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The Use of High Distillers Grains and Nutrient Management in Beef Feedlots

Amy R. Rich
University of Nebraska - Lincoln, arr@huskers.unl.edu

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by

Amy R. Rich

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THE USE OF HIGH DISTILLERS GRAINS AND NUTRIENT MANAGEMENT IN BEEF FEEDLOTS

Amy R. Rich, M.S.

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Advisors: Galen E. Erickson & Terry Klopfenstein

Two experiments were conducted to determine the effect of feeding wet distillers grains (WDGS) at 70% and wheat straw at 25% (DM basis) on finishing steer performance and N mass balance in open feedlot pens. Four treatments were tested as a 2x2 factorial with factors being diet and pen cleaning frequency (monthly or at the end of the feeding period). In both experiments the CON treatment (corn based diet) had greater DMI, ADG, HCW, marbling and fat depth. There was greater N intake and N excretion for both the WINTER and SUMMER experiments on the WDGS. Not all the additional N excreted by feeding WDGS above the animal's requirement was lost: some was removed in the manure during pen cleaning. Evaluation of nutrient mass balance experiments in feedlots will help minimize the negative impact of feeding those ingredients on the environment.

The influence of feeding high levels of wet distillers grains plus soluble (WDGS) with wheat straw or on performance and carcass characteristics on feedlot steers were evaluated in one experiment. Economical analysis was performed on all seven treatments. No cases of polio were observed when feeding WDGS diets with no inclusion of corn however, feedlot performance appeared to be negatively impacted when WDGS

was fed above 77% DM or wheat straw was increased in the diet above 10%. Feeding WDGS at 40% of diet DM resulted in improved ADG, G:F, and greatest profit. Feeding diets including high levels of WDGS and wheat straw resulted in lower feedlot performance which resulted in higher cost of gain (COG) and less profit.

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Introduction

Distillers products are important feedstuffs for beef feedlot cattle. Since nutrient management is an ever-lasting environmental concern for both consumers and the feedlot industry, it is important to understand the effects of feeding distillers products on nutrient management in open-dirt feedlots. One of the largest challenges facing these typical feedlots are N volatilization losses from the point of animal excretion to crop utilization. Discovering options to minimize this volatilization on the pen surface would help Nebraska's cattle feedlot industry become more sustainable.

Literature Review

Environmental concern of livestock manure

Intensified livestock production has been implicated as the primary source of the large increase in NH_3, with estimates of 80% of yearly emissions from livestock (Pain et al., 1998). Concerns about excessive nutrient accumulation on intensive food animal production operations stem from imports of elemental nutrients in purchased feeds being greater than the nutrient exports in food animal products (Van Horn et al., 1996). Agriculture in the Midwest is recognized for efficient large scale operations. Nearly 75-80% of the beef feeding industry in the United States occurs in Nebraska, Texas, Kansas, Iowa and Colorado. In the United States and Western Europe, agriculture contributes an estimated 90% of total NH_3 emissions to the atmosphere. Of that 90% of NH_3 emissions, nearly 66% are estimated to originate from manures produced by livestock enterprises (Meisinger and Jokela, 2000). Regulations from the Environmental Protection Agency have recently been adopted in the United States to reduce NH_3 emissions produced by the beef animal. These regulations may eventually increase the cost of production by decreasing the efficiency and/or potentially reduce the number of animals that can be produced.

There are several forms of N that exist through processes known as N-fixation, ammonification, nitrification, and denitrification. Through ammonification of urea, through urine, NH_3 escapes into the air followed by deposition and nitrification to NO^-_3, which can compromise water quality by leaking into soil water reservoirs. Denitrification of Nitrate leads to the escape of nitrous oxides (NO_x) gas, which produce harmful effects through green house gases to the ozone layer (Tamminga, 1996). Ammonia loss through volatilization into the air can contribute to acid rain deposition (soil acidification) and eutrophication (Bouwman and Van Der Hoek, 1997). N or P pollution in surface water causes eutrophication, which leads to the rapid growth of algae and microorganisms and the depletion of oxygen, in turn causing fish kills and ecosystem damage. The state that N assumes after excretion determines whether N is harmful or beneficial to the environment.

Ammonia volatilization is high in livestock manure because of the excess dietary N excreted in urine as urea (Tamminga, 1996). Urea is rapidly hydrolyzed to NH_4 (ammonium) and CO_2 by a readily available urease enzyme on the feedlot pen floor. Ammonium cannot be volatilized however, it is converted to a volatile form of N ($NH_{3,}$ ammonia). Temperature, pH, and [NH_4] are components that effect the volatilization of NH_3.

Eghball and Power (1994) concluded that 50% of the remaining N may be lost in storage, hauling, spreading, and the incorporation of manure into the soil. Considering these environmental losses, it would be beneficial to find ways to trap the N in manure therefore decreasing the amount lost to volatilization.

Nitrogen

Nitrogen is a vital nutrient for plants and animals and a precursor to proteins that all animals require for life. The majority of N in manure is excreted as urea in urine and lesser as organic N in feces. Depending on diet, 60 to 80% of the total N excreted is in urine, while the remaining N is excreted in the feces (Bierman et al, 1999; Van Horn et al., 1996). The NRC (1996) estimates N retention at ≤ 20% of N intake therefore ≥ 80% of N intake is excreted via urine and feces. Nitrogen losses can be highly variable with the time of the year, with twice as much N being volatized from the pen surface during the summer months when compared to the winter/spring (Adams et al., 2004). Other research concludes that as much as 60 to 70% of excreted N is lost during the summer months and 40% lost during the winter/spring months (Erickson and Klopfenstein, 2001a). These data suggest that the amount of volatilization is dependent on air temperature.

Manure utilization

Manure from feedlot operations is often managed as a waste product when it has the potential to be marketed and handled as a nutrient resource (NRC, 2003). A lack of manure resources and the decline in soil quality leaves grain production with shortages of nutrients and organic matter. Therefore, the increased need for commercial fertilizer to maintain soil quality and maximize yield is necessary (DeLuca and DeLuca, 1997). There is potential for the excess nutrients supplied in beef feedlot manure to provide the required nutrients that grain producers are seeking through commercial fertilizers. This relationship would provide the feedlot producer with an outlet for manure they have in excess and provide less expensive nutrients that the crop producer requires. Manure from feedlot operations has the potential to supply all the essential nutrients and restore depleted organic matter (Eghball and Power, 1999). However, because of the potential for excess nitrates, salts, pathogens, odors and possible weed seed, manure from beef cattle could be a source of pollution for water, air, and land (Eghball and Power, 1994). Manure from feedlots can be left on the feedlot pen surface for up to 1 year before it is collected and stored. By the time the pen is cleaned and hauled to be piled, the manure has lost about 50% of the excreted N, mostly to NH_3 volatilization (Gilbertson et al., 1971). However, following the initial NH_3 volatilization the remaining N is more stable.

Methods to reduce nitrogen losses

There have been many research trials conducted that evaluate the reduction of NH_3 emissions and capturing N in the manure. The most common method researched is altering the C:N ratio. By feeding less digestible feedstuff (fiber) to the steer, the excretion of OM increases therefore increasing the C:N ratio on the pen surface. Feeding a diet with decreased digestibility decreases the performance of these steers. Another method is by direct addition of carbon to the pen surface, such as bedding. Other methods of decreasing N losses, include: feeding rations that match the animals requirements (MP system), or changing the route of N excretion, urease inhibitors, and acidification of the manure or pen surface.

Another avenue of research evaluated the effects of decreasing nitrogen losses is pen cleaning frequency. As previously mentioned in the literature, volatilization is affected by [NH_4], pH on the pen surface, and air temperature. The speed of biological oxidation is in direct proportion to the amount of surface exposed to the reactive agent (de Bertoldi et al., 1983).

Dietary

Elzing and Monteny (1997) concluded that NH_3 emissions are positively correlated to the concentration of urinary urea-N. Total NH_3 and amine emissions represented about one-half the rate of urinary N deposition, or about one-fourth the rate of total N deposition (Hutchinson et al., 1982). Theoretically, if urinary urea-N excretion is reduced, than N would be more stable in the manure. The fate of N excretion whether it be urine or feces, in the ruminant, is dependent upon the amount of hindgut fermentation. Hindgut fermentation increases fecal N and decreases urinary N excretion (Ulyatt et al., 1975). Hindgut fermentation is increased when a diet includes feedstuffs high in carbohydrate sources and their availability in the rumen and small intestine are limited.

Rapidly degradable, non-structural carbohydrates such as corn starch are degraded in the rumen so are not available for fermentation in the hindgut. However, fiber sources (fibrous corn byproducts or roughage) do not digest completely and therefore are available for fermentation within the hindgut. The high NDF content, or amount of carbohydrates that reach the hindgut for fermentation, increases the amount of fecal N and OM excreted by the steer (Bierman et al., 1999). This is caused by the protein needs of the microbes in the hindgut, therefore blood urea is recycled across the intestinal wall due to microbial activity and the need for N (Canh et al., 1997). As a result, N excretion from urine shifts to a more stable form, as organic N in feces, and may decrease volatilization occurring on the pen surface (Bierman et al., 1999).

Experiments using dietary manipulation

In one of the first mass balance experiments conducted at UNL, Bierman et al. (1999) fed diets containing three levels of fiber to feedlot steers: 1) 41.5% wet-corn gluten feed with 7.5% roughage, 2) 7.5% roughage, and 3) 0% roughage to determine the effect of carbohydrate source on reducing the loss of N, through the distribution of N from urine to feces. Nitrogen intake was greatest for the WCGF, followed by the 7.5% roughage diet, and the lowest for 0% roughage. Since cattle retained similar amounts of N, then intuitively the cattle that consumed the most N, excreted the most N. The cattle consuming the WCGF excreted the greatest amount of N, followed by the 7.5% roughage diet, and lowest amount of N excreted was seen with the 0% roughage (20.8, 18.5, 16.3 kg, respectively). The amount of N removed in the manure was greatest for the WCGF treatment (3.9 kg), intermediate for the 7.5% roughage diet (2.3 kg), and lowest for the 0% roughage (1.5 kg).

Erickson and Klopfenstein (2001b) determined whether an increase in OM excretion would decrease N losses from open feedlots by feeding corn bran at 0, 15, and 30% of diet DM. Seasonal variation, as previously mentioned as a factor affecting volatilization was observed in this experiment. During the winter/spring trial, OM in manure was increased 51 and 105% for cattle fed 15 and 30% bran, respectively, compared to the cattle consuming 0% bran. N losses were linearly reduced by 14.5 and 20.7% for the 15 and 30% bran diets compared to the no bran diet. Manure N increased linearly by 67 and 98% with the cattle consuming 15 and 30% corn bran. However, in the summer/fall trial, OM in manure only increased 15 and 25% for the cattle consuming the 15 and 30% corn bran diets, respectively. These OM amounts observed in the summer trial were not great enough to impact manure N or N losses. Even though N volatilization was not impacted in the summer trial, there was still an increase in the C:N ratio of the manure removed. These data would suggest that the addition of corn bran has varying effects on manure N retention depending on the time of year. Adding corn bran to a feedlot ration at 15 to 30% during the cooler months could decrease N volatilization.

Wet Distillers Grains and Nutrient Mass Balance

Feeding less digestible feedstuffs has been successful in reducing the amount of N lost from the pen surface by increasing hindgut fermentation, which results in an organic N in the feces rather than urea in the urine, a more volatile form of N (Bierman et al., 1999; Adams et al., 2003; Farran et al., 2006). Adams et al. (2003) and Sayer et al. (2004) reported decreased cattle performance when diets contained feedstuffs that were less digestible than a “typical” feedlot ration. Wet distillers grains improves animal performance as well as increases the OM in the manure, which is partially due to its higher NDF content (37%) when compared to corn (Klopfenstein et al., 2008). Another benefit of feeding WDGS reported by Bremer et al (2008) is that, compared to a corn-based diet feeding WDGS can improve fertilizer value of feedlot manure.

Luebbe et al. (2008) performed two experiments to evaluate the impact of WDGS on cattle performance and nutrient mass balance. The WINTER experiment took place from November to May and the SUMMER experiment took place from June to October. Treatments consisted of 0, 15, and 30% dietary inclusion of WDGS (DM basis) replacing corn (CON, 15WDGS, 30WDGS, respectively). Dry-matter intake and ADG increased linearly with the inclusion of WDGS level in the WINTER and was not significanty different in the SUMMER. Feed efficiency was not different among treatment levels in either experiment. Nitrogen and P intake increased linearly with the level of WDGS inclusion in both the SUMMER and WINTER. The SUMMER experiment did not show an increase in N retention, however, the WINTER experiment, due to its ADG response, had an increase in N retention. Nitrogen excretion increased linearly with WDGS, however, the amount of N removed in the manure was not different among treatment in the WINTER but increased linearly with the inclusion of WDGS level in the SUMMER. Expressed as a percentage of N excretion, loss of N was not different among treatments (66.6 and 76.2%) in the WINTER and SUMMER, respectively. More N was lost when

WDGS were fed but not all of excreted N volatilized, a portion of the excreted N was removed in the manure.

