristics were analyzed using the Proc MIXED procedure of SAS (version 8.1; SAS Inst; Cary, NC 2002). The model statement included effects of grain processing method, DDG level, animal, period, and hour. Random effects were animal and the interaction between animal, grain processing method, DDG level, period and hour. Treatment means were calculated using the least-square means option and separated using the protected *F*-test.

RESULTS AND DISCUSSION

Digestibility characteristics for DRC vs. SFC yielded typical results. Steer intakes for DM, OM, and NDF for DRC and SFC were: 8.73 and 7.63, 8.50 and 7.43, and 1.33 and 1.19 kg/d, respectively ($P < 0.01$). Fecal DM, OM, starch, NDF, and ether extract excretion for DRC and SFC were: 1.94 and 1.23, 1.79 and 1.09, 0.48 and 0.05, 1.04 and 0.64, and 0.05 and 0.03, kg/d respectively ($P < 0.01$). Reductions in fecal OM and starch would be similar to observations made by Barajas and Zinn (1998), Corona et al. (2006), Zinn (1990). Apparent total tract digestibility percentages were improved when feeding SFC vs. DRC. Percentages for DRC and SFC of DM, OM, Starch, NDF and ether extract were 78.28 and 84.09, 79.34 and 85.54, 88.63 and 98.80, 23.11 and 46.76, and 90.36 and 92.58 respectively ($P \leq 0.01$). Improvements in total tract digestion of OM and starch between flaking and rolling corn have also been observed by Barajas and Zinn (1998), Corona et al. (2006), and Zinn (1990).

Average ruminal ammonia concentrations for DRC and SFC were 7.47 and 1.91 mM, respectively ($P < 0.01$). Ruminal VFA profiles for Holstein steers also produced typical values when comparing the grain processing methods. Ruminal Acetate, propionate, butyrate, and lactate concentrations for DRC and SFC were: 48.97 and 40.98, 26.40 and 35.15, 11.38 and 8.10, and 0.29 and 1.14, mM respectively ($P \leq 0.05$). Ruminal production of isobutyrate, isovalerate 2-methyl, and isovalerate 3-methyl were higher for cattle fed DRC than their SFC cohorts ($P \leq 0.05$). Acetate to propionate ratio was higher for steers fed DRC vs. SFC, 2.04 and 1.29 respectively ($P < 0.01$). Increases in ruminal acetate, butyrate, and AP ratio, and decreases in propionate production when rolling corn vs. flaking would be similar to the finding of Corona et al. (2006). Total VFA production was not different between grain processing methods; differences in intake may be responsible for this result. Cattle consuming DRC consumed an average of 1.1 kg more DM than their SFC counterparts. Average ruminal pH was not different between processing methods. This observation would be similar to Galyean et al. (1976), but contrary to Cooper et al. (2002), and Corona et al. (2006).

When evaluating ruminal pH, ammonia, acetate, propionate, AP ratio, lactate, and butyrate concentrations over the 24 h digestion period, grain processing method was one cause for differences. Ruminal pH was higher for cattle fed DRC vs. SFC at 0, and lower at 6 h post-feeding, those values were 6.72 vs. 6.16 and 5.58 vs. 5.31, respectively ($P < 0.01$). Ruminal ammonia concentrations were higher for cattle fed DRC compared to cattle fed SFC at h 0, 6, 10, 12, 14, 16, 18, 20, and 22 post-feeding; concentrations were: 6.74 and 3.00, 7.06 and 0.92, 7.53 and 1.88, 7.72 and 1.07, 7.48 and 0.58, 4.82 and 0.55, 6.96 and 0.93, 7.18 and 1.45, and 7.11 and 1.98 mM, respectively ($P \leq 0.05$). These results are similar to those of Cooper et al. (2002), where cattle fed DRC had higher ruminal ammonia concentration 12 h post-feeding than did cattle fed SFC. Cooper et al. (2002b) observed when comparing DRC and SFC, that cattle performance is improved at higher levels of DIP in cattle fed SFC vs. DRC counterparts, due to increases in microbial growth and assimilation of ruminal nitrogen. Increases in ruminal acetate and decreases in propionate, when comparing DRC to SFC, would be similar to observations made by Zinn et al. (1995). Additionally, increases in ruminal acetate, butyrate, AP ratio and decrease in propionate when comparing DRC and SFC would be similar to Corona et al. (2006).

Ruminal acetate production was higher for cattle fed DRC vs. SFC at 0, 14, 16, 18, 20, and 22 h post-feeding, concentrations were: 43.22 and 24.69, 50.15 and 41.45, 48.29 and 39.18, 49.58 and 37.74, 47.94 and 34.14, and 41.77 and 29.89 mM, respectively ($P < 0.05$). Ruminal propionate production was higher for cattle fed SFC vs. DRC at 4, 6, 8, 10, 12, 14, and 16 h post-feeding, concentrations were: 42.06 and 25.33, 40.52 and 25.99, 36.19 and 25.37, 47.00 and 32.52, 44.22 and 30.88, 38.69 and 29.25, and 36.07 and 26.85 mM, respectively ($P < 0.05$). Acetate to propionate ratio was higher for cattle fed DRC compared to cattle fed SFC from 0 to 22 h post-feeding, ratios were: 2.40 and 1.56, 2.09 and 1.40, 2.09 and 1.29, 2.14 and 1.29, 2.01 and 1.32, 1.90 and 1.26, 1.87 and 1.20, 1.88 and 1.15, 1.91 and1.17, 1.89 and 1.19, 2.05 and 1.26, and 2.19 and 1.39, respectively ($P < 0.05$). Ruminal butyrate concentrations were higher for cattle fed DRC vs. SFC at 0, 2, 8, 16, 20, and 22 h post feeding, concentrations were: 9.88 and 4.89, 12.36 and 6.47, 10.31 and 8.01, 10.70 and 7.65, 10.96 and 6.52, and 9.35 and 5.45, respectively ($P < 0.05$). Total VFA production was higher for cattle fed DRC compared to SFC at hours 0 and 20, values were 78.27 and 52.14 and 91.24 and 74.45 respectively ($P < 0.05$).

Ruminal lactate was higher for cattle fed SFC vs. DRC cohorts at 2, 4, 6, 8, 10, 12, 14, and 16 h post-feeding, concentrations were: 3.97 and 0.57, 1.19 and 0.07, 0.83 and 0.24, 0.99 and 0.33, 0.36 and 1.64, 1.09 and 0.32, 0.21 and 0.97, and 0.26 and 1.28 mM, respectively ($P < 0.05$). Increases in ruminal lactate when feeding a more rapidly fermentable feedstuff would be similar to results observed by Gross et al. (1988) that compared wheat to sorghum. Ruminal lactate was increased when feeding wheat, when compared to sorghum. Huntington (1997) stated starch digestion and fermentation within the rumen is increased when flaking vs. rolling. Increasing ruminal starch decreases ruminal pH and could lead to increased production of lactate.

