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Feeding condensed distillers solubles to feedlot finishing steers and the effects of feed additives in adaptation diets

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FEEDING CONDENSED DISTILLERS SOLUBLES TO FEEDLOT FINISHING

STEERS AND THE EFFECTS OF FEED ADDITIVES IN ADAPTATION DIETS

by

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By-products from the dry-milling ethanol process can be used in cattle diets to replace corn. There is a significant interaction between corn processing methods as CCDS concentration increases in the diet. Improvements are observed for SFC in final BW, ADG, and G:F over DRC. An experiment was conducted to determine if greater concentrations of CCDS could be fed in SFC based diets and maintain or improve performance. Performance and carcass characteristics were evaluated with increasing concentrations of CCDS at 0, 9, 18, 27, or 36% in place of SFC in feedlot finishing diets. As CCDS concentration increased, DMI decreased quadratically. Gain increased quadratically with optimum inclusion calculated at 18.2% CCDS. A quadratic improvement was observed for G:F with optimum inclusion calculation at 24.5% CCDS. These results suggest feeding corn condensed distillers solubles can be used to replace SFC in feedlot finishing diets while improving ADG and G:F.

Monensin has been fed for over 35 years to improve G:F and prevent/control coccidiosis in feedlot cattle. Two experiments were conducted to determine if a difference exists between monensin rates of 360 or 480 mg/steer daily during the adaptation period. A significant interaction between treatment and experiment was

observed for interim BW, ADG, and G:F during the adaptation period. During the adaptation period, cattle fed 360 mg/steer daily had greater ADG, increased interim BW, and improved G:F compared to steers fed 480 mg daily in Exp. 2. Carcass characteristics were not affected by monensin rate. This study suggests feeding 360 versus 480 mg/steer daily of monensin during the adaption period has little impact on overall performance of the cattle. Experiment 2 data indicate that 360 mg/steer daily of monensin may be more advantageous with the steers being more efficient during the adaptation period. However, they do not maintain that efficiency through the entire finishing period.

Key words: beef cattle, by-products, condensed distillers solubles, feed additive, monensin

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Marie Elizabeth

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REVIEW OF LITERATURE I

Condensed Distillers Solubles in Feedlot Diets

   Introduction. With high corn prices, cattle producers are looking for cheaper ways to feed cattle without reducing gain or efficiency. Producers are evaluating by-products as a solution to decrease their cost of gain. According to a survey of feedlot nutritionist, 83% of their clients use by-products in feedlot diets (Vasconcelos and Galyean, 2007). The dry-milling process that produces ethanol is a large industry throughout the Midwest. Two by-products commonly fed in cattle diets to replace corn are distillers grains and corn condensed distillers solubles (CCDS). There are many studies that assess feeding wet distillers grain with solubles (WDGS), but less work has been conducted with CCDS.

   The Ethanol Process. Ethanol is primarily produced from the dry-milling of corn or other grains. The plant grinds the corn before wetting it to form a mash and allowing it to cook. Then, enzymes followed by yeast are added to allow for fermentation to occur. The starch is then converted into sugar before creating ethanol and carbon dioxide. The remaining portion, called whole stillage, is centrifuged to produce both wet distillers grains (WDG) and thin stillage. Thin stillage is then evaporated to CCDS. Those by-products, CCDS and WDG, can be marketed separately or added together to form wet distillers grains with solubles. The WDGS can also be partially dried to produce modified distillers grains with solubles (MDGS) or dry distillers grains with solubles (DDGS), depending on the drying intensity of the grains (Stock et al., 2000; Erickson et al., 2010).

   Since approximately two thirds of the corn kernel is starch, the nutrient content of distillers grains increases about 3 fold once the starch is removed (Erickson et al., 2010).

The composition of WDGS as reported by Erickson et al. (2010) is around 34.9% DM, 31.0% CP, 65.0% UIP, and 0.84% P while the composition of CCDS is around 35.5% DM, 23.8% CP, 20.0% UIP, and 1.72% P.

Corn Composition. Hopkins et al. (1974) describes the composition of the corn kernel as consisting of six different parts: the tip cap, the hull, germ, and endosperm. The tip cap is a small covering over the end of the kernel, protecting the end of the germ. It makes up around 1.4% of the kernel. The material of the tip cap resembles the cob. The hull is the thin outer covering of the kernel, comprising around 5.8% of the kernel. The hull mainly consists of carbohydrates like fiber and cellulose. The germ is toward the tip end, comprising around 11.0% of the kernel. The germ can extend one half to two thirds the length of the kernel. The embryo stem and root both reside in the germ. The endosperm part comprises the rest of the kernel and makes up around 81.6% of the kernel. This portion also houses the majority of the zein protein.

Hopkins et al. (1974) describe the chemical constituents as follows: The tip cap contains approximately 0.9% protein, 0.6% oil, 1.2% ash, and 1.6% carbohydrates (starch, cellulose, pentosans, etc). The hull contains 2.2% protein, 1.1% oil, 3.4% ash, and 6.7% carbohydrates. The germ contains 19.3% protein, 82.3% oil, 73.0% ash, and 4.7% carbohydrates. The endosperm contains 23.6% protein, 2.8% oil, 5.4% ash, and 29.6% carbohydrates (Hopkins et al., 1974).

Jaeger et al. (2006) examined a variety of corn hybrids and reported no differences ($P > 0.20$) in DMI, ADG, or carcass characteristics. However, G:F was different ($P < 0.01$) among hybrids. There was a 9.5% increase in G:F from the least to most efficient hybrid. This difference was accounted to a greater proportion of soft

endosperm in the hybrids leading to increased concentrations of propionate in the cattle that experienced improved G:F (Jaeger et al., 2006).

   Corn Processing Methods. Corn can be processed in a variety of ways to increase starch utilization by the ruminant (Cooper et al., 2002). When cattle are fed diets primarily of processed corn, feed conversions will improve with the increased starch digestibility (Theurer, 1986). Common corn processing methods are dry-rolled corn (DRC), steam-flaked corn (SFC), and ensiling high moisture corn (HMC; Vasconcelos and Galyean, 2007)

   Dry-rolled corn is a processing method used in feedlot diets (Vasconcelos and Galyean, 2007). The kernel is sent through two roller pins which "crack" the corn to decrease the particle size. Dry-rolling allows for the starch to be readily available for digestion by ruminal microbes. The surface area of the kernel is increased which allows for easier microbial digestion. Whole corn is resistant to digestion because of a "waxy" outer coating that inhibits microbial digestion. Cattle must masticate and crack the kernels to utilize the nutrients (Erickson, 2013).

   Steam-flaking corn is the most popular processing method used by feedlots based on a survey of feedlot nutritionists (Vasconcelos and Galyean, 2007). Whole corn is allowed to steam in a chest for around 30 minutes to gelatinize the starch (Zinn, 2002). Gelatinization is when the starch particle swells and is defined by loss of birefringence, swelling power, solubility, and enzymatic reactivity, as described by Zinn (2002). The majority of corn kernels will typically lose their birefringence between 62-72°C which is called the gelatinization temperature range. After gelatinizing, the kernel is sent through a set of rollers to produce the flake. Flaking increases the surface area of the kernel to

allow for more rapid digestion of the starch by the microbes. Flake density can be changed by how tight or loose the rolls are when the corn is flaked. Decreasing flake density (360, 309, or 257 g/L), can lead to a decrease in ruminal pH and an increase in postruminal and total tract digestibility of starch (Zinn et al., 1990a). In a feedlot trial conducted by Zinn et al. (1990a), performance and carcass characteristics were not influenced by flake density. Therefore, there is little benefit to spending the extra energy to roll a flake with a lighter density when the increased starch digestibility can also lead to acidosis (Zinn et al., 1990a). Sindt et al. (2006) also observed that rolling to less than 360 g/L (28 lb/bu) has few benefits for performance and carcass characteristics. Hales et al. (2010) reported that there is an increase ($P \leq 0.02$) in the proportion of total starch for 283 g/L than for 335 or 386 g/L flakes. The increased starch could be due to the analytical procedure, but is still an indicator of increased starch availability for enzymatic digestion (Hales et al., 2010). Vasconcelos and Galyean (2007) reported an average flake density of 350 g/L recommended by feedlot nutritionists.

Compared with DRC, SFC increases digestibility of starch in the rumen, small intestine, and total tract by 21.9, 75.1, and 9.2% respectively (Zinn, 1990b). Huntington (1997) reported that SFC increases ruminal starch digestibility (as a percentage of intake) from 75 to 85% when compared to DRC. Corona et al. (2005) evaluated the performance of feedlot steers fed SFC, DRC, ground corn (GC), or whole corn (WC) based diets. Cattle fed WC had lower ($P < 0.10$) ADG than those fed DRC or GC. When fed SFC, the steers had greater ($P < 0.05$) ADG and G:F and decreased ($P < 0.10$) DMI than those consuming the other treatments. However, other articles have reported a decrease in DMI and improved G:F with no difference in ADG in SFC based diets when compared DRC

(Barajas and Zinn, 1998; Zinn, 1987). Increased digestibility ($P < 0.01$) of OM and starch were observed for DRC or GC processing. Steam-flaking corn had a higher digestibility of OM and starch when compared to the dry treatments (Corona et al., 2005).

High moisture corn is commonly utilized in areas where corn and storage are readily available. High moisture corn is produced by harvesting corn with a moisture content around 30% (Benton et al., 2005). The corn is then rolled (or ground) and stored in either a silo or bunker. Owens et al. (1997) reported that the moisture content tends be lower when stored in a silo versus a bunker. The grain is typically rolled prior to storage to allow for easier packing, which helps exclude oxygen during fermentation (Owens et al., 1997).

The process of HMC fermentation is described in 6 phases according to Rutherford (2006). Phase I is aerobic and starts when the grain is harvested. Cell respiration occurs and CO_2, heat, and water are produced. The pH remains fairly high, around 6.0-6.5. Phase II begins once oxygen is depleted; the corn is packed into the bunker. Without oxygen, anaerobic bacteria thrive, producing small amounts of acetic acid, lactic acid, and ethanol. The temperature increases and the pH drops to around 5.0. This occurs around three days in the bunker. Phase III initiates around day four when the pH decreases so only lactic acid producing bacteria can thrive. At about day five, phase IV occurs. Lactic acid continues to be produced by anaerobic bacteria until the temperature stabilizes and the pH becomes so acidic (around 4.0), no organisms can thrive, slowing down or going dormant. Phase IV lasts until day 21 when the grain enters phase V and is considered stable. The corn is now ready to be fed. Once the grain is removed from the pile for feeding, phase VI is initiated. Once oxygen is reintroduced,

molds and yeasts are active, pH increases, and decomposition begins, which is why correctly managing the open side of the pile is vital (Rutherford, 2006).