Amendments and Pen cleaning Frequency

Amendments to manure such as straw and sawdust have been utilized in several research trials. Using the application of straw in collected manure to reduce N losses resulted in variable results (Bussink and Oenema, 1998, Shi et al., 2001). Variability in results could be due to the storage method of the manure (anaerobic vs aerobic),

Lory et al. (2002) conducted a study in which sawdust was applied to the feedlot pen surface in an attempt to reduce N losses. The application rate of sawdust to the pen surface was a 2:1 ratio of sawdust to fecal DM, or 0.17lb/ft^2. This experiment was conducted from mid-June to mid-October. Nitrogen volatile loss was reduced by 21% when compared to pen surfaces that received no additional carbon source.

Adams et al. (2003) evaluated direct addition of OM to the pen surface vs. indirect addition through dietary manipulation. Summer and winter trials included a “typical” Nebraska feedlot diet (0% corn bran); a diet designed to decrease digestibility and increase OM excretion (30% corn bran); and a management treatment where cattle were fed diets identical to “typical” feedlot diet and weekly applications of sawdust were added to the pen surface at a rate calculated to match OM excretion by the corn bran fed cattle. During the winter trial, adding OM to the pen surface either directly (sawdust) or indirectly (feeding corn bran) decreased the amount of N lost and increased the about of N retained in the manure. There were 20 to 23% reduction in N loss for 30% corn bran fed cattle and pens in which the direct method was used (sawdust), respectively, compared to the "typical" feedlot diet (0% corn bran). Fecal N was highest for the cattle consuming the 30% corn bran diet, suggesting that the route of N excretion was shifted to less urinary urea-N and more fecal N. As Erickson et al. (2001a) observed, during the summer trial, the C:N ratio was increased with the corn bran feeding but was not enough to make an impact on reducing N losses.

Pen cleaning frequency

Adding carbon to the pen surface has improved the C:N ratio; however, this may have limited application due to management challenges. The addition of carbon to a pen floor during the summer months did not seem to impact the N retention in the manure. An alternative method researched for decreasing the amount of N volatilized from the pen surface is to increase the frequency of pen cleaning. Since warmer temperatures during the summer months result in rapid volatilization, the removal of manure more frequently results in less exposure of manure N to surrounding air which would reduce N losses. Improvements in the C:N ratio in manure has been recognized to aid in N retention during composting (Fogarty and Tuovinen, 1991).

Two experiments were conducted during the summers of 2001 and 2002 by Wilson et al. (2004). These experiments evaluated the impact on N volatilization when feedlot pens were cleaned either monthly cleaning or at the end of the feeding period cleaning. A total of four cleanings were performed in the monthly cleaning treatment which was approximately every 28 days throughout the feeding period. The amount of DM, OM and N removed were increased if pens were cleaned monthly compared to cleaning at the end of the feeding period. Nitrogen in manure for the monthly cleaning was increased 3.95 kg per steer or a 69.0% increase above manure N removed on the end cleaning treatment. The C:N ratio was improved due to the increase in OM in manure when the pen surface was cleaned and manure was collected more frequently. By cleaning pens every month, total OM removal increased per steer (95.5 kg, 81.5 kg) or increased (91.4%, 66.8%) above OM removed at the end of the cleaning period, 2001 and 2002 respectively.

Farran et al. (2004) evaluated the effect of dietary manipulation and management on N losses from open feedlot pens during both winter and spring feeding periods. To evaluate if there was an interaction between pen cleaning frequency and diet on N losses, a 2 X 2 factorial design was used. Pens were cleaned either monthly or once at the end of the feeding period. Corn bran was fed at 0% or 30% diet DM and applied to both pen cleaning treatments. An interaction for the effects of dietary treatment and pen cleaning frequency was observed for N balance in the feedlot. Nitrogen losses decreased and manure N increased for cattle fed 30% corn bran compared to 0% corn bran if pens were cleaned on a monthly schedule. Feeding 30% corn bran did not influence manure N, but resulted in higher N loss when pens were cleaned once at the end of the feeding period. Feeding 30% corn bran increased the C:N ration of manure and increased the amount of N recovered in manure, regardless of pen cleaning schedule.

Acidosis

Ruminal pH is maintained to a major degree through the high buffering capacity of saliva and the removal of volatile fatty acids through absorption from the rumen (Van Soest, 1994). Every corn-based finishing diet is associated with a degree of risk for acidosis because of the starch content of grain which is the primary source of energy. The digestion of the starch in the rumen produces organic acids. Therefore, if the starch is easily digestible, then more of it will be digested leading to more organic acids being produced, which in turn lowers pH. Acidosis is considered the most important nutritional problem that feedlots face and improper management of acidosis can lead to poor performance. Feed efficiency is increased with increased starch intake and rapid and complete ruminal starch digestion. However, the rapid degradation of starch in the rumen can lead to acidosis and therefore decreased DMI and ADG. A full understanding of acidosis is needed to manage this issue in commercial feedlot settings. Stock and Britton (1993) defined acidosis as an array of biochemical and physiological stresses caused by rapid production and absorption of ruminal organic acids and endotoxins when an animal over consumes a diet of readily fermentable carbohydrates. Sudden death syndrome, reduced feed intake, clostridial infections, impaired absorption, and grain bloat were also related problems associated with acidosis (Brent, 1976). So acidosis can be caused by or result from an array of stresses and not just linked to the single symptom of low ruminal pH.

Britton and Stock (1987) classified acidosis into one of two categories, subacute and acute. Acute acidosis may make the animal sick to the point of death or may impair some physiological function, such as absorption. This occurs because during acute acidosis, blood flow to the gastrointestinal tract is reduced, therefore decreasing the amount of organic acids that can be absorbed from the rumen. With the low pH caused by the trapped organic acids, the ruminal epithelial tissue is damaged, causing reduced absorption of acids into the blood. The domino effect of organic acids, causing permanent damage to the epithelial tissue in the rumen, ultimately causes the animal to reduce the amount of absorption of nutrients.

Most feedlot managers, nutritionists and health professionals rarely can diagnose an animal that falls into a subacute acidotic state. The main symptom of subacute acidosis is for the animal to reduce its intake (Fulton et al., 1979). Factors that may influence the incidence of subacute acidosis include grain processing, grain sources, roughage level, particle size, and bunk space (Fulton et al., 1979). Subacute acidosis can be caused by any disturbance of normal feed intake such as environmental factor (i.e., heat, cold, or mud), pen design, or more commonly bunk management. Indicators of an animal in a subacidotic state are; reduced feed intake followed by lethargy, diarrhea, panting, excessive salivation, and any other general signs of discomfort or pain. Reduced feed intake is difficult to observe in a group feeding system. Any fluctuations of intake by individuals may have very little effect on the total pen intake, therefore making subacute acidosis difficult to diagnose (Fulton, et al., 1979).

The adjustment from a forage based diet to a concentrated diet is needed for the ruminal microbes to adapt to different substrates while the animal's intake control mechanisms are shifted from mostly gut fill to an energy scensoring mechanism. Factors that may affect the severity of acidosis include roughage level, corn milling byproduct inclusion, ionophore inclusion, and buffering agents. Ionophores increase the frequency of meals and decrease meal size. This in turn, elevates rumen pH and decreases fluctuations in pH (Cooper et al., 1997; Fanning et al., 1999). The incidence of subacute acidosis is reduced, resulting in an improvement of cattle performance.

Historically, adding roughages to feedlot finishing diets has been the primary method for controlling acidosis and adjusting the animals to the concentrate load in the finishing period. Adding roughages in the diet of an animal with acidosis has been shown to improve intake, gain, and feed efficiency (Stock et al. 1990). However, roughages are hard to handle, relatively expensive per pound of gain, and cause a bulky adaptation ration.

An alternative adaptation method was conducted by Huls et al. (2009a), tested the hypothesis that starting cattle on high levels of WCGF-B and then decreasing it while increasing DRC could be an alternative method for adapting cattle to a high-concentrate diet. The steers consuming the WCGF-B had lower pH levels during the adaptation period however, they had higher DMI and less variation of ruminal pH. Huls et al. (2009b) followed the metabolism trial with a performance study and reported increased intakes which carried over to increased final BW, concluding that the higher energy content of WCGF-B increased the performance of the steers during adaptation.

Corn Milling Byproducts in Finishing Diets

Feeding high concentrate diets to finishing cattle allows maximal efficiencies at the lowest cost of gain because grains are cheaper on an energy basis then any forage. Forages are typically included at low levels in a finishing diet to reduce the severity of acidosis as well as reduce the difficulty with the handling and processing of forage. New methods of reducing the forage load while maintaining animal performance and preventing intake disturbances, such as acidosis, will result in improved animal performance economic efficiencies (Stock et al., 2000, Stock and Britton, 1993).

Corn Wet Milling

The main purpose of the corn wet milling process is to provide products for human consumption. One of the most popular of these products is the sweeteners used in most beverages and snacks. The corn kernel is composed of approximately 2/3 starch. During the wet milling process the aim is to expose the starch portion of the kernel. The wet milling process of corn has been written in detail by Stock et al. (2000) and Loy et al. (2004). The idea of the wet milling process is not new, Blanchard (1992) reported that the process has been done from as far back as 1842. Improvements on the method have been made since then to where almost 100% of the corn kernel is recovered. During the process, the individual components of the corn kernel are separated and are used in numerous ways to produce other products. Some of the separations include: starch, gluten, germ, solubles (corn steep liquor, corn steepwater, or condensed fermented corn extractives), and corn fiber (bran). These seperations are then either sold alone, modified, or combined to sell feed byproducts such as corn gluten meal, corn gluten feed (either wet or dry), or corn steep liquor. By selling these other byproducts to the animal feeding industry the initial cost of the process is reduced by 30 to 40% (Blanchard, 1992). Since the wet milling process products are mostly produced for human consumption, one disadvantage for this process is that only corn can be used in production and the corn must be #1 or #2 grade. Initially, corn is subjected through a screening process that removes all crop residues, broken kernels, fines, or foreign material. It is then steeped in a dilute sulfurous dioxide solution for 40 to 48h at a temperature of 49 to 53˚C. The process of steeping, softens the kernel and catalyzes the separation of starch by breaking down the protein matrix. Following the steeping period, the kernels are then passed through a series of grinds, differential separation and centrifugation with the isolation of starch, bran, germ, steep liquor, and gluten (Blanchard, 1992). The process is based on the use of water throughout the process as a separating and cleaning agent. By running the water countercurrent with respect to the flow of the grain, the water acquires soluble nutrients through each step of the process. Germ is removed and then undergoes oil extraction. The remaining product is called corn germ meal and this product can be combined with corn gluten feed and sold to the pet food industry because of its concentrated protein content. The next grinding process separates the bran and a series of screens removes the bran. The slurry that remains is composed of starch and gluten and is separated by a centrifuge. The gluten is dried and marketed as corn gluten meal to the pet and poultry food industries due to its high quantity and quality of protein. The slurry is then washed with fresh water and in this pure form can be marketed as flour or meals in the human food industry. Other processes or refinements can produce corn syrups, high fructose sweetners, fuel ethanol, and other feed byproducts.

The primary byproduct for feedlot cattle coming from the wet milling process is corn gluten feed (either wet or dry). The composition of corn gluten feed is variable from plant to plant, therefore, the nutritional value is different for the different feedstuffs.

Most commonly, corn gluten feed is composed of corn bran and steep liquor but can also contain varying levels of germ meal and distillers solubles.

Wet Corn Gluten Feed in Finishing Diets

Wet corn gluten feed is generally cited as 40 to 60% dry matter and between 16 and 22% crude protein. Stock et al. (2000) stated WCGF can be 100 to 115% the energy value of dry-rolled corn (DRC). However, Green et al. (1987) conducted a study evaluating the energy value of DCGF compared to an all corn diet. Green found that when DCGF was included in the diet at 46% DM, it was only 87% the feeding value of DRC. So the importance of nutrient analysis when formulating diets is critical to the performance of the animal. Compared with DRC, WCGF is much lower in starch (26 vs 72%, DM basis). Theoretically, if the starch load is replaced from DRC to WCGF, then subacute acidosis would be reduced as well. This could partially explain the higher energy value of corn gluten feed.