Adding 25% DDG to diets fed to steers decreased daily intake of starch, NDF, and ether extract ($P < 0.01$). Diets were balanced to include similar ether extract content across treatment groups, subsequently decreases in daily intake when adding DDG are responsible for differences in ether extract intake. Additionally, there were tendencies when adding DDG to the diet to decrease intake of DM and OM ($P = 0.10$). Apparent total tract digestibility of ether extract was decreased when feeding 25% DDG compared to 0% DDG ($P < 0.01$). Additionally, apparent total tract digestion of DM, and OM had a tendency to decrease when adding DDG in either grain processing method ($P \leq 0.11$). These results would be similar to those found by Depenbusch et al. (2005), where digestibility of DM, and OM were decreased when adding approximately 13% DDG or de-germed corn dried distiller's grains with solubles to SFC diets. Cattle fed DRC diets had similar results to those observed by Vander Pol et al. (2007), where there were no differences between cattle consuming DRC and wet distiller's grains, and DRC with no wet distiller's grains in total tract digestibility of DM, OM, or starch. Similar to our results, ether extract digestibility was decreased when adding wet distiller's grains to DRC diets vs. cattle not consuming distiller's grains.

Ruminal ammonia concentrations were decreased when feeding 25% DDG. Ruminal ammonia concentrations for 25% DDG and 0% DDG were 3.06 and 6.33 mM, respectively ($P < 0.05$). When feeding distillers grains many protein sources are substituted in the diet. Distiller's grains are commonly substituted for soybean meal and urea. When nitrogen is limiting within the rumen especially in SFC diets we could be limiting nitrogen assimilation, microbial growth and subsequent fermentation. Adding DDG increased ruminal lactate concentrations; cattle fed 25% DDG compared to 0% DDG had concentrations of 0.48 and 0.95 mM respectively ($P = 0.01$).

Feeding DDG also affected ruminal pH, ammonia, lactate, acetate, and propionate over the 24 h digestion period. Ruminal pH were different between 25% DDG and 0% DDG at h 2, 6, 20 and 22, pH values were 5.55 and 5.87, 5.32 and 5.57, 5.88 and 5.66, and 6.04 and 5.71, respectively ($P \leq 0.05$). Santos et al. (1984) observed when feeding DDG to lactating dairy cows, that ruminal pH was decreased over the feeding period vs. soybean meal, corn gluten feed, and wet brewer's grains. Hover (1986) stated that optimum fiber digestion would be greatest at ruminal pH between 6.2 and 6.8. Early in the digestion period, in h 2 to 6, is when the bulk of digesta is fermented and rumen pH could play an important role in fiber digestion, as well as other feedstuffs. The SFC 25% DDG fed cattle had lower ruminal pH at h 2 and 6, than the cattle not consuming DDG. Additionally, SFC 25% DDG cattle had numerically lower ruminal ph from 2 to 12 h compared to the other treatment groups. This combination of SFC and DDG could have deleterious effects on rumen microflora and subsequent fermentation because of low ruminal pH.

Ruminal ammonia concentrations were lower for steers fed 25% DDG vs. 0% DDG at 2, 4, 6, 8, and 10 h post-feeding; concentrations were: 10.48 and 4.07, 10.97 and 3.09, 6.05 and 1.48, 7.58 and 1.02, and 6.92 and 2.49 mM, respectively ($P \leq 0.05$). Similar to Santos et al. (1984) and Ham et al. (1994) who observed when feeding distiller's grains, that ruminal ammonia concentrations are decreased, and distiller's grains are more resistant to microbial degradation. Satter and Slyter (1974) stated ruminal ammonia concentrations falling below 50 mg/L (2.94 mM) will decrease microbial protein production. In the present study, feeding SFC and DDG decreased ruminal ammonia concentrations falling below 2.94 mM threshold in h 2 through 22. Adding DDG to diets containing DRC did decrease ruminal ammonia vs. DRC 0% DDG counterparts, but ruminal ammonia was well above 2.94 threshold, only falling below in h 6 and 8.

Ruminal lactate concentrations were increased when feeding 25% DDG vs. 0% DDG at 2, 4, 6, 8, 10, and 16 h post-feeding; concentration were: 2.70 and 1.84, 1.02 and 0.24, 0.82 and 0.26, 0.92 and 0.41, 1.48 and 0.53, and 1.08 and 0.46 mM, respectively ($P < 0.05$). Increases in lactate were increased in both grain types. Lactate concentrations in the SFC 25% DDG had higher lactate concentrations from 2 to 16 h post-feeding than either of the DRC steers. The high lactate concentration may be partly responsible for the lower ruminal pH observed in the SFC 25% DDG steers at 2 and 6 h post-feeding. Increases in ruminal lactate did not increase ruminal concentrations of propionate or butyrate. Increases in ruminal lactate when feeding distiller's grains was an unexpected result. Ethanol production removes most of the starch from the grain concentrating the fiber of the grain. The increase in dietary fiber should increase ruminal pH and lactate as observed by Coe et al. (1999), that as hay was replaced with concentrate, ruminal pH decreased, lactic acid production increased, and subsequently increased ruminal butyrate and valerate concentrations.

Ruminal acetate was decreased when adding DDG at 14 and 22 h post feeding; concentrations for 25% DDG and 0% DDG were: 41.78 and 49.82, and 31.84 and 39.82 mM, respectively ($P < 0.05$). Ruminal propionate was decreased when adding DDG at

20 and 22 h post-feeding, concentrations for 25% DDG and 0% DDG were: 24.07 and 31.72, and 16.90 and 28.97 mM respectively ($P < 0.05$). Decreases in acetate and propionate did not affect total VFA production when feeding DDG to steers ($P = 0.15$). Total VFA production was decreased when adding DDG to the diet at h 0, 14, and 22 post feeding, values for 0% DDG compared to 25% DDG were: 72.42 and 58.00, 104.19 and 85.07, and 82.82 and 59.01 respectively ($P < 0.05$).

Decreases in ruminal ammonia, increases in ruminal lactate, and decreases in ruminal pH may be responsible for lower optimum inclusion levels of distiller's grains of 15% diet DM in SFC diets observed by Daubert et al. (2003) compared to higher levels of inclusion of distiller's grains in DRC diets reported by Al-Suwaiegh et al. (2002), and Ham et al. (1994) of levels up to 40% diet DM.

This may also explain the grain processing method by distiller's grain interaction was observed by May et al. (2007a) where DMI, ADG, and HCW were increased in cattle consuming DRC and decreased in cattle fed SFC. May et al. (2007b) fed 25% DDG in SFC and DRC diets and cattle performance was comparable between treatment groups. Roughage level between the two experiments may be responsible for differences, as 6% alfalfa was fed in the first experiment and about 10% fed in the second experiment.

Intake characteristics of starch had a grain processing by DDG interaction ($P < 0.01$). These interactions were driven by the magnitude of change when adding DDG to DRC, compared to the change observed in adding DDG to SFC diets. There was a grain processing by DDG interaction with average ruminal ammonia concentrations ($P = 0.05$). This again was due to the difference in magnitude between grain processing and the addition of DDG. Lactate also had a tendency to have an interaction between grain processing method and DDG level, with the amount of lactate produced within the rumen almost doubling in cattle fed SFC ($P = 0.07$).

When separating treatment means over time, there was a grain processing method by DDG level interaction that occurred at 16 h post-feeding ($P = 0.01$). In this case, both of the SFC diets were higher than the DRC treatments, with the DRC 25% DDG being numerically higher than the DRC 0% DDG, and the SFC 25% DDG being lower than the SFC 0% DDG. Ruminal ammonia concentrations yielded grain by DDG interactions at 6, 10, and 18 h post-feeding ($P < 0.05$). These differences are driven by the low ruminal ammonia concentrations observed in the SFC 25% DDG during those time periods. Dry-rolled corn, 25% DDG had higher values for values of ammonia concentration throughout period when compared to SFC 25% DDG. When ruminal ammonia is decreased especially in SFC diets, which require more ruminal ammonia, digestion and subsequent cattle performance may be limiting when distiller's grains are present in the diet. In our diets there is an excess of dietary nitrogen but because of decreases in DIP between distiller's grains and other protein sources used we may be limiting fermentation. Ruminal lactate had a grain processing method by DDG interaction at 4 and 6 h post feeding ($P < 0.05$). This interaction was driven by the high ruminal lactate values for cattle fed SFC and 25% DDG vs. the other treatment groups. Cattle fed SFC and DDG had higher lactate levels throughout digestion period than the other treatment groups. Feeding DDG increased ruminal lactate in both grain processing methods, but in DRC diets lactate levels were low. Doubling lactate concentrations when adding DDG to DRC fed cattle was not as significant as the change observed when adding DDG to cattle fed SFC.