There are a variety of studies comparing DRC, HMC, and SFC. Cooper et al. (2002) reported that DMI is about 15% higher ($P < 0.05$) for HMC over DRC and SFC based diets. Owens et al. (1997) conducted a review with 605 comparisons of grain processing methods published in journals and bulletins. They reported a decrease ($P < 0.05$) in the DMI of SFC diets over DRC and HMC based diets. However, steers that consumed DRC still had increased ($P < 0.05$) intakes over those consuming HMC. Cattle consuming DRC and SFC based diets exhibited higher ($P < 0.05$) ADG than those consuming HMC with no difference between DRC and SFC diets. Furthermore, SFC based diets were reported to have increased ($P < 0.05$) G:F over cattle consuming DRC or HMC diets (Owens et al., 1997). Galyean et al. (1976) reported that total tract starch digestibilities were higher ($P < 0.05$) for HMC and SFC versus DRC, but HMC and SFC were not different. Additionally, Cooper et al. (2002) reported that HMC had greater ($P < 0.05$) ruminal starch digestibility over DRC and postruminal starch digestibility is greater ($P < 0.05$) for SFC versus DRC or HMC. High-moisture corn has a 29% greater ($P < 0.05$) bacterial CP flow into the duodenum, as exhibited by ruminal OM digestibility, than DRC or SFC, suggesting that the DIP requirement is approximately 12% greater in HMC based diets. Numerically, steers consuming SFC had increased bacterial CP flow into the duodenum than DRC based diets (Cooper et al., 2002).

Corrigan et al. (2009) reported that as WDGS increased from 0, 15, 27.5, to 40% in a HMC diet, ADG increased quadratically ($P = 0.04$) and G:F increased linearly ($P = 0.02$). Total tract starch digestibility was decreased ($P < 0.01$) and ruminal pH was

greater ($P < 0.01$) for steers fed HMC based diets when compared to SFC based diets (Corrigan et al, 2009).

    Wet Distillers Grains with Solubles. Wet distillers grains with solubles (WDGS) is commonly added to finishing diets throughout the Midwest. Replacing corn with WDGS adds more energy and protein to the diet. Klopfenstein et al. (2008) conducted a meta-analysis of distillers grains in feedlot diets and reported that WDGS contributes to an increase in ADG and G:F when compared to cattle fed normal corn-based diets without distillers grains. Dry distillers grains had less of a performance response in cattle, exhibiting a lower feeding value when compared to WDGS. Additionally, the feeding value of distillers grains further decreases when fed in diets containing SFC compared with DRC or HMC (Klopfenstein et al., 2008).

    Bremer et al. (2011) conducted a meta-analysis for distillers grains replacing diets of DRC and HMC at concentrations of 0, 10, 20, 30, or 40% diet DM. They reported that DMI, ADG, and G:F increased quadratically for increasing concentrations of WDGS and MDGS ($P < 0.01$). In the same study, the feeding values of WDGS, MDGS, and DDGS, when fed at 10 to 40% of the diet DM, ranged from 150 to 130%, 128 to 117%, and a constant 112% of corn, respectively. Distillers grains that do not undergo the drying process have more value in high concentrate finishing diets (Bremer et al., 2011).

    Corrigan et al. (2009) determined that an interaction exists between corn processing method and WDGS. Wet distillers grains with solubles can be beneficial by increasing ADG and G:F in diets containing DRC and HMC, but in diets with SFC as the grain source, ADG decreases quadratically ($P = 0.02$) with no change in G:F ($P = 0.52$). Steers fed SFC had greater ($P < 0.01$) total tract starch digestibility compared with those

fed DRC or HMC when WDGS is included in the diet (Corrigan et al., 2009). May et al. (2010) also reported a decrease ($P \leq 0.05$) in final BW and HCW as WDGS increased in a SFC based diet with a decrease ($P \leq 0.05$) in G:F as WDGS increased from 15-30% of the diet. Corrigan et al. (2009) also reported that the minimum ruminal pH was less ($P < 0.01$) for the steers fed SFC, but average pH was similar ($P = 0.43$) among processing methods. Vander Pol et al. (2008) compared processing methods in diets containing 30% WDGS. Diets with DRC, HMC, or a 1:1 blend of HMC:DRC had improved performance compared with diets that are more intensely processed (FGC or SFC) and whole, unprocessed corn (WC). Cattle fed DRC had increased ($P < 0.05$) ADG and final BW compared to FGC, SFC, and whole corn. Steers fed HMC or HMC:DRC had increased ($P < 0.05$) ADG over those fed SFC or FGC. Feeding HMC had improved ($P < 0.05$) G:F than animals fed FGC, SFC, and whole corn, but those fed DRC or HMC:DRC had improved G:F over WC and FGC (Vander Pol et al., 2008).

Buttrey et al. (2013) reported no interaction ($P \geq 0.11$) between corn processing (DRC or SFC) and 35% WDGS inclusion (DM basis). Steers consuming SFC exhibited a decrease ($P < 0.01$) in DMI and increase ($P < 0.01$) in G:F versus those fed DRC. Additionally, the inclusion of WDGS in the diet increased ($P \leq 0.04$) G:F for steers fed both DRC and SFC (Buttrey et al., 2013).

In 2012, Luebbe et al. examined increasing levels of WDGS (15, 30, 45, or 60% diet DM) in SFC based diets. Final BW, ADG, G:F, HCW, 12th rib fat depth, and marbling score decreased linearly ($P < 0.01$) as WDGS replaced corn. As more WDGS were added to SFC based diets, performance was negatively impacted; possibly because the energy density of the diet decreases (Luebbe et al, 2012). Bremer et al. (2011) further

examines this point finding that cattle eat to a constant energy intake since the DMI

increased as the moisture of the distillers grains decreased, with the same ADG.

   Fats and Lipids in By-product Diets. Lipids are organic compounds that are

largely not water soluble. The main lipid constituents vital in nutrition are fatty acids,

glycerol, monoglycerides, diglycerides, triglycerides, and phospholipids. Triglycerides

are typically found in animal tissues consisting of three chains connected by a glycerol

backbone (Pond et al., 1995).

   Lipids supply energy to meet maintenance and production needs. When

completely combusted, one gram of fat produces about 9.45 kcal of heat, compared to

about 4.1 kcal for carbohydrates. Lipids are also used as a source for linoleic and

linolenic acids (essential fatty acids) and as a carrier for fat-soluble vitamins (Pond et al.,

1995).

   When lipids are absorbed, they are carried as chylomicrons, formed from the

intestinal mucosa cell during absorption. Lipids that are stored in the body and

subsequently mobilized for use are transported as lipoproteins that range from very low

density to high density. When too much fat is consumed, animals deposit the excess

energy as triglycerides. All tissues can store triglycerides, but most are stored in the

adipose tissue where they are continuously stored and mobilized for energy. Excess

energy intake results in more deposition of triglycerides than mobilization resulting in

fattening. The fatty acid composition of deposited fat in ruminants tends to be constant

and not affect by diet because of digestion by the rumen microbes (Pond et al., 1995).

   When ruminants consume unsaturated free fatty acids (FFA), microbes in the

rumen hydrogenate and saturate the fats. This is called biohydrogenation. In

biohydrogenation, the cis-12 double bond of the unsaturated FFA ($C_{18:2}$) is converted via

isomerase to a trans-11 bond. The cis-9 bond is then hydrogenated by a microbial

reductase so the fat is now $C_{18:1}$. Depending on the rumen environment, the trans-11 bond

can then be further reduced to $C_{18:0}$ (Jenkins, 1993).

   With the processing of corn into distillers grains (DG), the fat concentration of

corn is increased 300% in the final DG product (Klopfenstein et al., 2008). The fat

provided in WDGS does not have the same effect on the animal as fat found in corn oil.

The added fat in WDGS improves animal performance, but supplementing corn oil,

rather than WDGS, can decrease feed efficiency (Vander Pol et al., 2009). The fat in

WDGS is bound in the germ and resistant to complete biohydrogenation in the rumen,

but the fat in corn oil can be degraded in the rumen. High levels of fat supplementation

can decrease ruminal and total tract digestion of organic matter and ADF as noted by

Zinn (1989) and Zinn et al. (2000). Protecting fat from biohydrogenation in the rumen,

and thus allowing postruminal digestion of the fats, can help minimize the negative

effects of fat supplementation (Zinn et al., 2000).

   Fats are typically used in ruminant diets to increase energy density, reduce

dustiness, and increase palatability. It was previously suggested to feed total dietary

levels of 2-4% fat as too much fat can reduce feed intake and alter fiber digestion (Pond

et al., 1995). However, new recommendations by feedlot nutritionists are at levels of 8%

of the total diet (Vasconcelos and Galyean, 2007). Zinn (1994) reported a linear decrease

in observed dietary NE for daily lipid intakes that exceed 1.6 g/kg of BW. For a 500 kg

animal with an intake at 2% of BW, this would equal 8% maximum dietary lipid intake

(Vander Pol et al, 2009).

Vander Pol et al. (2009) conducted a study to compare the effect of fat content when increasing amounts of corn oil or WDGS in a corn-based diet. The ether extract (EE) remained the same between oil and WDGS as the amount of fat increased in the diet. Fat in the diet increased from 4.0% EE in the control diet to 8.8% EE in the highest concentration of corn oil and WDGS. Average daily gain and G:F increased numerically as the amount of WDGS increased in the diet. However ADG and G:F had a significant linear decrease with supplemental corn oil (Vander Pol et al., 2009).

Sulfur in By-product Diets. When feeding diets high in distillers grains (DG), it becomes tempting to remove roughage to make an inexpensive diet with high efficiencies. However, polioencephalomalacia (PEM) can become an issue in diets high in DG that could be high in sulfur content. When the starch is removed in the process of fermenting corn into DG, the nutrient content of the by-product is 3 times higher than the original grain. The sulfur level in corn is about 0.14%, so DG should be about 0.42% (NRC, 1996). Buckner et al. (2011) collected distillers grains samples from 6 different ethanol plants with 4 different periods to determine the variation in nutrients. Sulfur concentration averaged 0.77% for the entire collection with a range from 0.67 to 1.06%. There was significant variation in S content within days and across days at the same plant (Buckner et al., 2011). Sulfuric acid is used in the process of producing DG which can cause variation and lead to elevated levels of inorganic S in the final DG product, subsequently being consumed by cattle. By adding more roughage to a diet with DG, the H_2S levels in the rumen will decrease, helping to reduce the risk of PEM (Vanness et al., 2009; Nichols et al., 2013).

When considering the sulfur content of a diet, the source of the sulfur must be taken in to consideration. Rumen available sulfur (RAS) is dietary sulfur that can be metabolized into H_2S by rumen microbes. The consumption of ruminal available sulfur is a more accurate indication of hydrogen sulfide concentration in the rumen and thus could more accurately predict PEM incidences (Sarturi et al., 2013). Nichols et al. (2013) reported that for every 0.1% increase in dietary sulfur or RAS, the risk for PEM increases by a factor of 2 and 2.6, respectively ($P < 0.01$). Rumen available sulfur could be a more effective measurement of PEM risk than dietary S concentration alone. If RAS comprises a significant amount of the dietary S level, the potential for PEM increases (Nichols et al., 2013).