A finishing trial was conducted by McCoy et al. (1997) to determine the metabolism and digestibility of WCGF compared to DRC. Dietary treatments were based on concentrate energy source (DRC, DRC/WCGF, or WCGF). The DRC diet contained 83% DRC, 6% molasses, and 7.5% alfalfa hay. The DRC/WCGF diet contained 45% *each* DRC and WCGF and 7.5% alfalfa hay. The WCGF diet contained 90% WCGF and 7.5% alfalfa hay. Ruminal passage for DRC was slower for the DRC diet compared with the DRC/WCGF diet. Ruminal pH, concentrations of acetate, and butyrate increased linearly while the concentrations of propionate decreased linearly with the inclusion of WCGF. There was no difference in the ruminal digestibility or rate of disappearance for DM, CP, NDF, or starch for WCGF. However, total tract digestibility of NDF increased with the increased inclusion of WCGF. The authors concluded that replacing DRC with WCGF may increase total tract digestibility of DM, resulting in improved feed efficiency.

A meta-analysis by Bremer et al. (2008a) was performed to evaluate the differences seen with two types of WCGF which are commonly used in the feedlot industry. The first (WCGF-A) is composed of wet bran and steep and contains 40 to 42% DM and 15 to 18% CP (DM basis). Dry matter intake was similar for cattle receiving the WCGF-A or the control corn diet. Average daily gain had a tendency ($P = 0.10$) to increase linearly when WCGF-A replaced corn in the finishing diet. However, there was not enough of an improvement in ADG and similar DMI to impact the feed conversion across the treatments. Therefore, the small performance value differences resulted in a feeding value of 99% for the WCGF-A.

The second (WCGF-B) is composed of dry bran, steep and germ meal and contains 60% DM and 22 to 25% CP (DM basis). The cattle consuming WCGF-B showed a linear increase in ADG and DMI with the increasing inclusion of WCGF-B. The increased ADG and DMI resulted in an increased feed efficiency. The authors of this trial concluded the same as Ham et al. (1995) that feeding the WCGF-B did reduce acidosis. The feeding value of WCGF is dependent on the ratio of bran to steep in the production process. And this is seen in the ADG and marbling of the steers.

Farran et al. (2004) conducted a trial where WCGF-A replaced corn at 35% of the diet DM. Three levels of alfalfa hay were fed (0, 3.75, 7.5 diet DM). This study was conducted to test the hypothesis that WCGF-A could replace the roughage in the diet because of its effect of diluting the starch load to reduce acidosis. Dry matter intake and average daily gain were both increased with increased roughage and WCGF-A. However, steers being fed 35% WCGF-A without any source of roughage displayed the best feed efficiency. Therefore, from this experiment we conclude that WCGF-A could reduce the alfalfa hay inclusion from conventional levels and WCGF-A reduced the acidosis severity.

Ham et al. (1995) evaluated the performance and carcass characteristic effects of feedlot steers on increasing levels of WCGF compared to DRC. Dietary treatments included wet corn gluten feed at increasing levels (17.5, 35, 52.5, 70, or 87.5%) replacing the level of corn. Feed efficiency was not impacted by the inclusion of WCGF. However, average daily gain and intake responded quadratically when WCGF was increased. At 35% DM cattle achieved maximal average daily gain and intake. The energy value of all the levels of WCGF was estimated to be equal to the dry-rolled corn treatment.

Two experiments were conducted to evaluate the optimal inclusion level of WCGF in barley based diets, as well as, particle size of dry-rolled corn and barley on performance of feedlot steers. Loe et al. (2006) concluded that there was a positive quadratic response to increased levels of WCGF-A in barley diets with the optimum inclusion at 52%. However, when corn and WCGF-A were evaluated, the greatest ADG and feed efficiency was observed at 35% WCGF-A. In the second experiment, WCGF-A was included at 50% of all diets (DM basis), and the authors concluded that at this level there was a grain effect with DRC, fine-ground or coarse, having the most improved efficiency and fine-ground dry-rolled corn having the highest ADG. Looking at the grain type, feeding DRC resulted in higher gains and better feed conversion than feeding barley. They also suggest including WCGF-A in the diet at 50% (DM basis) with DRC, either fine-ground or coarse, because the grain processing method did not impact the performance of these steers.

Corn dry milling

The major product produced by the dry milling industry is the ethanol. The alcohol production from grain involves the fermentative conversion of starch to alcohol. One of the advantages of the dry milling process is the flexibility in the type and quality of grain that can be used in the fermentation process. Unlike the wet milling industry's standards of #1 or #2 corn, the wet milling process can utilized corn, grain sorghum, wheat, barley, or a mixture of any of these grains. Or a portion of the grain mix can be of lower quality.

The first step in this process described by Stock et al. (2000) grain is ground so that the enzymes can get to the starch portion of the grain more easily. Then the grain is mixed with water to form a mash that is then cooked to reduce the amount of bacteria. The cooking of the mash also gelatinizes the starch, making it even easier to degrade enzymes. Alpha-amylase, an enzyme, is added to convert the starch to dextrose, along with ammonia, to assist with pH control and a nutrient for the yeast. During the 48 hours of fermentation, the mash is agitated while the tank is bathed in cool water to keep the yeast active. The course feed particle in the mash may or may not be separated from the liquid before processing through the distillation column. Processing the entire mash generally results in higher yield of alcohol per bushel fermented (Stock et al., 2000). After the separation of the ethanol and remaining slurry, called whole stillage, through the distillation column the stillage is either screened and pressed or sent through a centrifuge where the coarser grain particles are removed. The thin stillage is approximately at 5 to 10% DM and contains fine grain particles and yeast cells. The coarser grain particles that are removed from the stillage are called wet distillers grains (WDG) and are approximately 28-35% DM. What is left from the centrifuging is called thin stillage which is run through an evaporation process that condenses the product to condensed distillers solubles (CDS) which are approximately 30-34% DM. The WDG can be dried to about 88-91% DM and form dry distillers grains (DDG) or the CDS may be dried with the DDG to form dried distillers grains plus solubles (DDGS). The CDS can also be added to the WDG to produce wet distillers grains plus soluble (WDGS) or partially dried to produce (MDGS). Another method of producing MDGS is by adding CDS to DDGS. The CDS may be sold as its own feed ingredient and used as a carrier, supplement, or source of energy or protein in a ration (Erickson et al., 2007)

Again, the main product from this process is the ethanol, which is produced from the starch in the corn kernel. The kernel itself consists of two-thirds starch, and after the fermentation, approximately one-third of the original grain DM is recovered in the stillage. Therefore if only the starch is removed from the grain, the other nutrients are concentrated by three-fold. For example, the crude protein (CP) increases from 10% to

30%, neutral detergent fiber (NDF) from 12 to 36%, and P from 0.3 to 0.9% of DM. Oil is not removed like discussed in the wet milling process, therefore, distillers grains contains about three-fold the amount of fat that the original grain had, approximately from 4 to 12% of DM. Another difference in distillers grains is the high levels of escape protein, this is produced because the gluten fraction of the grain is not removed during the procedure. In conclusion, the nutrient composition of distillers grains can be variable depending on the type and quality of grains used and the differences in the processes from each ethanol plant (Scott et al., 1997, Stock et al., 2000).

Use of wet distillers grains plus solubles in finishing diets

With the expansion of the ethanol industry, the availability of by-products increased as well. This interested cattle nutritionists and producers due to the cheap, nutritious product. Aines et al. (1987) summarized several experiments feeding byproducts and reported that DDG had 2.4 times the value of protein compared with that from soybean meal, and DDGS had 1.8 times the value of protein compared to soybean meal. Klopfenstein et al. (2008) concluded that feeding DGS at levels of 15% or less of diet DM, serves the animal just as a protein supplement would. In these cases, the DGS could be used as a grazing supplement, or for animals in growing or maintaining cow herds. Because of its high content of undegradable intake protein (UIP), DGS can also be used as the source of UIP for finishing steers. DGS also contains a high level of protein values at 30% DM, therefore at 20% DM inclusion, DGS could be used instead of a degradable intake protein supplement (DeHaan et al., 1983, Klopfenstein et al., 2008).

Larson et al. (1993) conducted some of the earliest experiments determining the energy value of wet distillers grains plus thin stillage. The wet distillers grains plus thin stillage was fed at either 5.2, 12.6, or 40% of the diet DM. One complication that was observed in this experiment was the handling, storing, and feeding of the 40% diet DM treatment this was due to the lack of evaporators used on thin stillage at that time. This was overcome by the steers being offered their portion of the thin stillage as drinking water then if that was consumed, fresh water was offered. The yearlings on the 5.2, and 12.6% byproduct diets comsumed more DM than the steers on the 40% byproduct diet or the corn-based diet. Average daily gain had a tendency to increase with the increasing inclusion of byproduct. Feed efficiency increased with increasing levels of byproduct. A calf-fed trial was also performed and the results were similar to the yearlings, in that the calves consuming the 40% byproduct ate the least, gained the most, and had greater feed efficiency than the 0, 5.2, and 12.6% levels of byproduct. Therefore, the authors concluded that if the handling challenge of the wet byproduct could be overcome, then the 40% inclusion of the byproduct in finishing diets would be the optimal level for performance.

However, there was no solid conclusion as to how much could be added to the diet and still see performance results. Vander Pol et al. (2006) evaluated the effects of increasing dietary inclusion of wet distillers grains plus soluble on feedlot performance. Dietary treatments included a control (CON), 10%, 20%, 30%, 40%, and 50% WDGS (DM basis) and 5% alfalfa hay. Dry matter intake as well as ADG increased quadratically as the inclusion of WDGS increased from 0-50% DM. Feed conversion decreased quadratically as the inclusion of WDGS increased, leaving the 40% level of

WDGS with the best feed efficiency. All energy values for WDGS were reported in excess of 100% compared to corn. Therefore, the authors summarized that regardless of dietary inclusion, feeding WDGS in finishing diets generates higher energy values than a corn-based diet.

Wilken et al. (2009) evaluated the effects of feeding high levels of byproduct in finishing diets. Treatments included; 1) CORN, 82.5% DRC 2) WDGS:corn, 43.5% or each corn and WDGS 3) WDGS:hay, 65.6% WDGS and 21.9% grass hay. All diets included 7.5% alfalfa hay as a roughage source. Vaness et al. 2009 concluded that roughage level is important in minimizing the incidences of polio in feedlot steers consuming diets producing high levels of hydrogen sulfide gas. Additional grass hay was incorporated in the WDGS:hay treatment to minimize any effect of hydrogen sulfide gas from feeding WDGS at 66% DM. No steers on these treatments were diagnosed with polio during this experiment. Steers fed the WDGS:hay had greater DMI than the WDGS:corn and similar intakes to the CORN diet. WDGS:corn had the highest ADG and feed conversion followed by the CORN and WDGS:hay, which had similar ADG. All diets resulted in similar marbling scores but the WDGS:corn diet had the greatest final BW. In conclusion the high level of WDGS fed in the WDGS:hay diet performed similar to the traditional corn-based finishing diet.

Bremer et al. (2008) conducted another meta-analysis reviewing previous research involving WDGS and the effect of WDGS dietary inclusion level of diets. The feeding value of WDGS was consistently higher than corn and suggests a 30% improvement in these diets containing DRC or HMC. These authors calculated that the lower levels of WDGS inclusion had a feeding value of 160% relative to corn because of the ADG for the cattle in these trials. Average daily gain and marbling was significantly quadratic and increased as WDGS inclusion increased to 30% and then decreased. However, when feeding WDGS at 40% and 50% the feeding value was still 11-25% greater than corn.

Importance of roughage

Roughages have been used to control acidosis in feedlot finishing diets. However, byproducts have been shown to help manage acidosis, suggesting that roughages may be reduced or eliminated in the feedlot industry. This would reduce or eliminate an expensive, bulky challenge that forages bring to feedlots. Benton et al. (2007) conducted a finishing trial to determine the effects of roughage inclusion levels compared to no roughage inclusion in diets containing 30% WDGS (DM basis). Steers fed no roughage inclusion had lower DMI which resulted in lower final BW and ADG compared to the steers fed high roughage levels. When roughage was eliminated from the diet, DMI, ADG, and profit was decreased compared to the diets containing some roughage. The authors concluded that it is not beneficial to completely eliminate roughage sources from a finishing diet containing 30% WDGS.