Ruminal lactate production is increased when flaking vs. dry-rolling corn. Additionally, the addition of DDG in DRC and SFC diets also increased ruminal lactate production this was most evident when adding DDG to SFC fed steers. Ruminal pH was decreased when feeding DDG at 2 and 6 h post feeding. Feeding DDG to cattle fed SFC also had a ruminal pH below 5.50 from 2 to 12 h post feeding. Ruminal ammonia was lower for cattle consuming DDG. Ruminal ammonia concentrations were the lowest for cattle fed SFC and DDG.

LITERATURE CITED

Al-Suwaiegh, S., K. C. Fanning, R. J. Grant, C. T. Milton, and T. J. Klopfenstein. 2002. Utilization of distiller's grains from the fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. J. Anim. Sci. 80:1105-1111.

AOAC, 1995. Official Method of Analysis (16th Ed.) Association of Official Analytical Chemists, Arlington, VA.

Barajas, R., and R. A. Zinn. 1998. The feeding value of dry-rolled and steam-flaked corn in finishing diets for feedlot cattle: influence of protein supplementation. J. Anim. Sci. 76:1744-1752.

Broderick, G. A., and J. H. Kang. 1980. Automated simultaneous determination of ammonia and total amino acids in ruminal fluid and in vitro media. J. Dairy Sci. 63:64-75.

Cole, N. A., R. R. Johnson, and F. N. Owens. 1976. Influence of roughage level and corn processing method on the site and extent of digestion by beef steers. J. Anim. Sci. 43: 490-496.

Cooper R. J., C. T. Milton, T. J. Klopfenstein, T. L. Scott, C. B. Wilson, and R. A. Mass. 2002a. Effect of corn processing method on starch digestion and bacterial crude protein flow in finishing cattle. J. Anim. Sci. 80:797-804.

Cooper, R. J., C. T. Milton, T. J. Klopfenstein, and D. J. Jordan. 2002b. Effect of corn processing method on degradable intake protein requirement for finishing cattle. J. Anim. Sci. 80:242-247.

Corona, L., F. N. Owens, and R. A. Zinn. 2006. Impact of corn virtuousness and processing on site and extent of digestion by feedlot cattle. J. Anim. Sci. 84:3020-3031.

Daubert, R. W., J. S. Drouillard, E. R. Loe, J. J. Sindt, B. E. Depenbusch, J. T. Fox, M. A. Greenquist, and M. E. Corrigan. 2005. Optimizing use of wet sorghum distiller's grains with solubles in flaked-corn finishing diets. KSU Progress Report. 943:15-21.

Depenbusch, B. E., J. S. Drouillard, E. R. Loe, and M. E. Corrigan. 2005. Optimizing use of distiller's grains in finishing cattle diets. J. Anim. Sci. 83 (Supp 1):324 (Abstr.).

Depenbusch, B. E., J. S. Drouillard, E. R. Loe, M. E. Corrigan, and M. J. Quinn. 2007b. Efficacy of monensin and tylosin in finishing diets based on steam-flaked corn with and without corn wet distiller's grains with solubles. J. Anim. Sci. ***Accepted.***

Galyean, M. L., D. G. Wagner, and R. R. Johnson. 1976. Site and extent of digestion in steers fed processed corn rations. J. Anim. Sci. 43:1088-1094.

Gocham, N., and J. M. Schmitz. 1972. Application of new peroxide indicator reaction to specific automated determination of glucose with glucose oxidase. Clin. Chem. 18:943-950.

Gross, K. L., D. L. Harmon, and T. B. Avery. 1988. Net portal nutrient flux in steers fed diets containing wheat and sorghum grain alone or in combination. J. Anim. Sci. 66:2091-2094.

Ham, G. A., R. A. Stock, T. J. Klopfenstein, E. M. Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distiller's byproducts compared with dried corn distiller's grains with solubles as a source of protein and energy for ruminants. J. Anim. Sci. 72:3246-3257.

Hover, W. H. 1986. Chemical factors Involved in ruminal fiber digestion. J. Dairy Sci. 69:2755-2766.

Herrera-Saldana, R., and J. T. Huber. 1989. Influence of varying protein and starch degradabilities on performance of lactating cow. J. Dairy Sci. 72:1477-1483.

Huntington, G. B. 1997. Starch utilization by ruminants: from basics to the bunk. J. Anim. Sci. 75:852-867.

May, M. L., J. S. Drouillard, M. J. Quinn, and C. E. Walker. 2007a. Wet distiller's grains with solubles in beef finishing diets comprised of steam-flaked or dry-rolled corn. KSU Progress Report. 978:58-61.

May, M. L., M. L. Hands, M. J. Quinn, B. E. Depenbusch, J. O. Wallace, C. D. Reinhardt, and J. S Drouillard. 2007b. Dry distiller's grains with solubles in steam-flaked corn or dry-rolled corn diets with reduced roughage levels. J. Anim. Sci. 85 (Supp 1):528 (Abstr.).

Roeber, D. L., R. K. Gill, and A. DiCostanzo. 2005. Meat quality responses to feeding distiller's grains to finishing Holstein steers. J. Anim. Sci. 83:2455-2460.

Vander Pol, K.J., M. K. Luebbe, G. I. Crawford, G.E. Erickson, and T.J. Klopfenstein. 2007. Digestibility, rumen metabolism, and site of digestion for finishing diets containing wet distillers grains or corn oil. Nebraska Beef Report. University of Nebraska-Lincoln Extension. MP90-A: 39-42.

Santos, K. A., M. D. Stern, and L. D. Satter. 1984. Protein degradation in the rumen and amino acid absorption in the small intestine of lactating dairy cattle fed various protein sources. J. Anim. Sci. 58:244-255.

Satter, L. D., and L. L. Slyter. 1974. Effect of ammonia concentration on rumen microbial protein production in vitro. Br. J. Nut. 32:199-208.

Theurer, C. B. Grain processing effects on starch utilization in ruminants. 1986. J. Anim. Sci. 63:1649-1662.

Williams, C. H., D. J. David, and O. Iisamaa. 1962. The determination of chromic oxide in feces samples by atomic absorption spectrophotometry. J. Agri. Sci. 59:381-385.

Zinn, R. A. 1990. Influence of steaming time on site of digestion of flaked corn in steers. J. Anim. Sci. 68:776-781.

Zinn, R. A., C. F. Adams, and M. S. Tamayo. 1995. Interaction of feed intake level on comparative ruminal and total tract digestion of dry-rolled and steam-flaked corn. J. Anim. Sci. 73:1239-1245.