Gould et al. (1997) induced PEM by adding sodium sulfate to the diet of steers and comparing to a control diet without added sodium sulfate. Two of the three steers supplemented with sodium sulfate exhibited symptoms of PEM that coincided with an increase in ruminal H_2S gas production. The steers with added S had H_2S concentrations 40-60 times greater with 4 times the concentration of sulfide in the rumen fluid versus control steers (Gould et al., 1997).

Zinn et al. (1997) reported a quadratic decrease in ADG ($P < 0.10$) and longissimus muscle area ($P < 0.05$), linear decrease in DMI ($P < 0.10$) and diet NE ($P < 0.10$), and a quadratic increase ($P < 0.10$) in G:F as dietary S concentration increased (0.15, 0.20 or 0.25% DM) in a heifer feedlot diet. Poorest DMI, ADG, and G:F were reported at the 0.25% dietary S concentration (Zinn et al., 1997).

Besides feeding distillers grains high in sulfur, another significant source of sulfur intake in feedlot cattle is their water source (Gould, 1998). Loneragan et al. (2001)

experimented with water sulfate concentrations ranging from 136.1 to 2,360.4 mg/L. They observed a linear decrease in ADG ($P < 0.01$), G:F ($P < 0.01$), final BW ($P = 0.05$), HCW ($P = 0.02$), dressing percentage ($P = 0.09$), and predicted YG ($P = 0.09$) as water sulfate concentration increased. Steers also exhibited a quadratic decrease in 12th rib fat depth ($P = 0.01$) and linear increase in longissimus muscle area ($P = 0.07$) as sulfate concentration increased (Loneragan et al., 2001).

Effects of Condensed Distillers Solubles on Performance. In the dry-milling ethanol process, whole stillage is what remains after the ethanol has been distilled off. The whole stillage is then centrifuged to remove the coarse grain particles known as wet distillers grains. The remaining liquid, called thin stillage, undergoes an evaporation process to produce the CCDS product. The CCDS can either be added back to the grains or marketed as a separate product (Stock et al., 2000).

Rust et al. (1990) observed a decrease in DMI along with a significant increase in G:F in a DRC based diet as more CCDS was consumed, up to 20% of the diet DM. Trenkle and Pingel (2004) agree that CCDS has value in a finishing diet as long as the cost is economical. Feeding CCDS up to 12% of the diet does not reduce performance or carcass characteristics (Trenkle and Pingel, 2004). Pesta et al. (2012) evaluated the effects of higher concentrations of CCDS on finishing performance. Condensed distillers solubles has the potential to replace corn and lead to a more economical diet. When replacing a 1:1 ratio of HMC:DRC diet with either 0, 9, 18, 27, or 36% CCDS (DM basis), DMI decreased and ADG increased leading to an improvement in G:F. The recommended CCDS inclusion levels are 20.8% for maximum ADG and 32.5% for maximum G:F in a HMC:DRC based diet (Pesta et al., 2012).

Condensed corn distillers solubles can also be supplemented in forage-based diets. Gilbery et al. (2006) fed treatments of 0, 5, 10, and 15% CCDS in low-quality switchgrass hay diets. They reported that CP intake and total tract CP digestibility increased ($P \leq 0.06$) in a linear fashion as CCDS increased in the diet. Ruminal digestion of ADF and NDF also increased ($P \leq 0.02$) as CCDS concentration increased. The researchers conclude that supplementing CCDS in low-quality forage diets can be a source of protein and increase the digestibility of the forage (Gilbery et al., 2006).

Condensed distillers solubles has been fed in HMC and DRC diets, but few have researched the effect in a SFC based diet. Titlow et al. (2013) examined increasing levels of CCDS from 0, 15, or 30% diet DM in SFC or DRC based diets. It was determined that both DRC and SFC had improvements in final BW, ADG, and G:F as CCDS concentration increased. However, there was a significant interaction between corn processing methods with SFC having improved final BW, ADG, G:F and HCW. It is hypothesized that higher concentrations of CCDS (above 30%) may be fed without decreasing performance (Titlow et al., 2013).

The interaction between CCDS and SFC is much different than what was noted between WDGS and SFC in the WDGS section of this paper (Corrigan et al., 2009; Klopfenstein et al., 2008; Luebbe et al., 2012; Vander Pol et al., 2008). It is also reported that CCDS can be fed in diets already containing other by-products. If 20% of the diet is MDGS or Synergy, 14-21% CCDS may be fed with some improvements in performance (Pesta et al., 2012).

Conclusion. Condensed distillers solubles as a by-product of the dry-milling ethanol industry can be an ideal replacement for corn in feedlot cattle finishing diets. It

has been proven to improve G:F with a variety of corn processing methods and diets. As with all distillers byproducts, monitoring fat and sulfur concentrations is important to ensure the product is safe to feed and will not have negative effects on performance and carcass characteristics. Thus, the objective of the following experiment was to determine an appropriate feeding concentration of CCDS in SFC based diets.

REVIEW OF LITERATURE II

Monensin in Feedlot Diets

  Introduction. Monensin is a common ionophore feed additive in feedlot diets used to improve feed efficiency and prevent and control coccidiosis (FDA, 2006). The approved level of monensin in cattle diets is a concentration of 6.1-48.5 mg/kg (5.5-44 g/ton) of DM and a rate of 50-480 mg/animal daily. Both parameters must be met to be in compliance. The concentration and rate were increased in 2006 from a previous maximum of 36.4 mg/kg (33 g/ton) of DM and 360 mg/animal daily.

  Mode of Action. Monensin alters the movement of ions across rumen microbial membranes, favoring the growth of gram-negative bacteria (Kunkle et al., 2000). The Na^+, K^+ pump is activated and the rate to Na^+ entry into the cell increases (Smith and Rozengurt., 1978). Monensin has also been shown to alter volatile fatty acid ratios. The acetate to propionate ratio decreases with the addition of monensin in the diet, and butyrate concentrations decrease as well (Richardson et al., 1976; Bergen and Bates, 1984). Monensin increased the ruminal propionate concentration more in a low forage diet (Ramanzin et al., 1997). Propionate has the potential to be more energetically efficient compared to acetate as propionate can be used for gluconeogenesis (Schelling, 1984). Additionally, monensin supplementation has a small impact on decreasing the amount of methane produced by rumen microbes (Bergen and Bates, 1984; Schelling, 1984). With a decrease in methane production, the animal can be more efficient because carbon and energy are not lost to methane (Bergen and Bates, 1984; Richardson et al., 1976).

Monensin can also have an effect on protein utilization by increasing the amount of UIP (Bergen and Bates, 1984). The amount of protein that bypasses the rumen has been reported to increase from 22 to 55% across 5 experiments (Bergen and Bates, 1984).

A deceased DMI is often reported with the use of monensin in finishing diets (Duffield et al., 2012). Lower DMI can help reduce the incidence and severity of acidosis (Schelling, 1984). Burrin and Britton (1986) reported that when cattle were fed monensin at a rate of 0, 150, or 300 mg/steer daily, increased pH and propionate concentrations were observed with greater concentrations of monensin in the diet. Lower acetate and butyrate concentration were also noted. Increasing the concentration of monensin reduced the total ruminal VFA concentrations ($P < 0.01$), which likely led to a higher ruminal pH value (Burrin and Britton, 1986).

Monensin in Adaptation Diets. Monensin is commonly supplemented in adaptation diets to assist in transitioning cattle to high concentrate diets as monensin can help control acidosis (Montgomery et al., 2003). Blackford et al. (2000) reported that monensin at concentrations of either 33 or 49.6 mg/kg reduced acidosis on the day of an acidosis challenge, but 49.6 mg/kg reduced ($P < 0.05$) the area the rumen was below a pH of 5.6 for 5 d following the challenge compared to cattle on the 33 mg/kg concentration. Patterson et al. (2002) reported that DMI is reduced when feeding monensin during an acidosis challenge. Increasing the concentration from 33 to 49.6 mg/kg decreased DMI during the 5 d following the challenge (Patterson et al., 2002).

Burrin et al. (1988) conducted a trial where monensin was fed in a 21 d adaptation period at levels of 0, 11, or 33 mg/kg. A linear increase ($P < 0.05$) in G:F was observed as there was a trend ($P = 0.12$) for a quadratic increase in gain and numerical decrease in

DMI as monensin level increased in the diet. There were no differences between 11 and 33 mg/kg monensin, indicating the use of monensin, not necessarily high concentrations, in adaptation diets can be beneficial. Supplementing monensin in adapation diets can improve feed efficiency and decrease intake variation, but it is not carried over to the finishing period (Burrin et al., 1988). Similarly, Parsons et al. (2010) determined that feeding an increased concentration of monensin is more beneficial during the first 56 days of a trial. However, they also reported that increasing monensin from 36.4 to 48.5 mg/kg of DM can decrease DMI ($P < 0.01$) and improve gain efficiency ($P < 0.10$) through the entire finishing period (Parsons et al., 2010). Pendlum et al. (1978) also recorded a decrease in DMI and numerical improvement in G:F as monensin rate increased from 0 to 300 mg/steer daily.

Conversely, Montgomery et al. (2003) conducted an experiment where cattle were fed 33, 44, or 55 mg/kg monensin during an 88 d growing period and no significant differences in performance were observed. However, the steers tended ($P < 0.11$) to have a quadratic increase in DMI, and a linear increase in ADG ($P < 0.02$) and HCW ($P < 0.05$) during the finishing period as monensin concentration increased in the diet. Concentrations of monensin beyond the labeled maximum in the growing period could be beneficial in to the finishing period (Montgomery et al., 2003). A quadratic increase ($P < 0.01$) in longissimus muscle area has been reported as monensin rate increased from 0 to 300 mg/steer daily (Pendlum et al., 1978).

Monensin in Finishing Diets. After many years of research, acidosis continues to be a common issue in ruminant animals (Oba and Wertz-Lutz., 2011). Monensin can help decrease the incidence of acidosis by increasing rumen pH and decreasing the time spent

below a rumen pH of 5.6. Additionally, monensin controls changes in DMI, which also helps manage acidosis (Cooper et al., 1997). Feeding monensin controls intake variation, but concentrations above approved levels show little improvement in acidosis control (Erickson et al., 2003).

Stock et al. (1990) stated that the value of monensin in feedlot diets is variable across grain types and processing methods. Supplementing 27.5 mg/kg monensin to a DRC diet with no roughage tended to improve G:F, but adding monensin to a DRC based diet with 7.5% roughage tended to decrease efficiency. The addition of monensin to a dry rolled wheat-based diet improved G:F over no monensin in the diet (Stock et al., 1990). Xu et al. (2013) supplemented 28 and 48 mg/kg monensin in a diet consisting of barley grain with DDGS to heifers and determined that the higher concentration reduced DMI ($P < 0.05$).