Farran et al., 2003 evaluated the effects of removing alfalfa hay from corn-based diets containing wet corn gluten feed (WCGF). Experimental diets contained either 0 or 35% WCGF and 0, 3.75, or 7.5% alfalfa hay. Cattle fed WCGF had 4.4% improved feed conversions when compared to efficiencies of cattle fed no WCGF at 0% alfalfa hay. This result suggests that a reduction in acidosis was observed when WCGF was included in the diet. Cattle consuming the 35% WCGF diets had a decrease in feed conversion when alfalfa hay was increased. Removing alfalfa hay from diets containing only corn resulted in a depression of ADG. Diets containing WCGF and diets increasing in alfalfa hay had increased DMI and ADG. Similar to Benton et al., 2008, these authors concluded that the removed of fiber from either alfalfa hay or WCGF decreased performance in feedlot steers.

An evaluation of the effect of wet corn gluten feed (WCGF) and alfalfa hay combinations in steam-flaked corn (SFC) finishing diets was conducted by Sindt et al., 2003. Dietary treatments for this experiment included: SFC-based diets containing combinations of WCGF (25, 35, or 45% of diet DM) and AH (2 or 6% of dietary DM). Increasing dietary WCGF linearly resulted in decreased gain efficiency. Similar to Ham et al, (1995) and Hussein and Berger (1995) these authors observed that finishing diets containing intermediate levels of WCGF produced the greatest ADG. This improvement in performance when grain is replaced with a source of fermentable fiber such as WCGF, attributed to a decrease in subacute acidosis. From this experiment, the authors concluded that feeding WCGF likely decreases the potential for feedlot acidosis and may complement highly processed grain diets. Wet corn gluten feed may be used, due to its fibrous nature, to partially fulfill the roughage requirement in finishing diets.

Sulfuric acid is used to control pH in fermentation and for cleaning in ethanol production from grain; this cleaning process adds sulfur to the byproducts. When WDGS is fed at high levels in finishing diets, the dietary S levels may exceed nutritional guidelines. The suggested upper limit for S in diets of beef cattle should be 0.40% (NRC, 1996). High levels of S in the diet may cause polioencephalomalacia (polio). Vanness et al. (2009) reviewed past research at UNL and concluded that of 4,143 catlle, 23 were removed from the pens and classified as cases of polio. Of the 23 steers pulled, 11 of these were in one experiment consuming 0.47% S and no roughage. Of the cattle consuming diets containing 0.46% S or less, 3/2147 were considered polios. When sulfur levels were between 0.47% and 0.56% S, the polio incidence increased to 0.35%. When dietary S was fed above 0.56%, the polio cases increased to 6.06%. The authors concluded that diets at or below 0.46% S have a low risk of producing polio if roughage levels are maintained. Above the 0.46% level of S in the diet, the risk for polio incidence increases.

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Effect of pen cleaning frequency and feeding 70% distillers grains and wheat straw or corn on nutrient mass balance and performance of feedlot steers.

A. R. Rich, G. E. Erickson, T. J. Klopfenstein, M. K. Luebbe, J. R. Benton, and W. A. Griffin

Department of Animal Sciences, University of Nebraska-Lincoln, NE, 68583

ABSTRACT: Two experiments using calves fed 173 d from November to May (WINTER) and yearlings fed 145 d from May to September (SUMMER), were conducted to evaluate the effects of feeding a high inclusion level of both wet distillers grains plus soluble (WDGS) and wheat straw or a corn control diet (CON) on ADG, F:G, manure N, and N losses. In each experiment, 128 steers (WINTER: 311 ± 10 kg, SUMMER: 365 ± 5 kg) were stratified by BW and assigned randomly to 16 pens (8 steers/pen). Four treatments were tested as a 2X2 factorial with factors being diet and pen cleaning frequency (monthly or at the end of the feeding period). Diets consisted of 85% corn, 5% molasses, and 5% wheat straw (CON) or 70% WDGS and 25% wheat straw (WDGS+straw). Both diets contained 5% supplement. In both the WINTER and SUMMER experiments, the CON treatment had greater DMI, ADG, HCW, marbling and fat depth. There was greater N intake and N excretion for both the WINTER and SUMMER experiments on the WDGS+straw however, for the WINTER experiment, there was not a difference in the amount of N in the manure nor for pen cleaning frequency. In the SUMMER experiment, cleaning pens monthly almost doubled DM, OM, and N removed in manure. There was a tendency for the WDGS+straw treatment to have greater N loss than the CON treatment in the WINTER experiment and a significant

increase in N losses for the WDGS+straw treatment in the SUMMER experiment, despite the greater amount of manure N removed.

Keywords: Distillers grains, Nitrogen, Pen cleaning

Introduction

Feeding corn milling byproducts increases C excretion due to lower digestibilities presumably due the increased NDF compared to corn (Farran et al., 2004). Feeding corn bran, a component of wet corn gluten feed, was effective in reducing N losses (Erickson and Klopfenstein, 2001b, Adams et al., 2003, and Farran et al., 2004) in the winter, but cattle performance suffered. However, when steep was added to the corn bran treatment, ADG and G:F improved while still effective at reducing the amount of N lost (Sayer et al., 2004).

Wet distiller grains plus solubles (WDGS) are lower in digestibility than corn (Corrigan et al, 2007) and may increase C on the pen surface, while actually increasing ADG and G:F (Klopfenstein et al, 2008). However, feeding WDGS also increases dietary CP and increases N excretion (Luebbe et al., 2010). Feeding WDGS at 30% diet DM increased the amount of OM in the manure, increased manure N, but also increased N losses (Luebbe et al., 2009).

Pen cleaning frequency is another method to reduce the amount of time the manure is exposed to the environment. Wilson et al. (2004) evaluated monthly pen cleaning versus traditional end pen cleaning on N balance in open feedlots. Manure N removal was increased 150% and N losses were reduced by 19% when pens were cleaned monthly compared to those cleaned only once at the end (Wilson et al., 2004).

Our hypothesis is that feeding high levels of WDGS with a high inclusion of roughage from wheat straw will increase N excretion (from WDGS), but also increase the C:N ratio of manure by reducing diet digestibility. We also hypothesize that increasing the frequency of pen cleaning will reduce N losses. Therefore, determining an interaction between pen cleaning frequency and diet, is important for N mass balance. The objective of this study was to evaluate the effects of feeding a high level of wet distillers grains plus solubles with added fiber from wheat straw or a corn-based diet as well as pen cleaning frequency on cattle performance and nutrient mass balance**.**

Materials and Methods

Cattle Performance

Two experiments were conducted using 128 steers in each experiment. Calves (311 ± 10 kg) were fed for 173 d from November to May (WINTER) and yearlings (365 ± 5 kg) fed for 145 days from May to October (SUMMER). Steers were stratified by BW and assigned randomly to 16 pens within weight strata (8 steers/pen). A 2 x 2 factorial arrangement of treatments were used with one factor being diet and the other factor being pen cleaning frequency. Treatments were assigned randomly to pens. The SUMMER and WINTER dietary treatments (Table 1) consisted of 1) 85% dry-rolled corn, 5% molasses, 5% wheat straw, 5% supplement (CON) or 2) 70% WDGS and 25% wheat straw, 5% supplement (WDGS+straw). For the 21-d adaptation period, alfalfa hay was replaced by dry-rolled corn in the CON treatment by feeding 40.3%, 30.3%, 20.3%, and 10.3% alfalfa hay for 3, 4, 7, and 7 d, respectively. Wheat straw was kept constant through the adaptation period at 25% of diet DM and WDGS replaced alfalfa hay for the WDGS+straw treatment by feeding the same amounts of alfalfa for the same durations. The supplement used for the CON contained urea at 1.1% to meet protein requirements. Supplement for WDGS+straw was formulated to provide a minimum of 0.6% Ca or to keep the Ca:P ratio greater than 1.2:1. Both supplements provided Rumensin (*Elanco Animal Health, Indianapolis, IN)* at 320 mg/steer/d DM, Tylan (*Elanco Animial Health*) at a targeted consumption of 90mg/steer daily, and thiamine at 130 mg/steer daily.

Weekly feed samples were taken for DM analysis using a 60° forced air oven for 48-h. Composite samples for each ingredient over the feeding period were analyzed for CP, fat, and sulfur (S). The combustion method was used for CP analysis (Leco, AOAC 990.03). Fat was analyzed using a gravimetric fat procedure modified by the University of Nebraska as described by Bremer et al. (2009). The more traditional Soxlet procedure was shown to over-estimate lipid values for solubles so this new procedure was developed to provide more accurate fat values. The combustion method at 1300°C was used for S analysis with a Leco, Truespec (Model 630100700, Leco, 2010).

Steer calves in the WINTER trial were implanted on d 1 and d 85 with Synovex Choice (Fort Dodge Animal Health, Fort Dodge, IA). Yearling steers on the SUMMER trial were implanted with Revalor-S (Intervet/Schering-Plough Animal Health, Millsboro, DE) on d 35 of the feeding period. Due to the goal of slaughtering steers at similar BW and that steers fed WDGS+straw had lower ADG, the WINTER CON treatment was slaughtered on d 173 and the WDGS+straw treatment were slaughtered on d 229. For the SUMMER, the yearling steers were slaughtered on d 144 for the CON and d 159 for the WDGS+straw of the feeding experiment. Steers were harvested at a commercial abattoir (*Greater Omaha*, *Omaha, NE*) where hot carcass weights (HCW) and liver scores were recorded on d of slaughter. Fat thickness, LM area, and USDA called marbling score were collected after a 48-hour chill. Average daily gain and G:F were calculated based on HCW adjusted to a common dressing percentage of 63%. All animal care procedures were approved by the University of Nebraska's Institute for Animal Use and Care committee.

Nutrient Mass Balance

Mass balance analysis for N was conducted similar to experiments previously outlined (Bierman et al., 1999: Erickson and Klopfenstien 2001; Farran et al., 2006; Luebbe et al., 2009) in 16 feedlot pens. Nutrient mass balance was based on 173 d for the WINTER and 145 d for the SUMMER experiments. Throughout the feeding period dietary treatments were fed in the same pens (stocking density = 29.6 m^2) and weekly ingredient and feed refusals were collected and sampled to determine DM and nutrient intake. Ingredient sample and feed refusals were oven-dried for 48 h at 60°C (Leco FP 5528, Leco Corp., St. Joseph, MI). Feed samples were collected weekly and composited by month. All samples were ground through a Wiley Mill (Thomas Scientific, Swedesboro, NJ, 1-mm screen) and ashed at 600°C for 6 h (AOAC, 1999; method 4.1.10).

Pens that were assigned to the 28-d pen cleaning schedule were scraped and the manure was piled on a cement apron and sampled (n=16) for nutrient analysis while being loaded for removal. Pens that were assigned to the end-of-the-feeding-period cleaning were subjected to this cleaning and sampling (n=16) after the steers were removed for harvest. Two manure sample bags were taken then composited by pen/cleaning then four subsamples were collected for analysis.

Manure was weighed as-is and used for calculation of DM, OM, and N removal. When runoff did occur, it was collected in the retention ponds and they were drained, sampled, and quantified using an ISCO model 4230 air bubble flow meter (ISCO, Lincoln, NE). Runoff samples were then frozen (-4°C) for the duration of the trial and then analyzed by Ward Laboratories (Kearney, NE) for DM, OM, and N. Once collected, all manure samples were frozen at -4°C until analysis. To avoid N losses during the drying process, a portion of the manure samples (n =196) were freeze dried using a Virtis Freezemobile model 25 SL (Virtis, Gardiner, NY) for nutrient analysis and 192 samples were oven dried at 60°C for 48 h to determine DM content. Freeze-dried samples were ground through a Wiley Mill at a 1-mm screen size, composited into 1 sample/pen/cleaning, and analyzed for N, DM, and OM content. Total N (AOAC, 1999; method 4.2.04) for feed ingredient, feed refusals, and manure was determined using a combustion method N analyzer (Leco FP 5528, Leco Corp., St. Joseph, MI).

Amount of manure N and OM was calculated by multiplying manure nutrient concentration (kg of nutrient/kg of DM) by kg of manure removed (DM basis) from the pen surface. Nitrogen intake was calculated using the analyzed N content of individual ingredients multiplied by DMI and ingredient inclusion level and then corrected for N of feed refusals. Individual steer N retention was calculated using the NRC net energy and protein equations (NRC, 1996). Nutrient excretion was determined by subtracting nutrient retention from intake. Runoff N was determined using 12 open feedlot pens with retention ponds to collect run-off from rainfall. Runoff N was calculated using nutrient concentration in the runoff multiplied by the volume of water collected in the runoff ponds. Total N lost (lb/steer) was calculated by subtracting manure N and runoff N from excreted N. Percentage of N loss was calculated as N lost divided by N excretion.