Table 5-1. **Composition of diets containing steam-flaked corn or dry-rolled corn based finishing diets containing 0 or 25 percent corn dry distiller's grains with solubles (DDG) fed to cannulated Holstein steers.**

	Dry-rolled corn		Steam-flaked corn	
Item, % dry matter	0% DDG 15% Silage	25% DDG 15% Silage	0% DDG 15% Silage	25% DDG 15% Silage
Steam-flaked corn	-	-	73.85	56.44
Dry-rolled corn	73.82	56.40	-	-
Corn silage	13.84	13.84	13.82	13.83
DDGS	-	25.24	-	25.21
Vegetable oil	2.18	-	2.18	-
Soybean meal	4.45	-	4.45	-
Urea	1.17	0.14	1.19	0.14
Limestone	1.62	1.65	1.62	1.65
Supplement[a]	0.69	0.53	0.69	0.53
Feed additive premix[b]	2.19	2.20	2.19	2.20
Nutrients				
Ether extract	5.80	5.24	5.81	5.24
Starch	54.82	42.60	55.07	43.74
NDF	13.13	17.52	13.63	17.58
Organic matter	97.37	97.50	97.35	97.41
Crude Protein	15.48	15.35	15.00	14.99
Calcium	0.71	0.64	0.71	0.64
Phosphorus	0.30	0.46	0.30	0.46

[a] Minerals and Vitamins, %. Formulated to provide 2650 IU/kg Vitamin A, 0.15 mg Co, 10 mg Cu, 0.5 mg I, 50 mg Mn and 50 mg Zn per kg DM.

[b] Feed additive premix provided 300 mg monensin, and 90 mg tylosin, per animal daily in a ground corn carrier.

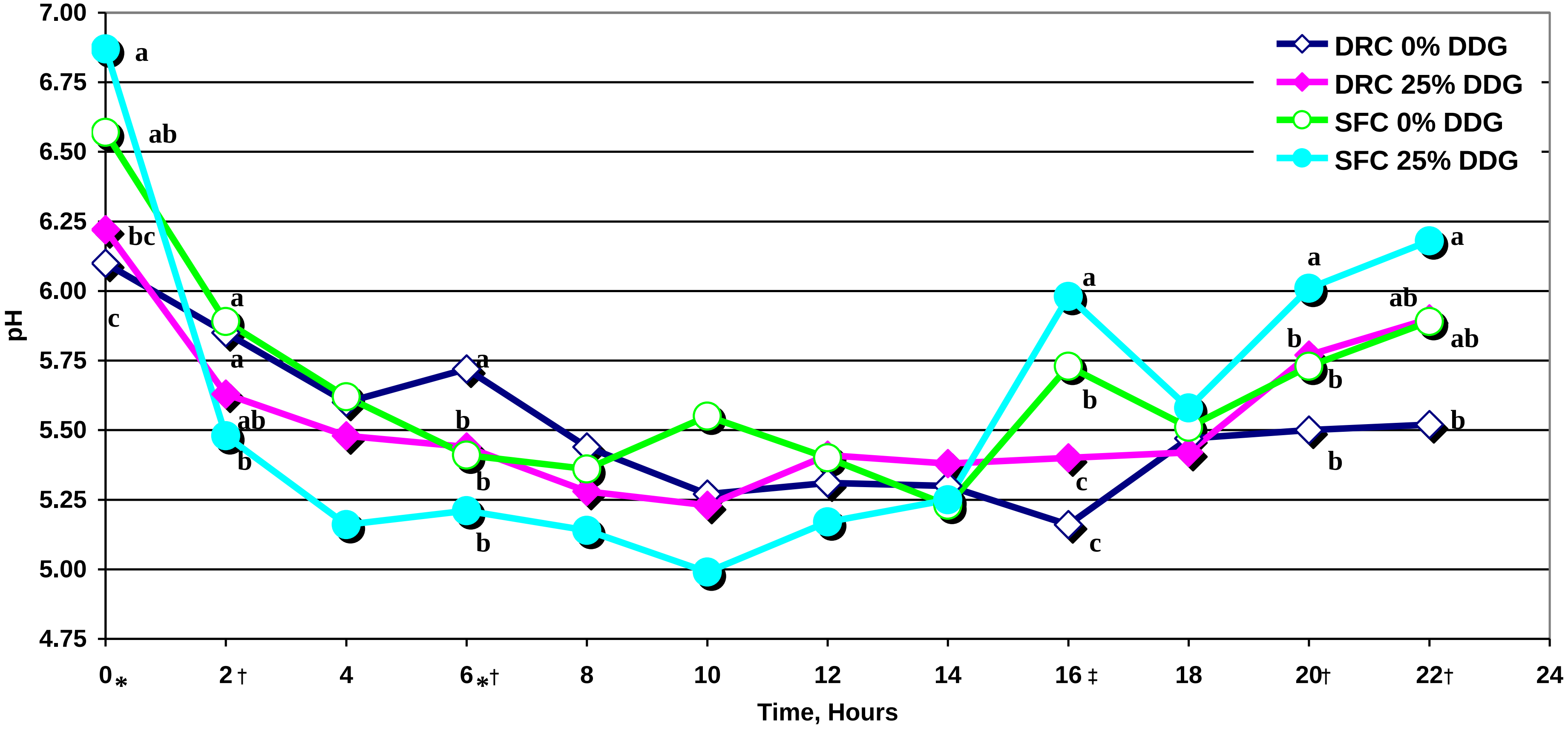
Table 5-2. Digestion characteristics for cannulated Holstein steers fed diets containing steam-flaked corn or dry-rolled corn based finishing diets containing 0 or 25 percent corn dry distiller's grains with solubles (DDG).

	Dry-rolled corn		Steam-flaked corn			P-Values		
Item	0% DDG	25% DDG	0% DDG	25% DDG	SEM	Grain	DDG	Grain*DDG
Intake, kg/d								
DM	8.81	8.64	7.90	7.36	0.33	<0.01	0.10	0.40
OM	8.58	8.43	7.69	7.17	0.32	<0.01	0.10	0.39
Starch	4.84	3.68	4.35	3.23	0.16	<0.01	<0.01	0.85
NDF	1.16	1.51	1.08	1.29	0.05	<0.01	<0.01	0.08
Ether extract	0.51	0.45	0.46	0.39	0.02	<0.01	<0.01	0.55
Fecal excretion, kg								
DM	1.88	1.99	1.18	1.28	0.17	<0.01	0.34	0.99
OM	1.76	1.84	1.02	1.15	0.16	<0.01	0.30	0.82
Starch	0.55	0.41	0.06	0.04	0.07	<0.01	0.17	0.35
NDF	0.96	1.11	0.58	0.70	0.10	<0.01	0.06	0.90
Ether extract	0.039	0.053	0.030	0.033	0.005	<0.01	0.03	0.12
Apparent total tract digestibility, %								
DM	78.84	77.71	85.30	82.88	1.49	<0.01	0.11	0.56
OM	79.80	78.88	86.88	84.20	1.44	<0.01	0.10	0.43
Starch	88.99	89.60	98.56	98.84	1.57	<0.01	0.94	0.65
NDF	17.09	29.14	47.10	46.42	6.28	<0.01	0.22	0.20
Ether extract	92.27	88.44	93.58	91.60	0.82	<0.01	<0.01	0.20

Table 5-3. Ruminal valerate, isobutyrate, isovalerate 2-methyl, and isovalerate 3-methyl production for cannulated Holstein steers fed diets containing steam-flaked corn or dry-rolled corn based finishing diets containing 0 or 25 percent corn dry distiller's grains with solubles (DDG).