Monensin is commonly fed with the addition of tylosin in the diet. When compared to a diet without additives, the supplementation of monensin and tylosin can decrease DMI ($P < 0.01$) and improve G:F ($P \leq 0.02$) (Galyean et al., 1992; Meyer et al., 2009). Stock et al. (1995) reported that supplementing monensin reduces DMI variation in high-concentrate feedlot diets. Cooper et al. (1999) indicate that increased intake variation can be a sign of subacute acidosis. Additionally, a combination of monensin and tylosin can reduce DMI ($P < 0.05$), increase ADG ($P < 0.05$), and improve feed efficiency ($P < 0.01$) when compared to a diet without supplementation (Stock et al., 1995). However, Depenbusch et al. (2008) reported that in a SFC or SFC with 25% WDGS based diet, the addition of 300 mg/steer daily of monensin or 300 mg/steer daily

of monensin with 90 mg/steer daily of tylosin, did not affect ADG, G:F, carcass characteristics, quality, or liver abscesses.

Conversely, Meyer et al. (2013) reported that the addition of WDGS, WDGS with 360 mg/steer daily monensin (WM), WDGS with 360 mg/steer daily monensin and 90 mg/steer daily tylosin (WMT), or WDGS with 480 mg/steer daily monensin and 90 mg/steer daily tylosin (WHMT) increased final BW, ADG and HCW when compared to the control with a 1:1 ratio of DRC:HMC, 360 mg/steer daily monensin, and 90 mg/steer daily tylosin (CON). Additionally, supplementing WM, WMT, or WHMT significantly increased G:F versus CON or WDGS alone. Steers consuming WMT or WHMT treatments were reported to have decreased DMI over the WDGS treatment (Meyer et al., 2013).

In a SFC based diet, Meyer et al. (2013) reported an increase in DMI in WDGS, WM, WMT, and WMHT treatments versus CON. However, CON fed cattle had increased ADG over ADGS and WM treatments, but WMT and WHMT exhibited increased ADG over the WDGS treatment. Steer consuming the CON treatment where more efficient than all other treatments. An increase in G:F was also reported for WMT and WHMT treatments over WDGS with an improve efficiencies in steer fed WM and WMT over CON and WDGS. In summary of the Meyer et al. (2013) trial, monensin and tylosin were effective at improving G:F and reducing the number of liver abscesses when added to diets with WDGS. When WDGS was added to a SFC based diet, G:F was decreased, but with the addition of monensin and tylosin, there was no effect on ADG. Alternatively, it was determined that increasing the monensin rate from 360 to 480

mg/steer daily has no additional benefits to the cattle, but also does not decrease performance or carcass characteristics (Meyer et al., 2013).

Ellis et al. (2012) has determined that monensin can shift rumen microbial populations to increase propionate and decrease acetate and butyrate proportions, depending on the concentration of monensin in the diet. This can account for improved feed efficiencies in diets with monensin supplementation (Ellis et al., 2012).

Monensin vs. Feed Additives. Monensin is not the only ionophore on the market. Four other options are: lasalocid (Bovatec), laidlomycin propionate (Cattlyst), virginiamycin (Vmax), and bambermycins (Gainpro). Meyer et al. (2009) suggested that cattle respond to feed additives differently depending on the type of additive and the dose that is implemented. An essential oil mixture supplemented at 1.0 g/animal daily with 90 mg/animal daily of tylosin improved G:F ($P \le 0.02$) in a feedlot finishing trial. There was also a decrease ($P < 0.05$) in liver abscesses in steers fed tylosin versus those that were not (Meyer et al., 2009).

Lasalocid, like monensin, is an ionophore feed additive. Delfino et al. (1988) reported that heifers supplemented with lasalocid in a high-grain barley diet tended to have improved feed conversions when compared to non-supplementation. Also, less ($P < 0.10$) energy was lost as methane when cattle were fed lasalocid in the diet (Delfino et al., 1988). Berger et al. (1981) stated that lasalocid can also decrease the incidence of coccidia oocysts in the feces. Additionally, steers fed lasalocid have increased ADG and improved efficiencies ($P < 0.05$) over those not fed lasalocid. In a similar trial, steers fed lasalocid had decreased ($P < 0.05$) DMI and improved ($P < 0.05$) G:F over the control (Berger et al., 1981).

Spires et al. (1990) reported that laidlomycin propionate, included in 6 feedlot trials from 0-12 mg/kg of feed DM, caused a quadratic increased in ADG, a linear improvement in G:F, and an increase in HCW in heifers and steers. However, laidlomycin propionate is more beneficial in low energy diets (Spires et al., 1990). With monensin, a decrease in DMI is often observed, but when feeding laidlomycin propionate, a decrease in DMI has not been detected (Galyean et al., 1992). Conversely, Bauer et al. (1995) detected a decrease in DMI in the first 13 d, but DMI was not different for the entire trial when laidlomycin propionate was supplemented. They also reported a decrease in DMI variation ($P < 0.10$) with an increase in G:F, concluding that laidlomycin propionate may reduce the severity of ruminal acidosis (Bauer et al., 1995). However, DelCurto et al. (1998) raised concerns of possible ruminal acidosis and liver abscesses with the use of bambermycins in high-concentrate diets. Cattle fed bambermycins have exhibited a lower rumen pH than the use of monensin or lasalocid and an increase in intake variation over monensin fed cattle (DelCurto et al., 1998).

Virginiamycin is another antibiotic that can be added to feedlot diets. Rogers et al. (1995) reported a decrease ($P < 0.01$) in the overall incidence and severity of liver abscess with the addition of 19.3 or 27.6 mg/kg virginiamycin. They also calculated the most effective dose of virginiamycin in feedlot diets to be 19.3 to 27.3 mg/kg for increasing ADG, 13.2 to 19.3 mg/kg for improving G:F, and 16.5 to 19.3 mg/kg for decreasing the incidence of liver abscesses (Rogers et al., 1995).

Bretschneider et al. (2008) reviewed the supplementation of ionophores to beef cattle consuming forage-based diets. Average daily gain and G:F quadratically increase ($P < 0.01$, $P = 0.01$, respectively) with increasing concentrations of monensin or

lasalocid. However, there was little impact on DMI with either ionophore ($P > 0.10$).
When cattle are fed higher quality forages, lasalocid has an increased response with
ADG, but monensin has a decrease response in ADG (Bretschneider et al., 2008). Kunkle
et al. (2000) also reported an increase in ADG with the use of antibiotic supplementation
on cattle consuming forage-based diets. The 18 trial summary concluded that the use of
bambermycins increases gain by 10.5% over the control with no supplemental medication
(Kunkle et al., 2000).

Conclusion. To summarize monensin in growing and finishing diets, a meta-
analysis was conducted by Duffield et al. (2012). Monensin reduced DMI ($P < 0.001$),
increased ADG ($P < 0.001$), and improved feed efficiency ($P < 0.001$) across 148
growing and finishing trials. There was approximately a 6.4% improvement in feed
efficiency, 3% decrease in DMI, and 2.5% increase in ADG with the use of monensin
across trials. The average concentration of monensin in the diets was 28.1 mg/kg of feed.
As monensin concentration increased in the diets, there was a linear improvement in feed
efficiency and ADG with a linear decrease in DMI. If concentrations become too high
(around 46 mg/kg), there was a decline in ADG. A greater effect was observed on feed
efficiency and DMI than ADG as monensin concentration increased (Duffield et al.,
2012).

Duffield et al. (2012) also reported that studies containing high gaining cattle
exhibited less improvement in ADG with the use of monensin. It becomes difficult to
administer the maximum rate with cattle that consume large amounts of feed because the
feedlot would exceed the maximum concentration allowed in the ration. This is one
explanation for the increase in 2006 from 36.4 to 48.5 mg/kg DM (33 to 44 g/ton) and

360 to 480 mg/steer daily of monensin allowed in feedlot diets. The following experiment was conducted to test additional benefits of the increased concentration and rate during the adaptation period.

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Evaluating corn condensed distillers solubles concentration in steam-flaked corn finishing diets on cattle performance and carcass characteristics

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ABSTRACT

Performance and carcass characteristics were evaluated using five concentrations of condensed corn distillers solubles (CCDS) replacing steam-flaked corn (SFC) and urea in finishing diets of crossbred steers (initial BW = 399 ± 27 kg). Concentrations of CCDS were: 0, 9, 18, 27, or 36% CCDS on a DM basis. Urea and soybean meal were included in all diets to meet or exceed NRC requirements for metabolizable protein. Steers were utilized in a randomized block design, blocked by BW, stratified by BW within block, and assigned randomly to pens. Pens were assigned randomly to treatment within BW block, with 8 pens/treatment and 11 steers/pen. Steers were fed for an average of 97 d. Dry matter intake decreased quadratically ($P < 0.01$) as the concentration of CCDS increased in the diet. Average daily gain increased quadratically ($P < 0.01$) with greatest gains observed at 27%. Similar to ADG, G:F increased quadratically ($P < 0.01$), with greatest G:F observed at 27% before decreasing at 36% CCDS. Hot carcass weight increased quadratically ($P < 0.01$), also maximized at 27% CCDS. Calculated YG and marbling score increased quadratically ($P = 0.06$ and 0.08, respectively). Fat thickness and LM area also tended ($P = 0.13$ and 0.07, respectively) to increase quadratically as CCDS concentration increased in the diet. Additionally, as CCDS increased in the diet, dressing percentage increased linearly ($P = 0.01$). Based on the first derivative of the quadratic response, the concentration of CCDS was calculated to be 18.2% and 24.5% for maximizing ADG and G:F, respectively. Feeding condensed distillers solubles can effectively be used to replace SFC in feedlot finishing diets while improving ADG and G:F.

Key Words: by-products, distillers solubles, feedlot, finishing, steam-flaked corn

INTRODUCTION

Corn can be processed in a variety of ways to increase starch utilization by the ruminant (Cooper et al., 2002). When cattle are fed diets primarily of processed corn, G:F will improve with increased starch digestibility (Theurer, 1986). Common corn processing methods are dry-rolled corn (DRC), steam-flaked corn (SFC), and ensiled high moisture corn (HMC; Vasconcelos and Galyean, 2007)

Steam-flaking corn is the most popular processing method reported in a survey of feedlot nutritionists (Vasconcelos and Galyean, 2007). Compared with DRC, SFC increases digestibility of starch in the rumen, small intestine, and total tract (Zinn, 1990). Huntington (1997) reported that SFC increases ruminal starch digestibility (as a percentage of intake) from 75 to 85% when compared to DRC. When fed SFC, steers have greater ADG and G:F compared with those consuming DRC, ground corn, or whole corn (Corona et al., 2005). Cooper et al. (2002) reported that DMI is about 15% higher ($P < 0.05$) for HMC over DRC and SFC based diets. Owens et al. (1997) reported cattle consuming DRC and SFC based diets exhibited higher ($P < 0.05$) ADG than those consuming HMC with no difference between DRC and SFC diets. Furthermore, SFC based diets were reported to have increased ($P < 0.05$) G:F over cattle consuming DRC or HMC diets (Owens et al., 1997).