Animal performance and nutrient balance data were analyzed using the MIXED procedures of SAS (SAS Inst. Inc. Cary, NC) as a 2 X 2 factorial design with the factors being dietary treatments and pen cleaning frequency. Model effects were dietary treatment, pen cleaning frequency, and interaction of the two. When a significant dietary treatment x pen cleaning frequency interaction was detected, simple effects are presented. Otherwise, main effects of treatment and pen cleaning frequency are presented.

Results and Discussion

Cattle Performance

There was not an interaction between dietary treatments or pen cleaning frequency for either SUMMER or WINTER trials for any performance variables; therefore, only main effects will be discussed. The goal of each experiment was to finish cattle, on each treatment, to similar endpoints. To achieve this goal, the WDGS+straw treatment in both the WINTER and SUMMER experiments were fed for an additional 56 d and 14 d, respectively. Therefore, performance results are based on the total DOF for each treatment. Results for performance and carcass characteristics are reported in Table 2. In the WINTER, cattle fed the WDGS+straw had lower DMI ($P < 0.01$). Average daily gain was also lower ($P < 0.01$) in the WDGS+straw treatment. Gain was reduced more than DMI, which resulted in a lower G:F (0.128 vs. 0.158 ($P < 0.01$)) for steers fed WDGS+straw compared to the cattle consuming the CON treatment. Even with the additional DOF, HCW for the WDGS+straw treatment was lower ($P < 0.01$) than the CON treatment. Marbling and 12th rib fat were greater ($P < 0.01$) for the CON treatment compared to the WDGS+straw treatment which had an additional 56 DOF. Cattle consuming the WDGS+straw treatment were unsuccessful in meeting similar carcass endpoints when compared to the corn-based CON treatment, even with the additional DOF.

Cattle fed during the SUMMER (Table 3) had similar performance differences between treatments as the WINTER calf-feds. Intake was lower for the WDGS+straw treatment ($P < 0.01$) as well as ADG ($P < 0.01$) which resulted in a higher G:F (0.134 vs. 0.125, ($P = 0.04$)). Hot carcass weight and 12th rib fat thickness, even with 14 additional DOF, were lower for the WDGS+straw ($P < 0.01$). However, marbling was similar between treatments ($P = 0.05$).

Bremer et al. (2010) conducted a meta-analysis of several UNL feedlot trials that showed the effect of adding WDGS to finishing diets. In these experiments, DRC or HMC were replaced with WDGS (10, 20, 30, 40, and 50% diet DM) and an observed feeding value increase was reported for all diets containing WDGS. The observed feeding value increase was dependent on inclusion level and corresponding ADG and efficiency. A 160% feeding value was calculated at the lower levels of WDGS inclusion, due to greater ADG for these cattle when compared to the corn diet. A quadratic response was reported for ADG and DMI with the highest values observed at the 30% inclusion level. ADG and DMI values decreased at the 40% and 50% inclusion of WDGS compared to the 30% and 40% inclusion levels. Feeding values calculated from G:F decreasing feeding values as level of WDGS in the diet increased. Following the numerical decline in performance values seen in the quadratic response of these data, the response observed in the current study would be supported for the CON fed steers having greater DMI, ADG, and G:F compared to the steers fed the WDGS+straw where WDGS was fed at 70% diet DM. However, in contrast to this study, Vanderpol et al. 2007 fed WDGS at 40% and reported greater fat digestibility compared to the corn-based control.

Most previous research has evaluated the effect of feeding 50% diet DM or less however, Wilken et al. (2009) evaluated the effects of feeding high levels of byproduct in finishing diets. Treatments in this experiment included; Corn Control containing 82.5% DRC, 43.5% WDGS with corn, and 66% WDGS with 21.9% grass hay. All diets included 7.5% alfalfa hay as a roughage source. Steers fed the 66% WDGS with hay had greater DMI than the 43.5% WDGS with corn and similar intakes to the Corn Control diet. 43.5% WDGS with corn had the highest ADG and feed conversion followed by the Corn Control and 66% WDGS with hay, which had similar ADG. All diets resulted in similar marbling scores but the 43.5% WDGS with corn diet had the greatest final BW. In conclusion the high level of WDGS fed in the 66% WDGS with hay diet performed similar to the traditional corn-based finishing diet. However, contrary to the current study, the CORN treatment had similar ADG to the 66% WDGS with hay treatment. This result could be due to the differences in digestibilities of the roughage sources between experiments. Wilken et al. used grass hay and alfalfa hay which have lower NDF content than wheat straw (NRC, 1996), the roughage source used in the current study.

Sarturi et al., 2011 conducted a study on the effects of sulfur concentration in distillers grains with solubles in finishing cattle diets. These authors used a 2x2x3+1 factorial treatment design with factor of co-product moisture (wet or dry), sulfur concentration (0.82 or 1.16% of DM), and co-product level of inclusion (20, 30, 40% DM basis). A Control diet without co-product was also fed. High sulfur concentration decreased DMI regardless of whether fed wet or dry co-product. Feeding greater sulfur decreased DMI and ADG for steers consuming the WDGS. Comparing these results to the current study, similar observations were reported with the steers consuming the high level of WDGS+straw.

Sulfur content in byproduct diets of feedlot cattle has been reported to increase the risk of developing polioencephalomalacia (polio). Vanness et al. (2009) evaluated the effects of byproducts and roughage level on polio. Incidences of polio increased slightly when cattle were fed diets above 0.46% S and dramatically increased when greater than 0.56% and 5-7% roughage was fed. Polio risk is decreased when roughage level is maintained or increased in the ration. Another trial conducted at UNL (Wilken et al. 2009), determined the effects of feeding WDGS with or without corn on feedlot performance. The WDGS:hay treatment included 66% WDGS, 21.9% grass hay and 7.5% alfalfa hay. The S level for this diet was 0.549% of diet DM and there were no polio cases reported for these treatments. The sulfur levels in both the WINTER and SUMMER experiments were 0.63% of the diet, which is well above previous research levels. However, no steers died or were removed from these two studies due to polio. Gould et al (1996) and Vanness et al. (2009) reported that hydrogen sulfide gas concentration is decreased as forage level in the diet is increased. Similar to Wilken et al., (2009), the forage levels for the WDGS+straw treatment potentially reduced the hydrogen sulfide gas concentration, resulting, in no occurrences of polio, though no measurements were taken.

The lower performance observed above for the WDGS+straw treatment in both the WINTER and SUMMER experiments is most likely due to the high inclusion of wheat straw in the diet, which was added to help increase the amount of OM on the pen surface and potentially reduce the hydrogen sulfide gas concentration. Erickson and Klopfenstein (2001b) evaluated the effects of feeding 0, 15, and 30% corn bran on performance of feedlot steers. Similar to results seen in the current study, they reported lower ADG with cattle fed corn bran compared to cattle fed the CON diet. Due to reducing the diet digestibility, the authors reported a linear decrease in ADG and feed efficiency when corn bran level increased.

In both the WINTER and SUMMER experiments, we observed no impact on steer performance when comparing pen cleaning frequency. Dry matter intake and ADG were similar across treatments in both experiments ($P > 0.50$), resulting in a similar G:F ($P > 0.27$) for both experiments. Due to similar performance, HCW ($P > 0.52$) and 12th rib fat thickness ($P > 0.70$) were similar when comparing monthly pen cleaning to end pen cleaning in both the WINTER and SUMMER experiments. Marbling was also not impacted ($P > 0.25$) by the frequency of pen cleaning for either the WINTER or SUMMER experiments.

Nutrient Balance

There was no interaction between dietary treatments and pen cleaning frequency for either the SUMMER ($P > 0.10$) or WINTER ($P > 0.37$) trials, therefore, only the main effects will be discussed. The goal of this experiment was to finish cattle, on each treatment, to similar endpoints. To achieve this goal, the WDGS+straw treatments in both the WINTER and SUMMER experiments were fed for an additional, 56d and 14d, respectively.

Steers fed WDGS+straw had 61.3% greater N intake compared to steers fed CON in the WINTER (Table 4). Nitrogen retention for the WINTER experiment was similar across treatments at 5.5 kg for the CON and 5.4 kg for the WDGS+straw. The amount of N excreted was greater (P<0.01) for WDGS+straw and lower for the CON. This increase in N excretion is similar to the percentage increase in N intake because the amount of retained N between treatments was not greatly different. However, manure N was similar (10.7 vs. 11.9 kg, P = 0.63) for the CON and WDGS+straw treatments in the WINTER experiment. Therefore, for the WINTER, because WDGS+straw calves excreted more N with the same amount in manure as the CON calves, the calves consuming the WDGS+straw had greater N losses (P<0.01). There was a tendency (P=0.08) for the WDGS+straw steers to have a greater amount lost (76.4% vs. 62.9%) when expressed as a percentage in the WINTER experiment. There was not enough precipitation during the WINTER trial to generate runoff therefore, no results will be presented. Dry matter removed and OM removed were similar across dietary treatments (P>0.10) in the WINTER experiment.

Steers fed WDGS+straw had 80.6% greater N intake compared to the CON in SUMMER experiment (Table 5). Retained N in the SUMMER was lower for the yearlings compared to calves at 4.0 kg for the CON and 3.8 kg for the WDGS + fiber and different between treatments (P = 0.02). The amount of N excreted was greater (P<0.01) for WDGS+straw compared to CON. This increase in N excretion is similar to the percentage increase in N intake because the amount of retained N between treatments was not greatly different. However, manure N was different (7.88 vs. 14.38 kg, P = 0.01) in the SUMMER experiment with the CON fed steers having less manure N than

WDGS+straw. In the SUMMER experiment the yearling steers consumed more N, retained less, yet with the greater amount of N excreted still resulted in a greater amount of N lost. The differences between the two experiments for amount of N retained were due, in part, to initial animal BW (311 and 365 kg in the WINTER and SUMMER, respectively) and composition of gain. Steers with a lower average BW deposit more lean tissue as a percent of BW compared with adipose tissue (Klopfenstein and Erickson, 2002). N loss was greater ($P < 0.01$) for the WDGS+straw (65.5%) than for the CON diet (60.9%) in the SUMMER experiment, when expressed as a percentage of N excreted. Dry matter removed and OM removed were greater for the WDGS+straw diet ($P < 0.01$) in the SUMMER experiment. Similar results were reported by Luebbe et al. (2008), who observed greater DM and OM removed in the SUMMER for the cattle consuming 35% WDGS compared to the CON. For the SUMMER experiment, the N runoff was similar across treatments at 6.2% of N excretion. These results were a little greater than what was observed by Bierman et al. (1999), Adams et al (2004), and Farran et al. (2004) who reported low amounts of N in the runoff. However, the higher amounts of runoff have been reported in observed in the SUMMER experiments compared to the WINTER experiments (Luebbe et al. 2009, Sayer et al. 2005). These differences in N runoff could be due to the amounts of effluent collected in the ponds during these months.

Sayer et al. (2005) determined the effects of corn bran and steep inclusion on nutrient mass balance. The dietary treatments consist of a CON (75% DRC), 30/0 (30% corn bran/0% steep), 30/15 (30% corn bran/15% steep), and 45/15 (45% corn bran/15% steep). These authors reported a decrease in N volatilization in the WINTER experiment when corn bran (higher fiber) inclusion increased. In contrast, the current research resulted in there being 20.3 kg/steer more N lost to volatilization when steers consumed the WDGS+fiber treatment. This is likely due to this diet containing almost double the amount of N and the steers retaining the same (5.5 kg/steer) across treatments. Lower protein intake decreased N excretion via urine thereby decreasing concentrations of ammonium exposed to the atmosphere (Erickson et al., 2001a, Cole et al., 2005).

Results for pen cleaning frequency of the WINTER experiment are reported in Table 6 and Table 7 contains results for pen cleaning frequency in the SUMMER experiment. The amount of DM that was removed was greater for the pens that were cleaned monthly compared to those cleaned at the end of the feeding period for both the WINTER ($P=0.03$) and SUMMER ($P <0.01$). Organic matter removed in pens cleaned every 28 d was greater than in the pens cleaned at the end for, both the WINTER ($P = 0.05$) and the SUMMER ($P < 0.01$), similar to DM removed. Manure N removed was almost double for the SUMMER and numerically greater for the pen cleaned monthly; this could be due to the excess carbon from the OM removed in the manure.