	Dry-rolled corn		Steam-flaked corn			P-Values		
Item, mM	0% DDG	25% DDG	0% DDG	25% DDG	SEM	Grain	DDG	Grain*DDG
Valerate	2.20	1.59	2.76	3.01	0.64	0.07	0.68	0.36
Isobutyrate	0.78	0.76	0.52	0.59	0.05	<0.01	0.59	0.37
Isovalerate 2-methyl	2.53	1.90	1.30	0.99	0.48	0.03	0.28	0.70
Isovalerate 3-methyl	0.67	0.66	0.39	0.50	0.07	<0.01	0.39	0.37

Figure 5-1. Ruminal pH of cannulated Holstein steers fed steam-flaked corn (SFC) or dry-rolled corn (DRC) based finishing diets and 0 or 25 percent corn dry distiller's grains with solubles (DDG).



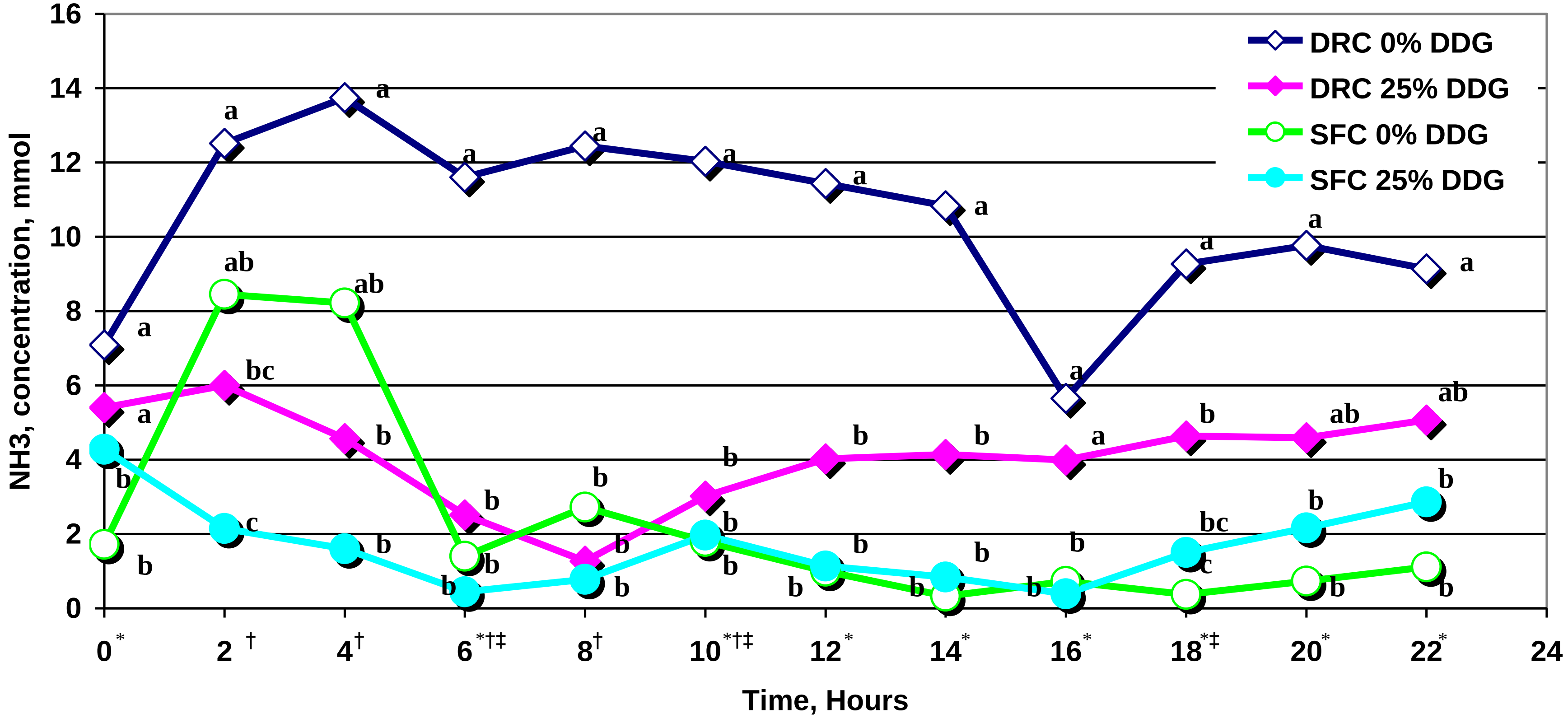
^{a,b,c}Within hour, means that do not have a common superscript differ ($P < 0.05$).

*Grain effect ($P < 0.05$)

†DDG effect ($P > 0.05$)

‡Grain by DDG interaction ($P < 0.05$)

Figure 5-2. Ruminal ammonia concentrations of cannulated Holstein steers fed steam-flaked corn (SFC) or dry-rolled corn (DRC) based finishing diets containing 0 or 25 percent corn dry distiller's grains with solubles (DDG).



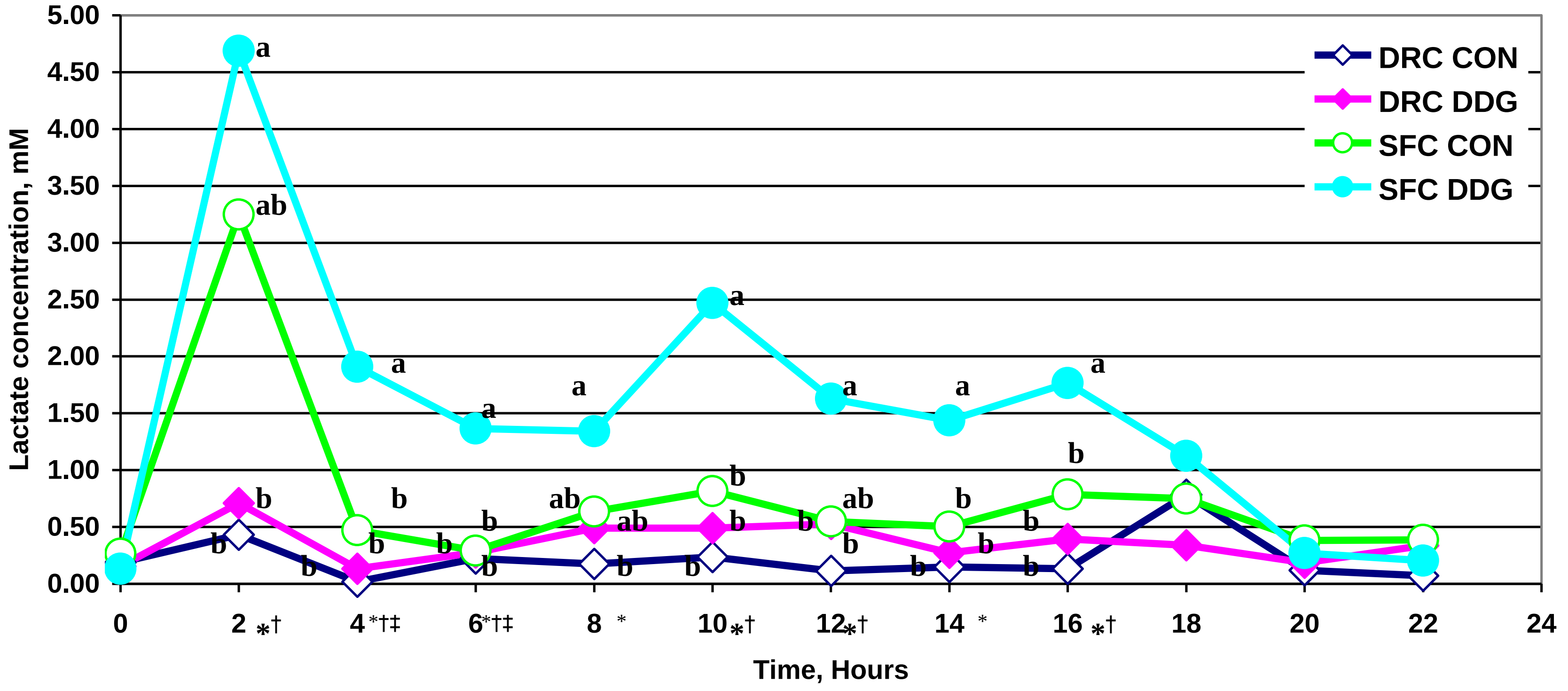
[a,b,c]Within hour, means that do not have a common superscript differ ($P < 0.05$).