By-products from the dry-milling ethanol process can be used in cattle diets to replace corn. Corrigan et al. (2009) reported that wet distillers grains with solubles (WDGS) interacts with corn processing methods. When replacing corn with WDGS,

there is a greater improvement in G:F when DRC diets are fed compared to SFC based

diets (Corrigan et al., 2009). However, with distillers solubles (CCDS), the same

interaction has not been observed (Titlow et al., 2013). Titlow et al. (2013) reported that

the inclusion of 30% CCDS in SFC based diets improved G:F to a greater extent

compared with DRC based diets, but 30% was the maximum inclusion evaluated.

Previous work has reported that up to 36% of the diet (DM basis) of CCDS can be fed

with a 50:50 blend of DRC and HMC (DRC:HMC) while improving ADG and G:F

(Pesta et al., 2012). Therefore, the objective of this study was to determine the optimum

concentration of CCDS in SFC based diets.

MATERIALS AND METHODS

All animal care and management procedures were approved by the University of

Nebraska-Lincoln Institutional Animal Care and Use Committee.

Four hundred forty crossbred steers (initial BW = 399 ± 22 kg) were utilized in a

feedlot finishing trial at the UNL Panhandle Research Feedlot near Mitchell, Nebraska.

Steers were vaccinated with a modified live virus vaccine for protection against:

Infectious Bovine Rhinotracheitis, Bovine Viral Diarrhea, Parainfluenza-3 Virus, and

Bovine Respiratory Syncytial Virus (Bovi-Shield Gold 5; Zoetis, Florham Park, NJ),

poured with ivermectin as a parasiticide (Ivomec; Merial, Duluth, GA), and implanted

with Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol; Merck Animal Health,

Summit, NJ) on d 0. Cattle were identified by a visual ear tag and electronic

identification tag. Cattle were limit fed a diet at 2% BW consisting of 40% wet distillers

grains with solubles, 30% alfalfa hay, 20% corn silage, and 10% wheat straw (DM basis)

for five days prior to initiation of the experiment to minimize variation in gastrointestinal tract fill (Watson et al., 2013).

Two-day initial weights were recorded on d 0 and 1 which were averaged and used as the initial BW to increase the probability of detecting differences in performance (Stock et al., 1983). The steers were blocked by BW into light, medium, and heavy BW blocks, stratified by BW and assigned randomly to one of 40 pens. The BW blocks consisted of 3, 2, and 3 replications per treatment in the light, medium, and heavy BW blocks, respectively. Pens were then assigned randomly to one of five dietary treatments. There were 11 head per pen and 8 replications per treatment. Dietary treatments included 0, 9, 18, 27, or 36% CCDS replacing SFC and urea (Table 1). All finishing diets contained 16% corn silage, 3.5% SBM, and 4.0% pelleted supplement (DM basis). The diet was formulated to provide 360 mg/steer daily of monensin (Rumensin; Elanco Animal Health, Greenfield, IN) and 90 mg/steer daily of tylosin (Tylan; Elanco Animal Health) added via micro machine (Model 271 Weigh and Gain Generation 7; Animal Health International, Greeley, CO) to ensure proper rate was administered. The corn was flaked at a target density of 360 g/L at a commercial feedlot (Panhandle Feeders, Morrill, NE).

Adaptation to the finishing diet consisted of 3 adaptation diets. Inclusion of alfalfa hay decreased from 18 to 0% and corn silage decreased from 36 to 16% of the diet as SFC increased to the finishing diet. The inclusion of CCDS (dependent on treatment), SBM (3.5%), and supplement (4%) remained the same in all steps. Urea was added to the diets to meet or exceed the MP requirement of the animal (NRC, 1996). The composition

of the CCDS used in this experiment (Colorado Agri Products, Bridgeport, NE) contained 24.3% DM, 16.0% CP, 20.1% Fat, and 0.41% S (DM basis).

All ingredients were sampled weekly and DM was determined on site in a 60°C forced-air oven for 48 h (AOAC, 2006). The weekly samples were also composited over the entire experiment and analyzed in a commercial laboratory for CP (AOAC Method 990.03), NDF (Ankom 05/03), fat (AOAC Method 945.16), Ca, P, K, S, and starch (Megazyme enzyme and a YSI analyzer; Hall, 2009; Xiong et al., 1990; YSI Inc., 2000; Servi-Tech Laboratories, Hastings, NE). Minerals were analyzed using nitric/perchloric digestion with HCl addition and analyzed by ICP (AOAC, 2006; Gavlak et al., 2005; Huang and Schulte, 1985; Mills and Jones, 1996; Servi-Tech Laboratories). Feed bunks were evaluated at approximately 0600 h and managed for only trace amounts of feed remaining at feeding (0800 h).

Upon completion of the experiment, steers were individually weighed prior to shipment. Weights were pencil shrunk by 4% and used as the final live body weight. Animals in the heavy BW block were harvested on d 89 and the medium and light BW blocks were harvested on d 104 (Cargill Meat Solutions, Fort Morgan, Colorado). Hot carcass weight and liver scores were recorded on the d of harvest. Fat thickness, LM area, and marbling score were recorded by camera after a 48-hour chill (Diamond T Livestock Services, Yuma, CO). Calculated yield grade was determined using carcass measurements of 12th rib fat thickness, LM area, KPH fat, and HCW entered in the formula reported by Boggs and Merkel (1993). Final BW, ADG, and G:F were calculated using HCW adjusted to a common 63% dressing percentage.

The feeding value of CCDS relative to corn on a DM basis was calculated by the following equation for each inclusion level:

$$[1 - ((\text{G:F of inclusion} - \text{G:F of control diet}) \div \text{G:F of control diet}) \div \text{inclusion level}]$$
$$\text{x } 100 + 100$$

The energy value of the diets were calculated by entering data per pen using the Galyean (2009) net energy calculator and analyzing the NE_m and NE_g using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). The calculator utilizes initial BW, final BW, DMI, ADG, and target endpoint.

Performance and carcass characteristics were analyzed using the MIXED procedure of SAS (SAS Institute Inc.) as a randomized block design. Pen was the experimental unit and BW block was included as a random effect. Orthogonal contrasts were used to test linear and quadratic effects of CCDS inclusion. The percentage of liver abscesses was analyzed using the GLIMMIX procedure of SAS with a binomial distribution and logit link function. Optimum CCDS concentration was calculated using the first derivative of the quadratic response, when significant.

RESULTS AND DISCUSSION

Dry matter intake decreased quadratically ($P = 0.02$) as the concentration of CCDS increased in the diet (Table 2). Titlow et al. (2013) also observed a quadratic decrease in DMI as CCDS concentration increased in both SFC and DRC based diets. However, a linear decrease in DMI with increasing concentration of CCDS was observed in a basal diet of a 1:1 ratio of DRC:HMC (Pesta et al., 2012). Additionally, Rust et al. (1990) reported a decrease in DMI as CCDS concentration increased in a DRC based diet, up to 20% of the diet DM. Zinn et al. (2008) determined that a decrease in DMI in

feedlot diets is likely due to an increase in the energy density of a diet. In the current trial, dietary fat concentration increased as CCDS concentration increased in the diet (Table 1). The increased fat from the CCDS increased the energy density of the diet and therefore may have decreased DMI. Vander Pol et al. (2009) reported an increase in ADG and G:F as WDGS increased in the diet (0, 20, and 40% diet DM), possibly due to the increasing amount of fat. However, DMI numerically decreased for both increasing concentrations of WDGS and supplemental corn oil (0, 2.5, and 5% diet DM), with a significant decrease in DMI at the highest concentration of corn oil (Vander Pol et al., 2009). Recommendations by feedlot nutritionists propose a fat concentration of 8% of the total diet (Vasconcelos and Galyean, 2007) which has increased from the 2-4% previously recommended (Pond et al., 2005).

Average daily gain increased quadratically ($P < 0.01$) as CCDS concentration increased with greatest gains observed at 27% and a slight decrease at 36%. Calculated optimum ADG using the first derivative of the quadratic response (y = -0.00116 (± 0.000322) x^2 + 0.04222 (± 0.0121) x + 4.1583 (± 0.0920)) occurred at 18.2% inclusion of CCDS. Pesta et al. (2012) reported greatest gains at 18% CCDS of the diet in a DRC:HMC blend and calculated an optimum concentration of CCDS at 20.8% to maximize ADG. Whereas Titlow et al. (2013) observed greatest ADG at 15% CCDS in DRC based diets, and a linear increase in ADG with greatest gains at 30% CCDS in SFC based diets.

The NE_m and NE_g values both increased quadratically ($P < 0.01$) as CCDS concentration increased in the diet with maximum NE_m and NE_g observed at 18% CCDS. There was a quadratic improvement ($P < 0.01$) in G:F as CCDS concentration increased

in the diet. Gain efficiency improved as CCDS increased up to the 27% CCDS diet, but

G:F decreased at 36% CCDS. Even though a small decrease in G:F was observed for

cattle fed 36% CCDS compared with the most improvement at 27%, G:F at 36% CCDS

was still 8.7% more efficient than the control diet. Calculated optimum G:F using the first

derivative of the quadratic response (y = -0.00003095 ($\pm$ 0.000014) x^2 + 0.001517 ($\pm$

0.000529) x + 0.1604 ($\pm$ 0.00402)) occurred at 24.5% inclusion of CCDS. Rust et al.

(1990) reported an increase in G:F as CCDS concentration increased up to 20% of the

diet DM of a DRC based diet. Alternatively, Titlow et al. (2013) observed the greatest

G:F at 30% CCDS for both DRC and SFC based diets, which concur with the results

from Pesta et al. (2012), as greatest G:F was observed at 36% CCDS. Pesta et al. (2012)

calculated an optimum CCDS concentration of 32.5% for maximizing G:F in a

DRC:HMC blended diet.

　　　The feeding value of CCDS was calculated for each inclusion concentration

(Table 2). The feeding values were 117, 148, 152, and 176% the value of SFC at the 9,

18, 27, and 36% CCDS inclusion, respectively. The increased feeding values for the

increasing concentrations of CCDS can be attributed to the increased dietary fat from the

CCDS. The additional fat from CCDS improves animal performance (Vander Pol et al.,

2009). The fat in CCDS is bound in the germ and resistant to complete biohydrogenation

in the rumen, while the fat in corn oil can be degraded in the rumen (Zinn et al., 2000).

　　　Hot carcass weight increased quadratically ($P < 0.01$) as CCDS concentration

increased, maximized at 27% CCDS. Marbling score and calculated YG tended to

increase quadratically ($P = 0.08$ and 0.06, respectively) as the concentration of CCDS

increased in the diet. Longissimus muscle area and 12th rib fat thickness also tended to

increase quadratically (P = 0.07 and 0.13, respectively) as CCDS concentration increased

in the diet. There was a trend (P = 0.10) for an increasing linear response for dressing

percentage as CCDS concentration increased in the diet. These results align with previous

data where CCDS was fed in DRC:HMC based diets (Pesta et al., 2012). A quadratic

increase in HCW and a linear increase in dressing percentage were reported by Pesta et

al. (2012) with no other carcass differences with increasing CCDS concentration.