Wilson et al. (2004) evaluated the impact on N volatilization when feedlot pens were cleaned either monthly or at the end of the feeding period. The amounts of DM, OM and N removed were doubled if pens were cleaned monthly compared to cleaning at the end of the feeding period. In the present SUMMER experiment, DM, OM, and N removed in the manure was almost doubled ($P < 0.01$) when pens were cleaned on a monthly basis. Surprisingly, there was no difference ($P = 0.24$) in manure N between monthly or end cleaning in the WINTER experiment, but pens cleaned monthly had numerically more (3.2 kg/steer) manure N removed.

Due to the similar amounts of N recovered in the manure for the WINTER experiment, N lost was similar for the end pen cleaning and the monthly pen cleaning ($P = 0.21$). However, there was a numerical difference observed of 3.3 kg/steer decrease if pens were cleaned monthly compared to being cleaned at the end of the feeding period. Adams et al. (2004) showed an improvement in manure N removal with monthly cleaning during winter months when cattle consumed 30% bran compared to the corn-based control diet. Results from Sayer et al.(2005), Luebbe et al. (2009), and Erickson et al. (2001) show that winter months have lower amounts of overall N volatilization. Therefore, the numerical differences seen in the current research are not large enough to be significant. Results for N loss as a percentage for the WINTER experiment were similar for end and monthly cleaning. Monthly pen cleaning in the SUMMER reduced N lost ($P < 0.01$) by 43% compared to end pen cleaning. The SUMMER experiment resulted in greater N losses for the pens cleaned at the end of the feeding period compared to the pens cleaned monthly. Monthly cleaning reduced N loss 22.9 percentage units from 74.6 to 51.7% compared to end cleaning. Overall, monthly cleaning was more effective in recovering N in manure and reducing the overall loss from the pen surface during the SUMMER when compared to the WINTER experiment. Nitrogen losses can be highly variable with the time of year, with twice as much N being volatized from the pen surface during the summer months when compared to the winter/spring (Adams et al., 2004).

Wilson et al. (2004) evaluated the effects of pen cleaning frequency during two consecutive summers. Treatments were similar to the current study, where pens were assigned to an end-of-the feeding period cleaning or a monthly pen cleaning. By cleaning pens every month, N removal was increased 3.95 kg per steer or 69.0% increase above manure N removed at the end of the feeding period in Exp. 1. Monthly cleaning in Exp. 2 increased manure N removal by 2.2 kg per steer or 34.8% increase above manure N removed at the end of the feeding period. By cleaning pens monthly, OM removal increased 95.5 kg per steer in Exp. 1 and 81.7 kg per steer in Exp. 2 compared to end cleaning. Manure N was significantly greater for the monthly cleaning in both experiments. These results support the current SUMMER conclusions, where monthly pen cleaning resulted in an increase of 7.0 kg/steer of N removed in the manure when pens were cleaned monthly versus end cleaning. Dry matter and OM removed were also greater (3571kg/steer and 441 kg/steer more, respectively) for the monthly cleaning compared to the end pen cleaning.

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Table 1. Composition of dietary treatments for WINTER and SUMMER trials (% DM basis).

Ingredient	CON	WDGS+straw
WDGS[1]	-------	70.0
HMC:DRC[2]	85.0	-------
Wheat Straw	5.0	25.0
Molasses	5.0	5.0
Supplement		
Limestone	1.71	1.69
Urea	1.46	---
Fine ground corn	1.64	3.07
Salt	0.30	---
Tallow	0.13	0.13
KCl	0.05	---
Trace mineral	0.02	0.05
Rumensin-80	0.02	0.02
Vitamin A-D-E	0.02	0.02
Tylan-40	0.01	0.01
Thiamine	---	0.02
Diet Composition		
CP	11.6	23.5
Fat	3.6	9.0
Sulfur	0.11	0.63

[1] Wet Distillers Grains plus Solubles
[2] High moisture corn: Dry rolled corn, fed at a 1:1 ratio (DM basis)
*Supplement identical for WINTER and SUMMER experiments

Table 2. Growth performance and carcass characteristics for steers fed during the WINTER

Dietary Treatments[1]	CON	WDGS+straw	SEM	P-value[2]
WINTER[3]				
Performance				
Initial BW, kg	310	310	0.54	0.87
Final BW, kg	591	556	3.60	< 0.01
DMI, kg	10.25	8.38	0.12	<0.01
ADG, kg	1.62	1.07	0.02	<0.01
Gain:Feed	0.158	0.128	.002	<0.01
Carcass characteristics				
HCW, kg	372	350	2.25	< 0.01
Marbling [4]	490	387	12.63	< 0.01
12^{th} Rib Fat, cm	1.17	0.82	0.05	< 0.01

[1]Dietary treatments: CON = Control corn-based diet, WDGS+straw = 70% WDGS, 25% wheat straw
[2]*F*-test statistic for dietary treatment.
[3] CON – fed for 173 d, WDGS – fed for 229 d
[4] Marbling Score = 400 = Slight 0, 500 = Small 0, etc.

Table 3. Growth performance and carcass characteristics for steers fed during the SUMMER

Dietary Treatments[1]	CON	WDGS+straw	SEM	P-value[2]
Performance				
Initial BW	365	365	0.75	0.88
Final BW	569	523	7.0	< 0.01
DMI, lb	10.70	9.57	0.15	<0.01
ADG, lb	1.43	1.19	0.02	<0.01
Gain:Feed	0.134	0.125	0.003	0.04
Carcass characteristics				
HCW, kg	361	349	2.55	0.01
Marbling [4]	522	456	6.71	< 0.01
12th Rib Fat, cm	0.97	0.86	0.13	0.01

[1]Dietary treatments: CON = Control corn-based diet, WDGS+straw = 70% WDGS, 25% wheat straw
[2]*F*-test statistic for dietary treatment.
[3] CON – fed for 144 d, WDGS – fed for 156 d
[4] Marbling Score: 400 = Slight 0, 500 = Small 0, etc

Table 4. Effect of dietary treatment on nitrogen mass balance[1] during WINTER[2]

Dietary treatment[3]	CON	WDGS+straw	SEM	P-value[4]
N intake	34.6	55.8	0.50	<0.01
N retention[5]	5.5	5.4	0.12	0.25
N excretion[6]	29.1	50.5	0.50	<0.01
Manure N[7]	10.7	11.9	1.6	0.63
N Run-off	-	-	-	-
N Lost	18.3	38.6	1.9	<0.01
N loss%[8]	62.9	76.4	5.1	0.08
DM removed	2166	2384	305	0.62
OM removed	505	643	77	0.23

[1]N mass balance analyzed for equal days across treatments, 173- d
[2]Values are expressed as kg/steer over 173-d of the feeding period.
[3]Dietary treatments: CON = Control corn-based diet, WDGS+straw = 70% WDGS, 25% wheat straw
[4]*F*-test statistic for dietary treatment
[5]Calculated using the NRC net protein and net energy equations.
[6]Calculated as N intake – N retention.
[7]Manure N with correction for soil N.
[8]Calculated as N lost divided by N excretion.

Table 5. Effect of dietary treatment on nitrogen mass balance[1] during SUMMER[2]

Dietary treatment[3]	CON	WDGS + straw	SEM	P-value[4]
N intake	28.9	52.2	0.2	<0.01
N retention[5]	4.0	3.8	0.1	0.02
N excretion[6]	24.9	48.4	0.2	<0.01
Manure N[7]	7.88	14.38	0.76	<0.01
N Run-off	1.9	2.3	0.63	0.64
N Lost	15.2	31.7	1.0	<0.01
N loss%[8]	60.9	65.5	2.5	<0.01
DM removed	3530	5572	427	<0.01
OM removed	526	1051	44	<0.01

[1]N mass balance analyzed for equal days across treatments, 145-d.
[2]Values are expressed as kg/steer over 145-d of the feeding period.
[3]Dietary treatments: CON = Control corn-based diet, WDGS+straw = 70% WDGS, 25% wheat straw
[4]*F*-test statistic for dietary treatment
[5]Calculated using the NRC net protein and net energy equations.
[6]Calculated as N intake – N retention.
[7]Manure N with correction for soil N.
[8]Calculated as N lost divided by N excretion.

Table 6. Effect of pen cleaning frequency on nitrogen mass balance[1] during WINTER[2]

Pen cleaning frequency[3]	End	Monthly	SEM	P-value[4]
N intake	*45.5*	44.9	0.50	0.39
N retention[5]	5.5	5.4	0.12	0.91
N excretion[6]	40.1	39.5	0.51	0.41
Manure N[7]	9.9	12.7	1.6	0.24
N Run-off	-	-	-	-
N Lost	30.1	26.8	1.9	0.21
N loss%[8]	*73.5*	65.5	5.1	0.29
DM removed	*1740*	2809	304	0.03
OM removed	*456*	692	77	0.05

[1]N mass balance analyzed for equal days across treatments, 173- d
[2]Values are expressed as kg/steer over 173-d of the feeding period.
[3]Pen cleaning frequency : end, monthly
[4]*F*-test statistic for dietary treatment
[5]Calculated using the NRC net protein and net energy equations.
[6]Calculated as N intake – N retention.
[7]Manure N with correction for soil N.
[8]Calculated as N lost divided by N excretion.

Table 7. Effect of pen cleaning frequency on nitrogen mass balance[1] during SUMMER

Pen cleaning frequency[2]	End	Monthly	SEM	P-value[3]
N intake	*40.1*	40.3	0.3	0.68
N retention[4]	3.88	3.90	0.36	0.91
N excretion[5]	36.8	36.5	0.5	0.79
Manure N[6]	7.6	14.6	0.8	<0.01
N Run-off	1.6	2.6	0.6	0.28
N Lost	27.6	19.3	1.0	<0.01
N lost%[7]	*74.6*	51.7	2.5	<0.01
DM removed	*2762*	6341	427	<0.01
OM removed	*568*	1009	44	<0.01

[1]N mass balance analyzed for equal days across treatments, 145-d.
[2]Pen cleaning frequency : end, monthly.
[3]*F*-test statistic for dietary treatment
[4]Calculated using the NRC net protein and net energy equations.
[5]Calculated as N intake – N retention.
[6]Manure N with correction for soil N.
[7]Calculated as N lost divided by N excretion.

Feeding increased amounts of wet distillers grains plus solubles on feedlot cattle performance.

A. R. Rich, G. E. Erickson, T. J. Klopfenstein, M. K. Luebbe, J. R. Benton, W. A. Griffin, and D R. Mark.

Department of Animal Sciences, University of Nebraska-Lincoln, 68583

Department of Agricultural Economics, University of Nebraska-Lincoln, 68583

ABSTRACT: A finishing study evaluated inclusion of corn wet distillers grains plus solubles (WDGS) and wheat straw on the performance and carcass characteristics of 336 (270+/- 9kg) crossbred steers. Seven treatments included: 1) control (CON) containing 85% corn and 4.7% wheat straw, 2) 40% WDGS and 4.7% wheat straw (40-5), 3) 70% WDGS and 8.23% wheat straw (70-8), 4) 77.5% WDGS and 9.1% wheat straw (77-9), 5) 85% WDGS and 10% wheat straw (85-10), 6) 77.5% and 17.5% wheat straw (77-17), 7) 70% WDGS and 25% wheat straw (70-25). Six pens per treatment (8 steers/pen) were used in the RCBD experiment. The CON, 40-25, 70-8, and 77-9 were fed for 183 d and the 70-25, 77-17, and 85-10 treatments were fed 225 d to target similar final BW. Steers fed the 40-5 had the greatest ($P < 0.01$) ADG, G:F, and HCW; however, G:F was similar to steers fed the 77-9. Steers fed 70-25 had the least ($P < 0.01$) ADG, G:F, and HCW. Steers being fed the CON, 70-8, and 77-9 had similar ADG, followed by steers fed 77-17, then 85-10, which were different ($P < 0.01$). Steers fed CON, 85-10, and 77-17 had similar G:F ($P > 0.10$) but less ($P < 0.05$) than 40-5, 70-8, and 77-9. However, steers fed 85-10, 77-17, and 70-25 were fed 42 d longer. Marbling score was greatest ($P < 0.05$) for CON and 40-5, least ($P < 0.05$) for 70-25, and intermediate for the other treatments.

Feeding WDGS at 40% inclusion improved ADG and G:F. Feeding 70 to 77% WDGS resulted in similar ADG and improved G:F compared to corn. Increasing straw above 10% or WDGS above 77% depressed ADG, G:F, or both compared to feeding corn. Economics analysis was performed on all seven diets using average 2008 5 area yearly weighted direct slaughter steer live price from USDA Market News Service. Cost of gain (COG) was calculated by dividing total finishing cost by average gain per pen. Slaughter breakeven (BE) was calculated by dividing the total cost of production by the carcass-adjusted final BW. Profit or loss (P/L) was calculated by subtracting the total cost of production from the final steer value. When corn is priced at $3.50/bu and WDGS is 85% the cost of corn, treatments with the blend of WDGS and some inclusion of corn (70-8, 77-9) had greater profit, lower COG, and lower breakeven prices than the treatments with no corn (85-10, 77-17, 70-25) or the CON treatment.