*Grain effect ($P < 0.05$)

†DDG effect ($P < 0.05$)

‡Grain by DDG interaction ($P < 0.05$)

Figure 5-3. Ruminal lactate concentrations of cannulated Holstein steers fed steam-flaked corn (SFC) or dry-rolled corn (DRC) based finishing diets containing 0 or 25 percent corn dry distiller's grains with solubles (DDG).



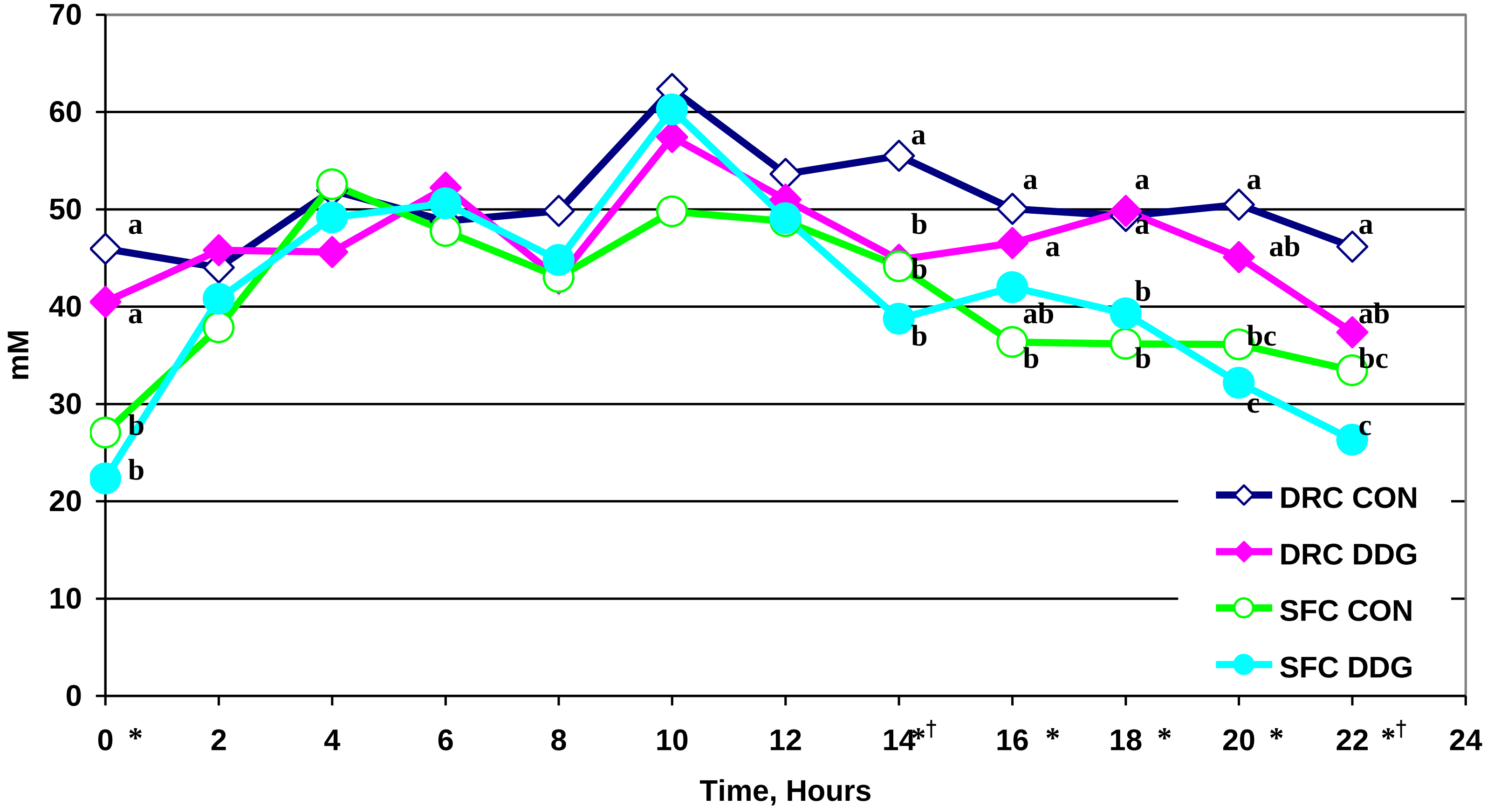
[a,b]Within hour, means that do not have a common superscript differ ($P < 0.05$).

*Grain effect ($P < 0.05$)

[†]DDG effect ($P < 0.05$)

[‡]Grain by DDG interaction ($P < 0.05$)

Figure 5-4. Ruminal acetate concentrations of cannulated Holstein steers fed steam-flaked corn (SFC) or dry-rolled corn (DRC) based finishing diets containing 0 or 25 percent corn dry distiller's grains with solubles (DDG).