However, Titlow et al. (2013) reported a linear increase in HCW, fat thickness, and yield

grade when increasing CCDS up to 30% in SFC based diets.

The carcass differences between this trial and Titlow et al. (2013) is likely

because the current trial tested up to a 36% CCDS concentration whereas Titlow et al.

(2013) only examined up to 30% inclusion of CCDS. The differences in HCW

demonstrate that the optimal HCW must be between 30 and 36% CCDS in SFC based

diets. Even though Titlow et al. (2013) reported a linear increase in 12th rib fat thickness

as CCDS increased in the diet, the 15 and 30% CCDS were numerically the same for

SFC based diets. In the current trial, there was no significant difference for 12th rib fat

thickness, but the values were also similar for CCDS concentrations of 9% and above.

The current trial reported a tendency (P = 0.06) for a quadratic increase in calculated YG,

suggesting that the optimum for SFC based diets is between 30 and 36% CCDS

concentration when compared with the data of Titlow et al. (2013).

These data evaluating CCDS in SFC based diets disagree with previous data

evaluating SFC and distillers grains plus solubles (Vander Pol et al., 2008; Corrigan et

al., 2009; May et al., 2010; Luebbe et al., 2012). Vander Pol et al. (2008) compared

processing methods in diets containing 30% WDGS. Diets with DRC, HMC, or a 1:1

blend of DRC:HMC had greater performance compared with diets that were more intensely processed (Finely ground corn (FGC) or SFC) and whole, unprocessed corn. Cattle fed DRC had increased ($P < 0.05$) ADG and final BW compared to FGC, SFC, and whole corn. Additionally, steers fed HMC had improved ($P < 0.05$) G:F relative to cattle fed FGC, SFC, and whole corn (Vander Pol et al., 2008).

Previous data by Corrigan et al. (2009) suggest that increasing concentrations of WDGS in SFC based diets quadratically decreases ($P = 0.02$) ADG and has no effect ($P = 0.52$) on G:F. May et al. (2010) also reported a decrease ($P \leq 0.05$) in final BW, HCW, and G:F as WDGS increased in a SFC based diet. However, in HMC or DRC based diets, ADG and G:F are significantly improved with the addition of WDGS (Corrigan et al., 2009). In 2012, Luebbe et al. examined increasing levels of WDGS up to 60% of the diet DM in SFC based diets. Final BW, ADG, G:F, HCW, 12th rib fat depth, and marbling score decreased linearly ($P < 0.01$) as WDGS replaced corn. As more WDGS were added to SFC based diets, performance was negatively impacted (Luebbe et al., 2012). In our hypothesis, we expected a similar result would occur with CCDS and SFC, but ADG and G:F were actually improved with increasing concentrations of CCDS in SFC based diets in this study as well as a previous study (Titlow et al., 2013).

Feeding distillers by-products with greater concentrations of sulfur (S) has the potential to increase the incidence of S toxicity (Polioencephalomalacia; PEM). Titlow et al. (2013) observed a S concentration of 0.39% for the CCDS (DM basis) and Pesta et al. (2012) reported a 1.1% S concentration. The CCDS in this study averaged 0.41%. During the experiment, a load of CCDS was delivered after the plant flushed their system with sulfuric acid. Subsequently, six steers were treated for PEM. Three steers were on the

18% CCDS diet and one each from the 9%, 27%, and 36% CCDS diets. Two steers became chronic and were ultimately removed from the trial; one each from 18% and 27% CCDS diets. An analysis of the S content of the CCDS for that load was 2.59% S on a DM basis. A diet sample from the bunk of the 36% CCDS treatment was analyzed at 0.92% S (DM basis). These concentrations of S exceed toxic amounts of around 0.40% S of the total diet DM (NRC, 1996). Monitoring S content is vital as Buckner et al. (2011) observed an average sulfur concentration of 0.77% with a range from 0.44 to 1.72% S between 6 different plants. There was significant variation in S content within days and across days at the same plant (Buckner et al., 2011).

There is a difference between dietary sulfur and rumen available sulfur (RAS). Rumen available sulfur (RAS) is dietary sulfur that can be metabolized into H_2S by rumen microbes. The consumption of ruminal available sulfur is a more accurate indication of hydrogen sulfide concentration in the rumen and thus could more accurately predict PEM incidences (Sarturi et al., 2013). Nichols et al. (2013) reported that for every 0.1% increase in dietary sulfur and RAS, the risk for PEM increases by a factor of 2 and 2.6, respectively ($P < 0.01$). This indicates that the risk of PEM increases more when measuring RAS. Rumen available sulfur could be a more effective measurement of PEM risk than dietary S concentration alone (Nichols et al., 2013). Logically, it was thought more S toxicity diagnoses would have been observed from steers fed the 36% CCDS concentration diet, but it is believed those concentrations were greater than the threshold and steers decreased DMI, similar to previous studies (Sarturi et al., 2013). However, the steers on the 18% CCDS diet may have continued to consume feed and subsequently exhibited a greater incidence of adverse reactions.

This study suggests feeding CCDS can effectively be used to replace SFC in feedlot finishing diets up to 36% of the total diet DM. The greatest observed G:F was at 27% CCDS, at which the steers were 13% more efficient than those fed 0% CCDS. This response is different compared with Vander Pol et al. (2008), Corrigan et al. (2009), and Luebbe et al. (2012) who observed an interaction between SFC and WDGS concentration. They reported a decrease in ADG and either no improvement or a decrease in G:F in SFC based diets versus less intensely process corn.

IMPLICATIONS

The optimum corn condensed distillers solubles concentration replacing steam-flaked corn for maximum average daily gain was calculated at 18.2% inclusion with maximum gain efficiency determined to be at 24.5% inclusion. The decision to feed corn condensed distillers solubles to replace corn would depend on price relative to corn on a DM basis. Markets will dictate whether elevated concentrations of corn condensed distillers solubles will be economical in finishing diets with steam-flaked corn.

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TABLES

Table 1. Dietary treatments and nutrient analysis for steers fed corn condensed distillers solubles (DM basis)

	CCDS, % Diet DM				
	0	9	18	27	36
Ingredient, %[1]					
SFC[2]	75.6	66.8	57.9	49.2	40.4
Silage	16.0	16.0	16.0	16.0	16.0
CCDS[3]	0.0	9.0	18.0	27.0	36.0
SBM[4]	3.5	3.5	3.5	3.5	3.5
Urea	0.9	0.7	0.6	0.3	0.1
Supplement[5,6]	4.0	4.0	4.0	4.0	4.0
Urea	0.687	0.687	0.687	0.687	0.687
Limestone	1.34	1.34	1.34	1.34	1.34
Salt	0.30	0.30	0.30	0.30	0.30
Potassium	0.182	0.182	0.182	0.182	0.182
Analyzed Composition, %[7]					
Crude Protein	13.46	13.47	13.74	13.47	13.48
Ether Extract	2.72	4.29	5.85	7.41	8.97
Calcium	0.55	0.56	0.57	0.58	0.59
Phosphorus	0.25	0.36	0.46	0.57	0.68
Sulfur	0.11	0.12	0.14	0.15	0.17
Potassium	0.70	0.90	1.10	1.30	1.49

[1]Diet formulated to contain 360 mg/steer daily monensin and 90 mg/steer daily tylosin added via micro machine (Model 271 Weigh and Gain Generation 7; Animal Health International)

[2]SFC = steam-flaked corn; flake density was 360 g/L

[3]CCDS = corn condensed distillers solubles

[4]SBM = soybean meal

[5]The same pelleted supplement was used for all diets and contained: 30 mg/kg Zn, 50 mg/kg Fe, 10 mg/kg Cu, 20 mg/kg Mn, 0.1 mg/kg Co, 0.5 mg/kg I, and 0.1 mg/kg Se

[6]Vitamins added in pelleted supplement: 10670 IU/kg Vitamin A, 1342 IU/kg Vitamin D, and 77 IU/kg Vitamin E

[7]Analysis completed by ingredient

Table 2. Effect of corn condensed distillers solubles in steam-flaked corn based diets on performance and carcass characteristics

Item	CCDS[1], % Diet DM					SEM[2]	P-Value	
	0	9	18	27	36		Linear[3]	Quad.[4]
Performance								
Initial BW, kg	400	398	399	399	400	1	0.58	0.11
Final BW, kg[5]	588	601	600	605	588	9	0.63	< 0.01
DMI, kg/d	11.8	11.8	11.5	11.4	10.8	0.4	< 0.01	0.02
ADG, kg[5]	1.90	2.05	2.03	2.08	1.90	0.10	0.83	< 0.01
G:F[5]	0.161	0.173	0.176	0.182	0.175	0.004	< 0.01	< 0.01
NE_m[6]	1.96	2.04	2.08	1.71	1.53	0.06	< 0.01	< 0.01
NE_g[6]	1.31	1.38	1.41	1.09	0.93	0.06	< 0.01	< 0.01
Feeding Value[7]	-	117	148	152	176	-	-	-
Carcass Characteristics								
HCW, kg	370	379	378	381	370	6	0.65	< 0.01
Marbling Score[8]	425	432	434	433	412	12	0.37	0.08
Calculated YG[9]	3.37	3.46	3.52	3.52	3.45	0.07	0.21	0.06
12th rib fat, cm	1.42	1.47	1.50	1.52	1.47	0.01	0.11	0.13
LM area, cm^2	80.7	81.9	81.3	81.9	79.4	0.2	0.24	0.07
Dressing, %	61.6	61.9	62.0	62.2	62.0	0.3	0.10	0.22
Liver abscess[10,11], %	10.98	8.43	14.46	9.76	9.52	-	0.83	-
A, %	4.88	4.82	9.64	6.10	5.95	-	0.71	-
A+, %	6.10	3.61	4.82	3.66	3.57	-	0.93	-

[1]CCDS = concentration of condensed distillers solubles in diet.
[2]SEM = standard error of the mean for the interaction
[3]Linear effect for the concentration of CCDS included ($P < 0.05$)
[4]Quad. = quadratic effect for the concentration of CCDS included ($P < 0.05$)
[5]Final BW calculated from hot carcass weight adjusted to a common dressing percentage of 63%
[6]NE_m = net energy for maintenance; NE_g = net energy for gain; Galyean, 2009
[7]Feeding Value = value relative to corn
[8]Marbling score: 300 = Slight 0, 400 = Small 0
[9]Calculated YG = 2.5 + 6.35 (fat thickness, cm) – 2.06 (LM area, cm^2) + 0.2 (KPH fat, %) + 0.0017 (hot carcass weight, kg)
[10]Liver score: A = 3 or 4 abscesses; A+ = 4 or more abscesses
[11]P-value listed is Protected F-test value

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Evaluating two rates of monensin fed during the grain adaptation period on cattle performance and carcass characteristics