Key Words: feedlot cattle, roughage, wet distillers grains plus solubles.

Introduction

As the corn market continues to be volatile, cattle producers are seeking effective, yet less expensive methods for cattle finishing. Langemeier et al. (1992) showed that corn prices account for 22% of profit variability and that fed cattle prices impact profit variability for the cattle feeder by 50%. Corn prices also explain 65% of the cost-of-gain variability. Wet distillers grains plus solubles (WDGS) are typically less expensive and provide a high protein and energy source than corn. A previous meta-analysis of UNL feedlot trials evaluated replacing corn with WDGS (Bremer et al. 2010). The meta-analysis contained previous research trials that included WDGS up to 50% of the diet DM with a typical roughage level inclusion of 5-7%. Replacing corn up to 50% of diet DM as WDGS resulted in superior performance compared to cattle fed 0% WDGS. Wilken et al. 2009 determined the effects of feeding WDGS with or without corn on feedlot performance. The WDGS:hay treatment included 66% WDGS, 21.9% grass hay and 7.5% alfalfa hay. The S level for this diet was 0.549% of diet DM and there were no polio cases reported for these treatments. Sulfur content in byproduct diets of feedlot cattle may increase the risk of developing polioencephalomalacia (polio). Vanness et al. (2009) evaluated the effects of byproducts and roughage level on polio. Incidences of polio increased slightly when cattle were fed diets above 0.46% S and dramatically when greater than 0.56% and typical feedlot levels of roughage, 5-7%. Polio risk is decreased when roughage level is maintained or increased in the ration.

Previous research indicates that the optimal feeding value of WDGS is between 30-40%, however, feeding above 40% to as high as 66% has shown to be comparative to a typical corn feedlot diet. Therefore, if higher levels of byproduct can be added to a feedlot diet without a negative economic impact, this would interest many cattle feeders due to the decrease cost-of-gain associated with WDGS. The objectives of this study were to evaluate the effects of feeding increased amounts of WDGS and greater amounts of roughage on feedlot cattle performance and economics.

Materials and Methods

Cattle performance

A finishing study was conducted using 336 (BW = 270+/- 9kg) crossbred yearling steers that were assigned randomly in a RCBD with 2 blocks for BW. With 8 steers per pen, pen was assigned randomly to one of seven treatments. Two consecutive day individual weights were collected for initial BW. Cattle were then stratified by BW within respective weight block and assigned randomly to 42 pens, providing 6 replications per treatment.

The seven treatments included: 1) control (CON) of 85% dry-rolled corn (DRC), 4.7% wheat straw, and 5.0% molasses; 2) (40-5) 40% WDGS, 4.7% wheat straw, and 50.3% DRC; 3) (70-8) 70% WDGS,16.8% DRC, and 8.2% wheat straw; 4) (77-9) 77.5% WDGS, 8.4% DRC, and 9.1% wheat straw; 5) (85-10) 85% WDGS and 10% wheat straw; 6) (77-17) 77.5% WDGS and 17.5% wheat straw; 7) (70-25) 70% WDGS and 25% wheat straw all on a DM basis. According to previous research, sulfur content of these diets were a concern with the high levels of WDGS inclusion. Vanness et al. (2009) evaluated the effects of byproducts and roughage level on polio. Incidences of polio increased slightly when cattle were fed diets above 0.46% S and dramatically when greater than 0.56% and typical feedlot levels of roughage, 5-7%. Polio risk is decreased when roughage level is maintained or increased in the ration. Therefore, the high levels of distillers grains inclusion were accompanied by a level of roughage above 4.7% to counteract any negative impacts of sulfur.

All diets contained a supplement at 5.0% which was formulated to provide a minimum of 0.6% Ca and to maintain the Ca:P ratio > 1.2:1. Supplement used for the CON was formulated to have a diet CP of 13.3% and included urea at 1.5%. Supplements were also formulated to provide Rumensin (*Elanco Animal Health*, *Indianapolis, IN*) at 320 mg/steer/d DM, Tylan (*Elanco Animal Health*) at 90 mg/steer daily, and thiamine at 130 mg/steer daily.

An adaptation period of 21 days was utilized for all treatments. Cattle consuming the CON and 40-5 treatments had the roughage (wheat straw) kept constant, while the DRC was increased at increments of 10% DM and alfalfa hay was decreased by the same. The cattle on the high levels of WDGS treatments were adapted to diets by decreasing alfalfa hay and increasing the inclusion of WDGS. Steers were implanted with Revelor-XS (*Intervet Schering Plough Animal Health, Millsboro, DE*) on d 1 of the feeding trial. Steers fed CON, 40-5, 70-8, and 77-17 were fed for 183 d and steers fed 85-10, 77-17, and 70-25 were fed for 225 d to target similar final BW. Steers were harvested at a commercial abattoir (*Greater Omaha, Omaha, Neb*.). Hot carcass weights (HCW), and liver scores were collected on the d of slaughter. After a 48-hr chill, LM area, 12^{th} rib fat thickness and USDA marbling scores were recorded. Calculated USDA YG was calculated from HCW, fat depth, LM area and an assumed 2.5% kidney, pelvic, and heart fat (KPH) YG = 2.5 + (2.5*12^{th} rib fat) + 0.2*KPH%) + 0.0038*HCW) – (0.32*ribeye area). A common dressing percent (63%) was used to calculate the carcass adjusted performance of final BW, ADG, and G:F. All animal care procedures were approved by the University of Nebraska's Institute for Animal Use and Care Committee.

Weekly feed samples were taken for DM analysis using a 60° forced air oven for 48-h. Composite samples for each ingredient over the feeding period were analyzed for CP, fat, and sulfur (S). The combustion method was conducted for CP analysis (Leco, AOAC 990.03). Fat was analyzed using a gravimetric fat procedure modified by the University of Nebraska as described by Bremer et al. (2009). The more traditionally used Soxlet procedure was shown to over-estimate lipid values for solubles so this new procedure was developed to provide more accurate fat values. The combustion method at 1300°C was used for S analysis with a Leco, Truespec (Model 630100700, Leco, 2010).

Economics

Budgets were created for all 7 dietary treatments using the average 2008 5-area yearly weighted direct slaughter steer live price from the USDA Market News Service ($93.13/cwt). Initial steer price was calculated as average initial BW of pen multiplied by $126.39/cwt to make CON steers profit equal to zero. The price of corn was set at $3.50/bu, WDGS price was constant at 85% the price of corn, and wheat straw was constant at $72.70/DM ton (delivered and processed). Yardage was charged at $0.40 per steer daily with health and processing costs of $20 per steer and a death loss of 1.5%. Interest was estimated as 8.0% for feed costs and initial steer cost. Total production costs included total feed costs with interest; all health, processing and death loss costs; and initial steer cost with interest. Cost of gain (COG) was calculated by dividing total finishing cost by average gain per pen. Slaughter breakeven (BE) was calculated by dividing the total cost of production by the carcass-adjusted final BW. Profit or loss (P/L) was calculated by subtracting the total cost of production from the final steer value.

Statistical Analysis

All data were analyzed using MIXED procedures of SAS as a RCBD with pen as the experimental unit. The effects of treatment and block were included in the model. Treatment means were compared using a protected F-test and when the F-test statistic was significant.

Results and Discussion

Performance Results

There were no animals removed from this trial for having symptoms or diagnosis of polioencephomalacia (polio) however, two steers were pulled from the experiment and treated for respiratory illness. Treatments 85-10, 77-17, and 70-25 were fed for a total of 225 days to achieve similar final BW, whereas treatments CON, 40-5, 70-8, and 77-9 were fed for 183 days.

Steers fed 40-5 had the greatest ($P < 0.01$) ADG, G:F, and HCW; however, G:F was similar to steers fed 77-9. Steers fed 70-25 had the least ($P < 0.01$) ADG, G:F, and HCW. DMI was the greatest ($P < 0.05$) for the 40-5 and CON followed by the 70-8 and 77-17 steers, 77-9, and lastly the 70-25 and 85-10 steers. The observed decrease in DMI is likely due to the high level of roughage contained in those diets. Therefore, the animals were reaching their limitations due to gut fill compared to DMI being controlled by energy intake as shown with the diets containing lower levels of roughage. Steers fed CON, 70-8, and 77-9 had similar ADG, followed by steers fed 77-17, then 85-10, which were different ($P < 0.01$). Steers fed CON, 85-10, and 77-17 had similar G:F ($P > 0.10$)

but less ($P < 0.05$) than 40-5, 70-8, and 77-9. However, steers fed 85-10, 77-17, and 70-25 were fed 42 d longer.

Carcass characteristics followed a similar trend as the performance results. Overall 40-5 had the greatest and 70-25 had the least marbling scores, LM area, 12th rib fat, and calculated USDA YG when compared to the other treatments. Marbling score was greatest ($P < 0.05$) for CON and 40-5, least ($P < 0.05$) for 70-25, and intermediate for the other treatments. Fat depth at the 12th rib was greatest for the 40-5 treatment followed by the intermediate treatments and CON having subtle differences. The lowest rib fat was observed for cattle fed the 70-25 treatment. As to be expected, the steers reported with the lowest FW also had the lowest HCW. The steers on the 40-5 had the greatest HCW, the 70-25 treatment resulted in the lowest HCW, and all other treatments (70-8, 77-9, 85-10, & 77-17) were intermediate.

Bremer et al. (2008) conducted a meta-analysis consisting of several feedlot trials that showed the effect of adding WDGS to finishing diets at levels up to 50% diet DM. The feeding value as defined by Klopfenstein et al. (2008) was calculated as the difference in G:F divided by inclusion decimal percentage. The feeding value of WDGS was consistently greater than corn and suggests a 30% improvement above corn in diets containing DRC or HMC. The authors calculated that feeding lower levels of WDGS (< 40%) resulted in a feeding value of 160% that of corn. Gain and marbling was significantly quadratic and increased as WDGS inclusion increased to 30% and then decreased. However, when feeding WDGS at 40% and 50%, the feeding value was still greater than corn and G:F was numerically greatest. Similar results were seen in the current study, when comparing the 40-5 treatment to the CON treatment. The 40-5 treatment had a numerically higher ADG and DMI therefore, resulting in a significantly higher feed efficiency compared to the CON treatment without WDGS.

Bremer et al. (2010) provided an updated meta-analysis that included a total of 14 feedlot experiments 2534 steers where WDGS replaced corn. The authors concluded that the replacement of corn up to 50% of diet DM as WDGS resulted in superior performance when compared to cattle fed no WDGS. As seen in the previous meta-analysis, DMI, ADG, F:G, 12th rib fat, and marbling score improved quadratically as WDGS inclusion increased. The authors also reported that the feeding value of WDGS was greater at lower WDGS inclusion levels and decreased as inclusion levels increased. These results can be observed in the current research, where ADG decreases with the higher (> 40%) levels of WDGS inclusion when compared to the CON or 40-5 treatment. Feed efficiency parallels this conclusion with decreasing levels of G:F observed with increasing levels of WDGS inclusion.

Vander Pol et al. (2006) evaluated the effects of increasing dietary inclusion of wet distillers grains plus soluble on feedlot performance. Dietary treatments included a control (CON), 10%, 20%, 30%, 40%, and 50% WDGS (DM basis) and 5% alfalfa hay. Dry matter intake as well as ADG increased quadratically as the inclusion of WDGS increased from 0-50% DM. Feed conversion decreased quadratically as the inclusion of WDGS increased, leaving the 40% level of WDGS with the best feed efficiency. All energy values for WDGS were reported in excess of 100% compared to corn. Therefore, the author summarized that regardless of dietary inclusion, feeding WDGS in finishing diets generates higher energy values than a corn-based diet. Vanderpol et al. reported a quadratic response for ADG and G:F, however, his research evaluated WDGS only up to

50% diet DM. These results lead to the current research, to evaluate the effects of feeding WDGS at > 50% diet DM. Our current research would conclude that the optimum level of WDGS is at the 40% inclusion level and that feeding in excess of 40% DM results in decreased feed efficiency and longer DOF. Vanderpol et at. CON and 40% WDGS treatments were identical, except for roughage type, to the current research treatments (CON and 40-5). The differences observed for the 40-5 treatment having greater ADG and G:F in the current research were supported by Vanderpol et al. data.