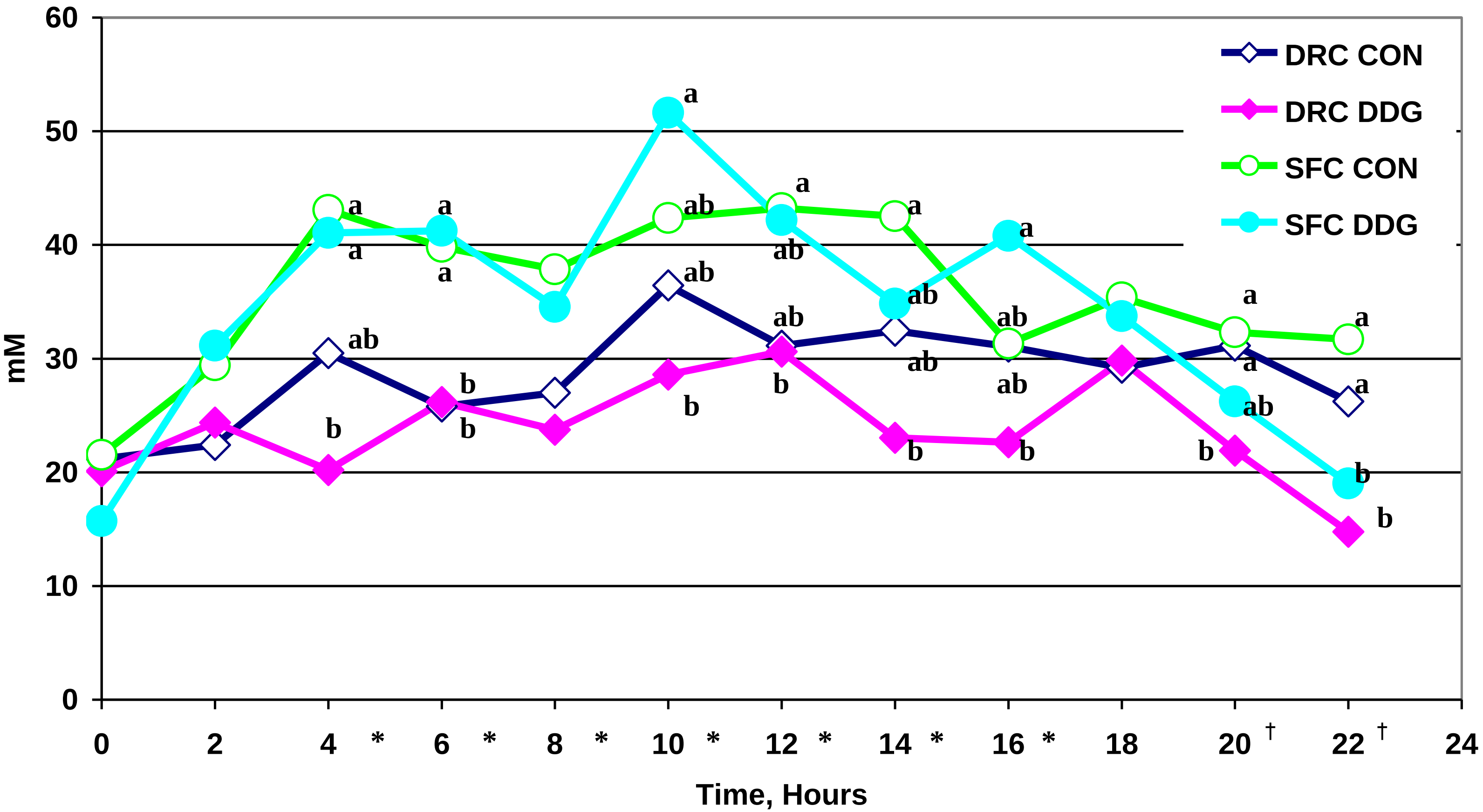


[a,b,c]Within hour, means that do not have a common superscript differ ($P < 0.05$).

*Grain effect ($P < 0.05$)

†DDG effect ($P < 0.05$)

Figure 5-5. Ruminal propionate concentrations of cannulated Holstein steers fed steam-flaked corn (SFC) or dry-rolled corn (DRC) based finishing diets containing 0 or 25 percent corn dry distiller's grains with solubles (DDG).

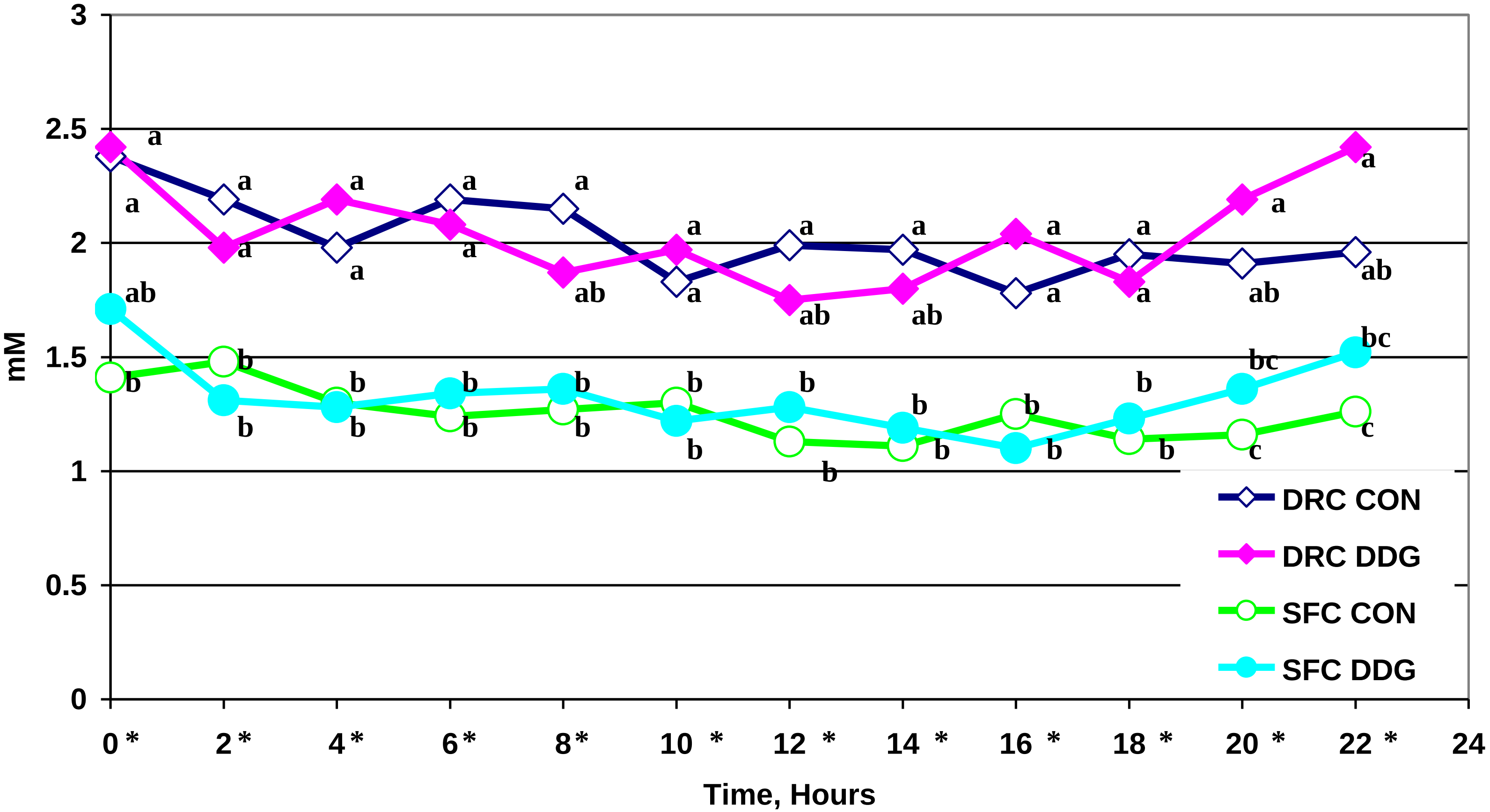


[a,b,c]Within hour, means that do not have a common superscript differ ($P < 0.05$).

*Grain effect ($P < 0.05$)

†DDG effect ($P < 0.05$)