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ABSTRACT

Two studies were conducted to evaluate two rates (360 or 480 mg/steer daily) of monensin fed during the adaptation period. Both Exp. utilized 18 pens with 9 replications per treatment. In Exp. 1, 197 crossbred steers (initial BW = 375 ± 29 kg) were adapted to a finishing diet over 20 d. Interim performance was determined on d 26, after being on a common finishing diet for 6 d. Exp. 2 was conducted similar to Exp. 1 with identical treatments, except 198 crossbred steers (initial BW = 415 ± 17 kg) were utilized in an 18 d adaptation period. Interim performance was determined by weighing on d 24 and 25, after being on a common finishing diet for 7 d. Data were analyzed by testing an Exp. by treatment interaction. Data from Exp. 1 determined there were no significant differences for performance or carcass characteristics between treatments. In Exp. 2, steers consuming 360 mg/steer daily had higher ADG ($P = 0.02$), increased interim BW ($P = 0.01$), and therefore improved G:F ($P = 0.03$) than those consuming 480 mg/steer daily during adaptation. There was more ($P = 0.05$) variance in DMI during adaptation in Exp. 2 versus Exp. 1. No significant differences were found for final BW and ADG for the entire trial ($P = 0.66$ and 0.68, respectively). Monensin rate had no impact ($P \geq 0.10$) on carcass characteristics. These data indicate feeding 360 mg monensin/steer daily may improve G:F during the adaptation period. However, these studies suggest feeding 360 versus 480 mg/steer daily of monensin during the adaption period has little impact on overall performance

Key Words: adaptation, additive, ionophore, monensin

INTRODUCTION

Monensin is an ionophore that is approved to improve G:F and prevent/control coccidiosis in feedlot cattle (FDA, 2006). Additionally, feeding monensin decreases acidosis, with greater rumen pH and less time with ruminal pH below 5.6 (Cooper et al, 1997). Monensin controls intake rate and decreases intake variation which can also minimize acidosis (Burrin et al., 1988; Stock et al., 1995; Cooper et al., 1997).

Monensin is approved to be fed up to 48.5 mg/kg (DM) to provide up to 480 mg/steer daily, which was increased from 36.4 mg/kg (DM) and 360 mg/steer daily in 2006 (FDA, 2006). The increased amount approved lead to the question of whether a higher rate could have benefits on adapting cattle to high concentrate diets by controlling acidosis and bloat. Blackford et al. (2000) reported that monensin at concentrations of either 33 or 49.6 mg/kg reduced acidosis on the day of an acidosis challenge, but 49.6 mg/kg reduced ($P < 0.05$) the area the rumen was below a pH of 5.6 for 5 d following the challenge compared to cattle on the 33 mg/kg concentration. Patterson et al. (2002) reported that DMI is reduced when feeding monensin during an acidosis challenge. Increasing the concentration from 33 to 49.6 mg/kg decreased DMI during the 5 d following the challenge (Patterson et al., 2002). Decreased DMI and increased rumen pH suggest better acidosis control. Parsons et al. (2010) also found that greater concentrations of monensin are more beneficial during the first 56 d compared to the entire feeding period. During the first 56 d, increasing from 36.4 to 48.5 mg/kg monensin, G:F increased by 8% ($P < 0.10$), but only increased 3% ($P < 0.05$) for the entire trial (Parsons et al., 2010).

Duffield et al. (2012) conducted a meta-analysis to summarize feeding monensin in 148 growing and finishing trials in 64 papers and reports. As monensin concentration increased in the diet, there was a linear decrease in DMI and linear improvement in G:F. An increase in ADG was observed up to 46 mg/kg of feed, and then gain declined (Duffield et al., 2012).

Therefore, the objective of this study was determine if a difference exists between feeding 360 or 480 mg/steer daily of monensin on cattle performance and carcass characteristics during the adaptation period.

MATERIALS AND METHODS

All animal care and management procedures were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

Exp. 1

One hundred ninety-seven crossbred steers (initial BW = 376 ± 29 kg) were used at the UNL Panhandle Research Feedlot near Mitchell, Nebraska. Cattle were limit fed a diet at 2% BW consisting of 55% alfalfa hay, 40% WDGS, and 5% supplement (DM basis) for five days prior to initiation of the experiment to minimize variation in gastrointestinal tract fill (Watson et al., 2013). Two-day initial weights were recorded on d 0 and 1 which were averaged and used as the initial BW to increase the probability of detecting differences in performance (Stock et al., 1983). The steers were blocked by BW into light, medium, and heavy BW blocks (6 replications per block), stratified by BW and assigned randomly to one of 18 pens. Pen was assigned randomly to one of two dietary treatments. There were 10 or 11 steers per pen (balanced by replication) and 9

replications per treatment. Dietary treatments included 360 or 480 mg/steer daily of monensin (Rumensin; Elanco Animal Health, Greenfield, IN) during the adaptation period. All treatments were fed a common diet and 360 mg/steer daily of monensin after adaptation through finishing.

Upon arrival, cattle were vaccinated with a modified live virus vaccine for protection against: Infectious Bovine Rhinotracheitis, Bovine Viral Diarrhea, Parainfluenza-3 Virus, and Bovine Respiratory Syncytial Virus (Bovi-Shield Gold 5; Zoetis, Florham Park, NJ) and for the prevention of Clostridium chauvoei, C. septicum, C. novyi, C sordelli, C perfringens types C & D, and Moraxella bovis (Vision 7; Merck Animal Health, Summit, NJ), poured with ivermectin as a parasiticide (Ivomec; Merial, Duluth, GA), and fixed with a visual and electronic identification tag. Steers in the heavy BW block were implanted on d 1 with Component TE-S (120 mg trenbolone acetate, 24 mg estradiol, and 29 mg tylosin tartrate; Elanco Animal Health). Those in the medium and light BW blocks were implanted with Component TE-IS (80 mg testosterone acetate, 16 mg estradiol, and 29 mg tylosin tartrate; Elanco Animal Health) on d1 and re-implanted with Component TE-S (Elanco Animal Health) on d 33.

The adaptation program consisted of 4 diets where dry-rolled corn (DRC) was increased with decreasing amounts of alfalfa hay (Table 1). Step 1 was 6 d in length, while step 2 and 3 were 7 d each. Step 4 was the finishing ration. Besides monensin rate, the diets were the same for all treatments. Monensin was added via micro machine (Model 271 Weigh and Gain Generation 7; Animal Health International, Greeley, CO) to ensure the proper rate was administered. On d 26, upon completion of the adaptation period and after being on a common diet for 6 d, weights were taken prior to feeding and

used as the interim BW. Cattle weights were pencil shrunk 4% for calculation of ADG and G:F during the adaptation period.

All ingredients were sampled weekly and DM was determined on site in a 60°C forced-air oven for 48 h (AOAC, 2006). The weekly samples were also composited and analyzed as one sample in a commercial laboratory for CP (AOAC Method 990.03), NDF (Ankom 05/03), fat (AOAC Method 945.16), Ca, P, K, S, and starch (Megazyme enzyme and a YSI analyzer; Hall, 2009; Xiong et al., 1990; YSI Inc., 2000; Servi-Tech Laboratories, Hastings, NE). Minerals were analyzed using nitric/perchloric digestion with HCl addition and analyzed by ICP (AOAC, 2006; Gavlak et al., 2005; Huang and Schulte, 1985; Mills and Jones, 1996; Servi-Tech Laboratories). Feed bunks were evaluated at approximately 0600 h and managed for only traces of feed remaining at feeding (0800 h). All finishing diets contained 25% WDGS, 14% corn silage, and 6% liquid supplement (DM basis).

Upon completion of the experiment, steers were individually weighed prior to shipment. Weights were pencil shrunk by 4% and used as the final live BW. Steers in the heavy BW block were weighed and shipped on d 113, medium BW block on d 127, and the light BW block on 141 days on feed (Cargill Meat Solutions, Fort Morgan, Colorado). Hot carcass weight and liver score were recorded on the harvest date. Calculated yield grade was determined using carcass measurements of 12th rib fat thickness, LM area, KPH fat, and HCW entered in the formula reported by Boggs and Merkel (1993). Fat thickness, LM area, and marbling score were recorded after a 48 h chill (Diamond T Livestock Services, Yuma, CO). Final BW, ADG, and G:F were calculated using HCW adjusted to a common 63% dressing percentage.

Exp. 2

One hundred ninety-eight crossbred steers (initial BW = 415 ± 17 kg) were utilized in a feedlot finishing trial at the same location as Exp. 1. Cattle were limit fed a diet at 2% BW consisting of 30% wheat straw, 20% corn silage, 20% dry-rolled corn (DRC), 15% wet distillers grains with solubles (WDGS), 10% corn condensed distillers solubles (CCDS), and 5% supplement (DM basis) for five days prior to initiation of the experiment to minimize variation in gastrointestinal tract fill (Watson et al., 2013). Two-day initial weights were recorded on d 0 and 1 which were averaged and used as the initial BW (Stock et al., 1983). The steers were blocked by BW into light (6 replications) and heavy (12 replications) BW blocks, stratified by BW and assigned randomly to one of 18 pens. Pen was assigned randomly to one of two dietary treatments. There were 11 steers per pen and 9 replications per treatment. Dietary treatments were the same as Exp. 1.

Steers were vaccinated on d 0 with a modified live virus vaccine for protection against: Infectious Bovine Rhinotracheitis, Bovine Viral Diarrhea, Parainfluenza-3 Virus, and Bovine Respiratory Syncytial Virus (Bovi-Shield Gold 5; Zoetis) and poured with ivermectin as a parasiticide (Ivomec; Merial). On d 1, all cattle were implanted with Revalor XS (200 mg trenbolone acetate and 40 mg estradiol; Merck Animal Health). Cattle were then revaccinated with Bovi-Shield Gold 5 (Zoetis) on d 23.

The adaptation program consisted of 5 diets where DRC was increased with decreasing amounts of straw and silage (Table 2). Step 1 and 2 were 4 d in length, while step 3 and 4 were 5 d each. Step 5 was the finishing ration. With the exception of monensin rate, the diets were the same for all treatments. Monensin was added via micro

machine (Model 271 Weigh and Gain Generation 7; Animal Health International) to ensure the proper rate was administered. On d 24 and 25, upon completion of the adaptation period and after being on a common diet for 7 d, two-day weights were taken prior to feeding, averaged, and used as the interim BW. Cattle weights were pencil shrunk 4% for calculation of ADG and G:F during the adaptation period.

Ingredients were sampled and analyzed as described in Exp. 1. All finishing diets contained 10% WDGS, 10% CCDS, and 5% liquid supplement (DM basis). Urea was added at 0.7% of the diet to meet or exceed the MP requirement of the animal. Animals in the heavy BW block were harvested on d 86 and those in the light BW block were harvested on d 114 (Cargill Meat Solutions, Fort Morgan, Colorado).