Another trial conducted by Wilken et al. (2009) evaluated the effects of feeding high levels of byproduct in finishing diets. Treatments in this experiment included; Corn Control containing 82.5% DRC, 43.5% WDGS with corn, and 66% WDGS with 21.9% grass hay. All diets included 7.5% alfalfa hay as a roughage source. Steers fed the 66% WDGS with hay had greater DMI than the 43.5% WDGS with corn and similar intakes to the Corn Control diet. 43.5% WDGS with corn had the highest ADG and feed conversion followed by the Corn Control and 66% WDGS with hay, which had similar ADG. All diets resulted in similar marbling scores but the 43.5% WDGS with corn diet had the greatest final BW. In conclusion, the high level of WDGS fed in the 66% WDGS with hay diet performed similar to the traditional corn-based finishing diet. The steers fed the CON, 40-5, and 70-25 treatments in the current study are comparable to the Corn Control, 43.5% WDGS with corn, and 66% WDGS with hay treatments. Steers fed the 70-25 had lower DMI compared to the 40-5 and the CON treatments. The 40-5 treatment had the greatest ADG, as seen previous with the 43.5% WDGS with corn treatment, followed by the CON and then the 70-25, which were similar to the data reported by Wilken et al. In the current research, G:F was greatest for the 40-5 followed by the CON and then the 70-25. This was in contrast to the data from Wilken et al. (2008) where the Corn Control treatment had greater G:F than the 66% WDGS with hay. Marbling scores were similar for the CON and 40-5 and followed by the 70-25 however, the 40-5 treatment had the greatest final BW.

Economic Results

When corn is priced at \$3.50/bu and WDGS is 85% the cost of corn, then the 70-25 treatment had the greatest breakeven value at \$101.20. The 40-5 treatment had the lowest breakeven value at \$84.18/cwt, followed by the 77-9, 70-8, 77-17, CON, and lastly 85-10. The 40-5 treatment had the lowest breakeven due to selling the most weight at the end of the feeding period and having the greatest feed conversion values. The treatments (85-10, 77-17, 70-25) that were fed for additional days still did not sell similar final BW and had additional feed costs therefore, the breakeven values were much greater for these treatments. When analyzing marginal rate of return and CON is equal to zero profit/loss, the greatest loss is seen with the 70-25 treatment at -\$93.04/hd followed by 85-10 at \$-28.42/ hd and the greatest profit is observed with the 40-5 treatment with \$124.33 followed by the 70-8, 77-9, and lastly the 77-17. Again this is a consequence of having lower weight to sell at the end of the feeding period and greater feed costs. Likewise, COG was greatest for the 70-25 treatment at \$75.02/hd followed by the 85-10 at \$67.58/hd, and 77-17 at \$61.90/hd due to these treatments having lower final BW and extended DOF. The 40-5 treatment at \$52.90/hd has the least COG followed by the 70-8 at \$55.35/hd and 77-9 at \$55.94/hd which were similar and lastly CON with a COG at \$64.00/cwt. Treatments with the blend of WDGS and some inclusion of corn (70-8, 77-

9) had greater profit, lower COG, and lower breakeven prices than the treatments with no corn (85-10, 77-17, 70-25) or the CON treatment.

Wilken et al. (2009) evaluated the effects of feeding high levels of byproduct in finishing diets. Treatments included; 1) CORN, 82.5% DRC 2) WDGS:corn, 43.5% or each corn and WDGS 3) WDGS:hay, 65.6% WDGS and 21.9% grass hay. All diets included 7.5% alfalfa hay as a roughage source. After performing economic analysis on these treatments, the authors reported that the steers fed the WDGS:corn had the greatest profit regardless of corn price. The steers on this treatment were the most efficient and sold the most weight. Steers fed WDGS:hay performed similarly to steers fed CORN; however, their profitability was greater due to feeding a less expensive diet and selling the same weight. With increasing the price of corn, the WDGS:hay diet became increasingly competitive in relationship to the CORN and the WDGS:corn diets. With corn priced at $3.50 and WDGS at 85% the cost of corn, the WDGS:hay was slightly less profitable than the WDGS:corn however, was more profitable than the CORN treatment. In comparison with the current research, the COG for the 40-5 and CON were nearly the same and less than the 70-25 treatment. However, when profit/loss was set at zero for the CON treatment the 40-5 treatment was much more profitable when compared to the 70-25, which lost $93.02/hd. Similar to Wilken's data, the 40-5 treatment was the most efficient, sold the most weight, which created the greatest profit.

Huls et al. (2008) reviewed the economics of modified wet distillers grains plus solubles use in the feedlot. The review included feeding MDGS at 0, 10, 20, 30, 40, 50% DM. Corn was set at $3.70/bu and MDGS was 85% the price of corn. Huls et al. reported DMI, ADG, and final BW as quadratic when increasing the % of MDGS in the diet. In comparison to the current study, the increase of WDGS inclusion resulted in a decrease in DMI, ADG, and final BW. The 40% WDGS treatment in the current study and the 20-40% MDGS in Huls et al. had the optimal performance when compared to the other treatments.

From this study, we can conclude it is possible to feed very high levels of WDGS and roughage without negative implications from polio. Knowing that roughage can be substituted on an equal NDF basis (Benton et al,. 2007), grass hay, alfalfa hay or even cornstalks or wheat straw need to be included at higher levels in diets containing large inclusions of WDGS to manage dietary S (Vanness et al., 2009, Wilken et al., 2009). However, the most economical treatment included distillers grains at 40% DM and the treatments including wheat straw above at 9% had lower ADG and feed efficiencies therefore resulting in poorer economic profit.

Implications

Larger ADG and G:F were observed with 40% WDGS and 5% roughage. Higher levels of WDGS were successfully fed with levels of roughage above 8% but the diets were less profitable than the 40% WDGS diet. Compared to the CON, feeding WDGS above 77% or including straw in place of all the corn decreased ADG, G:F, or both. Feeding 70% WDGS and 25% Wheat straw resulted in the lowest performing cattle which had the lowest ADG and G:F, 12th rib fat thickness, and marbling when compared to any of the treatments. Profitability paralleled steer performance with the greatest profit, least COG and breakeven observed with the 40-5 treatment. The cattle consuming the 70-25 treatment resulted in the greatest loss, COG, and breakeven compared to all other treatments. Treatments with the blend of WDGS and some inclusion of corn (70-8, 77-9) had greater profit, lower COG, and lower breakeven prices than the treatments with no corn (85-10, 77-17, 70-25) or the CON treatment.

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Table 1. Composition of diets							
	Corn				**No corn**		
Ingredient	***CON***	**40-5**	**70-8**	**77-9**	**85-10**	**77-17**	**70-25**
WDGS[1]	-	40	70	77-5	85	77.5	70
DRC[2]	85	50.3	16.8	8.4	-	-	-
Wheat straw	4.7	4.7	8.2	9.1	10	17.5	25
Molasses	5.0	-	-	-	-	-	-
Supplement							
Limestone	1.71	1.69	2.23	2.23	2.23	2.23	2.23
Urea	1.46	---	---	---	---	---	---
Fine ground corn	1.16	3.07	2.53	2.53	2.53	2.53	2.53
Salt	0.30	---	---	---	---	---	---
Tallow	0.13	0.13	0.13	0.13	0.13	0.13	0.13
KCl	0.13	---	---	---	---	---	---
Trace mineral	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Rumensin-80	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Vitamin A-D-E	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Thiamine	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Tylan-40	0.01	0.01	0.01	0.01	0.01	0.01	0.01
% CP	13.3	18.2	24.7	26.4	28.0	26.1	24.0
% Sulfur	0.11	0.41	0.63	0.68	0.74	0.68	0.63
% Fat	3.61	7.23	9.66	10.26	10.80	9.90	9.00

[1]WDGS = wet distillers grains plus soluble.

[2]DRC = dry rolled corn.

Table 2. Performance results for treatments.

Dietary Treatment[1]:	Con	40-5	70-8	77-9	85-10	70-17	70-25	SEM
Performance[2]								
Initial BW, lb	269	270	269	269	270	269	4	1
Final BW, lb	569^{b}	630^{a}	572^{b}	565^{b}	563^{b}	581^{b}	523^{c}	7
DMI, lb/day	10.25^{a}	10.39^{a}	9.16^{b}	8.66^{c}	8.07^{d}	8.66^{bc}	8.25^{d}	0.11
ADG, lb	1.63^{a}	1.96^{a}	1.66^{b}	1.62^{b}	1.31^{d}	1.39^{c}	1.13^{e}	0.03
Gain:Feed	0.160^{b}	0.189^{a}	0.181^{b}	0.187^{ab}	0.162^{c}	0.157^{c}	0.138^{d}	0.002
Carcass Characteristics								
HCW, lb	358^{b}	397^{a}	361^{b}	356^{b}	355^{b}	366^{b}	329^{c}	4
Marbling score[2]	525^{a}	523^{a}	491^{b}	468^{bc}	457^{c}	467^{bc}	404^{d}	9.12
LM area, in^2	79.67^{ab}	83.35^{a}	78.84^{bc}	78.06^{bc}	75.03^{c}	75.81^{c}	77.10^{bc}	0.002
12^{th} rib fat, in	0.17^{c}	0.24^{a}	0.19^{bc}	0.17^{bc}	0.17^{c}	0.20^{b}	0.11^{d}	0.01
Calculated USDA YG[3]	3.0^{de}	3.7^{a}	3.4^{bc}	3.2^{cde}	3.3^{cd}	3.6^{ab}	2.5^{f}	0.1

[1] CON = control diet of 85% DRC; 40-5 = 40% WDGS and 5% wheat straw; 70-8 = 70% WDGS and 8% wheat straw; 77-9 = 77% WDGS and 9% wheat straw; 85-10 = 85% WDGS and 10% wheat straw; 77-17 = 77% WDGS and 17% wheat straw; 70-25 = 70% WDGS and 25% wheat straw.

[a,b,c,d,e,f]Within a row, means without common superscript differ ($P<0.05$).

[2] Marbling Score = 400 = Slight 0, 500 = Small 0, etc.

[3] Calculated USDA YG = 2.5 + (2.5*12^{th} rib fat) + (0.2*KPH%) + (0.0038*HCW) – 0.32*ribeye area)

Table 3. Effect of Inclusion of WDGS on economics when corn is \$3.50/bu and WDGS is 85% the price of corn.

	Treatments[1] (%DM)						
Dietary Treatments[1]	**CON**	**40-5**	**70-8**	**77-9**	**85-10**	**77-17**	**70-25**
BE, \$/cwt[2]	93.13	84.18	89.87	89.52	95.42	91.73	101.20
P/L, \$/hd[3]	0.00	124.33	54.61	45.02	-28.42	17.97	-93.04
COG, \$/cwt[4]	64.00	52.90	55.35	55.94	67.58	61.90	75.02

[1] CON = control diet of 85% DRC; 40-5 = 40% WDGS and 5% wheat straw; 70-8 = 70% WDGS and 8% wheat straw; 77-9 = 77% WDGS and 9% wheat straw; 85-10 = 85% WDGS and 10% wheat straw; 77-17 = 77% WDGS and 17% wheat straw; 70-25 = 70% WDGS and 25% wheat straw.

[2]Breakeven (BE) = (initial steer cost (\$126.39/cwt) + feed cost (DRC(\$3.50/bu); WDGS (\$125/DM ton); Wheat straw (\$72.70/DM ton)) + interest (8.0% interest applied to initial steer value (initial BW * \$126.39/cwt) and to feed costs) + health&processing (\$20/steer applied) + yardage (\$0.40/steer/d applied) + deathloss (1.5% death loss applied)) / FW.

[3]Profit/Loss (P/L) = final steer value (\$93.13/cwt) – (initial steer cost (\$126.39/cwt) + feed cost (DRC(\$3.50/bu); WDGS (\$125/DM ton); Wheat straw (\$72.70/DM ton)) + interest (8.0% interest applied to initial steer value (initial BW * \$126.39/cwt) and to feed costs) + health&processing (\$20/steer applied) + yardage (\$0.40/steer/d applied) + deathloss (1.5% death loss applied)).

[4]Cost of Gain (COG) = (feed cost (DRC(\$3.50/bu); WDGS (\$125/DM ton); Wheat straw (\$72.70/DM ton)) + interest (8.0% interest applied to initial steer value (initial BW * \$126.39/cwt) and to feed costs) + health&processing (\$20/steer applied) + yardage (\$0.40/steer/d applied) + deathloss (1.5% death loss applied)) / (FW-IW).