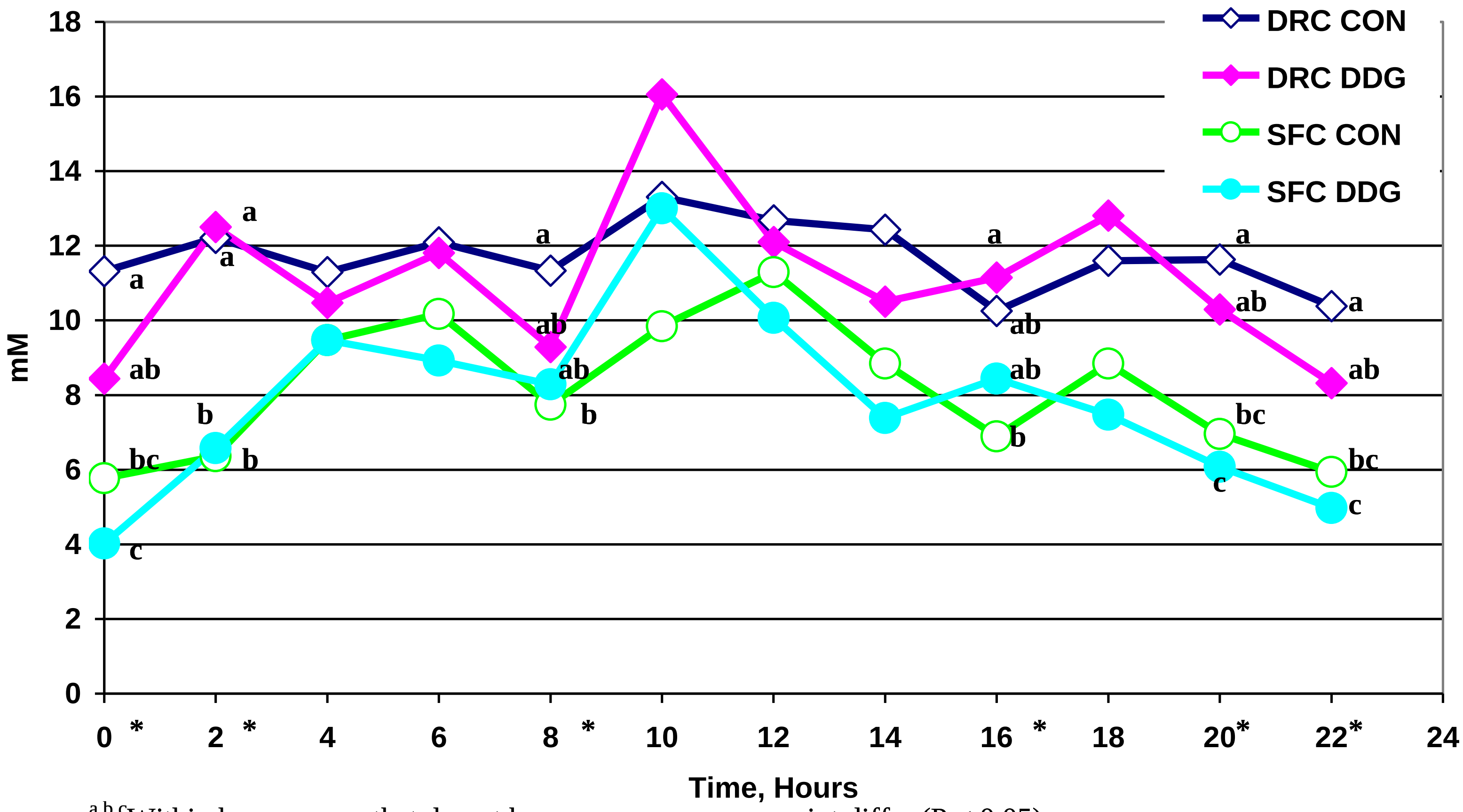
Figure 5-6. Ruminal acetate to propionate ratio concentrations of cannulated Holstein steers fed steam-flaked corn (SFC) or dry-rolled corn (DRC) based finishing diets containing 0 or 25 percent corn dry distiller's grains with solubles (DDG).



^{a,b,c}Within hour, means that do not have a common superscript differ ($P < 0.05$).

*Grain effect ($P < 0.05$)

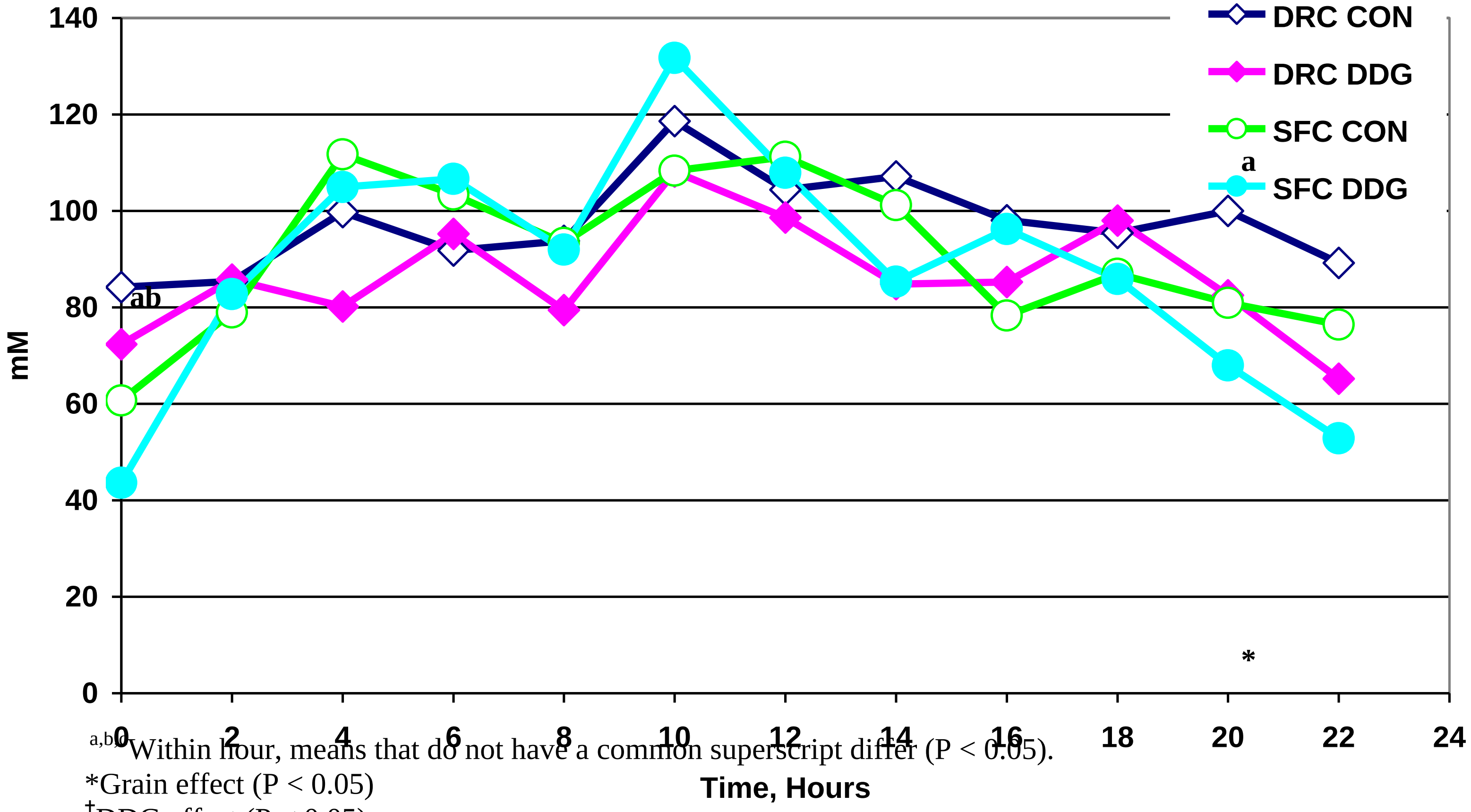
Figure 5-7. Ruminal butyrate concentrations of cannulated Holstein steers fed steam-flaked corn (SFC) or dry-rolled corn (DRC) based finishing diets containing 0 or 25 percent corn dry distiller's grains with solubles (DDG).



^{a,b,c}Within hour, means that do not have a common superscript differ ($P < 0.05$).

*Grain effect ($P < 0.05$)

Figure 5-8



[a,b,c]Within hour, means that do not have a common superscript differ ($P < 0.05$).

*Grain effect ($P < 0.05$)

†DDG effect ($P < 0.05$)