Statistical Analysis

Data for both Exp. were analyzed separately using the MIXED procedure of SAS (SAS Institute, Cary, NC) as a randomized block design. Pen was the experimental unit, treatment was a fixed effect, and block was treated as a random effect. Percentage of liver abscesses was analyzed using the GLIMMIX procedure of SAS with a binomial distribution and logit link function. Intake variance was also calculated using the GLIMMIX procedure of SAS with data analyzed by a common 18 d on adaptation and 6 d on the finisher diet. Experiments were pooled by testing an Exp. by treatment interaction. If there was an Exp. by treatment interaction, the simple effects were reported; otherwise, the main effects were reported.

RESULTS AND DISCUSSION

A significant interaction between treatment and experiment was observed for interim BW ($P = 0.02$), ADG ($P = 0.03$), and G:F ($P = 0.03$) during the adaptation period; with a tendency for an interaction in DMI ($P = 0.07$; Table 3). There were no significant differences in interim performance between 360 and 480 mg/steer daily in Exp. 1. However, in Exp. 2, cattle fed 360 mg/steer daily had greater ADG ($P = 0.02$), increased interim BW ($P = 0.01$), and improved G:F ($P = 0.03$) compared to steers fed 480 mg, during the adaptation period. Steers in Exp. 2 consumed significantly more feed during the adaptation period than those in Exp. 1 ($P < 0.01$), but there were no differences ($P \geq 0.15$) between 360 and 480 mg/steer daily within experiment. There were no differences in the variance in DMI between treatments for the first 6 d steers were on the finishing diet. However, there was significantly more variance ($P = 0.05$) in the 18 d adaptation period in Exp. 2 versus Exp. 1.

Since steers in Exp. 2 had numerically larger initial BW, they consumed more dry matter ($P = 0.05$) rendering them less efficient ($P < 0.01$) than those in Exp. 1 during the 100 d feeding period. However, no significant differences were observed for final BW or ADG for the entire trial ($P = 0.66$ and 0.68, respectively). Additionally, HCW, 12th rib fat, LM area, calculated YG, and overall liver scores were not affected ($P \geq 0.10$) by monensin level. Cattle in Exp. 1 had an increased ($P = 0.05$) dressing percentage and a tendency for a greater ($P = 0.06$) marbling score than cattle in Exp. 2, but there was no significant difference ($P \geq 0.30$) between treatments in either Exp. Cattle fed 480 mg/steer daily of monensin, in both trials, had a tendency ($P = 0.06$) for a lower percentage of "A" liver scores.

In contrast to Exp. 2, Burrin et al. (1988) observed an increase in G:F and a trend for an increase in ADG as monensin concentration increased in the diet. However, that trial only tested up to a concentration of 33 mg of monensin per kg of feed. Parsons et al. (2010) fed 36.4 or 48.5 mg/kg of monensin for an entire 153 d trial. The higher concentration was more beneficial in the first 56 d with an 8% improvement in G:F (Parsons et al., 2010). Similar results were not observed in the current trials.

Montgomery et al. (2003) evaluated monensin in an 88 d growing period at concentrations of 33, 44, or 55 mg/kg of feed. Similar to Exp. 1, there were no differences in the growing period. In the subsequent finishing period, DMI tended to increase while ADG and HCW both increased as monensin concentration increased. They concluded that supplementing monensin beyond the labeled concentration (36.4 mg/kg or 360 mg/steer daily) during the growing period could be beneficial to performance and carcass characteristics in the finishing period (Montgomery et al., 2003). However, this was not observed in the current trials or by Burrin et al. (1988). Conversely, Erickson et al. (2003) reported that monensin controls intake variation, but concentrations above approved levels (36.4 mg/kg and 360 mg/steer daily) show little improvement in acidosis control.

Previous studies have reported results similar to the current study. With increasing monensin concentration in the diet, the performance benefits in the adaptation period do not carry over to the finishing period (Burrin et al., 1988). Parsons et al. (2010) saw less improvement in G:F over the entire trial with only a 3% increase between monensin concentrations. Increasing from 360 to 480 mg/steer daily for the entire trial had no

additional benefits to the cattle, but also did not decrease performance or carcass characteristics (Meyer et al., 2013).

Conversely, a meta-analysis conducted by Duffield et al. (2012) observed an increase in ADG and G:F as monensin concentration increased in the diets of 64 various trials. For the entire finishing trial, Parsons et al. (2010) reported an increase in G:F, which was not observed in either of the current trials. However, the increased concentration to 48.5 mg/kg was fed for the entire trial, which is different from the methods of the current trials (Parsons et al., 2010).

In contrast to the current trial, Depenbusch et al. (2008) reported no differences in liver abscesses when monensin was added to the diet. Conversely, Meyer et al. (2013) reported a decrease in liver abscesses when monensin and tylosin were added to the diet, which is likely due to the tylosin as there were no observed differences is liver abscess prevalence with just monensin added to the diet compared to the control.

This study suggests feeding 360 versus 480 mg/steer daily of monensin during the adaption period has little impact on overall performance of the cattle. These data indicate that 360 mg/steer daily of monensin may be more advantageous with the steers being more efficient, eating less and gaining more, during the adaptation period in experiment 2. However, they do not maintain that efficiency through the entire finishing period.

IMPLICATIONS

If feeding elevated rates of monensin were economical, many producers may add up to the maximum concentration. However, this experiment suggests there is little benefit from an increased rate if not a decline in performance during the adaptation

period. Future research may dictate the need to feed the maximum concentration in

adaptation diets.

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TABLES

Table 1. Dietary treatments for steers fed two rates of monensin during grain adaptation in Exp. 1 (DM basis)

Days fed:	1 – 6	7 – 13	14 – 20	
	Step 1	Step 2	Step 3	Finisher
Ingredient, %[1]				
Alfalfa hay	30	20	10	0
Corn silage	14	14	14	14
Dry rolled corn	25	35	45	55
WDGS[2]	25	25	25	25
Supplement[3,4]	6	6	6	6
Calcium	0.55	0.55	0.55	0.55
Salt	0.30	0.30	0.30	0.30

[1]Diets contained 360 or 480 mg/steer daily monensin and 90 mg/steer daily tylosin (DM) added via micro machine (Model 271 Weigh and Gain Generation 7; Animal Health International)

[2]Wet distillers grains with solubles

[3]The same liquid supplement was used for all diets and contained: 30 mg/kg Zn, 50 mg/kg Fe, 10 mg/kg Cu, 20 mg/kg Mn, 0.1 mg/kg Co, 0.5 mg/kg I, and 0.1 mg/kg Se

[4]Vitamins added in liquid supplement: 2200 IU/kg Vitamin A, 275 IU/kg Vitamin D, and 3.3 IU/kg Vitamin E

Table 2. Dietary treatments for steers fed two rates of monensin during grain adaptation in Exp. 2 (DM basis)

Days fed:	1 – 4	5 – 8	9 – 13	14 – 18	
	Step 1	Step 2	Step 3	Step 4	Finisher
Ingredient, %[1]					
Dry rolled corn	34.3	44.3	54.3	64.3	69.3
WDGS[2]	10	10	10	10	10
CCDS[3]	10	10	10	10	10
Wheat straw	25	20	15	10	5
Corn silage	15	10	5	-	-
Supplement[4,5]	5	5	5	5	5
Urea	0.7	0.7	0.7	0.7	0.7
Calcium	0.5	0.5	0.5	0.5	0.5
Salt	0.3	0.3	0.3	0.3	0.3

[1]Diets contained 360 or 480 mg/steer daily monensin and 90 mg/steer daily tylosin (DM) added via micro machine (Model 271 Weigh and Gain Generation 7; Animal Health International)
[2]Wet distillers grains with solubles
[3]Corn condensed distillers solubles
[4]The same liquid supplement was used for all diets and contained: 30 mg/kg Zn, 50 mg/kg Fe, 10 mg/kg Cu, 20 mg/kg Mn, 0.1 mg/kg Co, 0.5 mg/kg I, and 0.1 mg/kg Se
[5]Vitamins added in liquid supplement: 2200 IU/kg Vitamin A, 275 IU/kg Vitamin D, and 3.3 IU/kg Vitamin E

Table 3. Effect of two rates of monensin during grain adaptation on performance and carcass characteristics

	Exp. 1		Exp. 2			*P* –Values[1]		
	360[2]	480[3]	360[2]	480[3]	SEM[4]	TRT	EXP	TRT*EXP
Interim Performance[5]								
Initial BW, kg	376	376	410	409	45	0.72	0.30	0.61
Interim BW, kg[6]	421[ab]	423[ab]	455[a]	450[b]	38	0.23	0.27	0.02
DMI, kg/d	9.10[b]	9.05[b]	10.30[a]	10.35[a]	0.39	0.85	0.01	0.07
ADG, kg[7]	1.74[ab]	1.80[ab]	1.80[a]	1.64[b]	0.29	0.28	0.79	0.03
G:F	0.192[ab]	0.199[ab]	0.175[a]	0.159[b]	0.018	0.36	0.30	0.03
Overall Performance								
Final BW, live, kg[6]	636	638	633	631	30	0.94	0.79	0.64
Final BW, carcass, kg[8]	638	640	616	616	31	0.66	0.29	0.64
DMI, kg/d	12.14	12.23	13.33	13.49	0.66	0.12	0.05	0.66
DMI adapt variance, kg/d[9]	1.87	2.06	3.23	3.26	0.14	0.56	0.05	0.64
DMI finish variance, kg/d[10]	0.064	0.071	0.080	0.084	0.152	0.62	0.31	0.87
ADG, kg	2.07	2.09	2.06	2.06	0.12	0.68	0.84	0.70
G:F	0.170	0.171	0.155	0.153	0.002	0.74	<0.01	0.52
Carcass Characteristics								
HCW, kg	402	404	388	388	20	0.66	0.29	0.66
Dressing, %	63.10	63.29	61.29	61.44	0.46	0.30	0.05	0.91
Marbling Score[11]	490	490	431	426	17.23	0.73	0.06	0.73
12th rib fat, cm	1.45	1.47	1.32	1.32	0.03	0.68	0.26	0.74
LM area, cm^2	82.71	82.00	81.42	80.71	0.28	0.24	0.60	0.99
Calculated YG[12]	3.58	3.66	3.40	3.43	0.14	0.28	0.32	0.67
Liver abscess, %[13]	15.15	10.20	19.21	12.12	0.22	0.10	0.42	0.88
A, %	10.95	6.07	16.17	8.08	0.30	0.06	0.32	0.85
A+, %	4.04	4.08	3.03	4.04	0.39	0.77	0.77	0.79

[a,b]Means within a row with different superscripts differ P ≤ 0.04

[1]TRT = main effect of the treatment, EXP = main effect of the experiment number, TRT*EXP = treatment and experiment interaction

[2]360 mg/steer daily monensin

[3]480 mg/steer daily monensin

[4]SEM = standard error of the mean for the interaction

[5]Interim Performance = Calculated after being on a common finishing diet for 6 d (Exp. 1) or 7 d (Exp. 2)

[6]Weight pencil shrunk 4%

[7]Calculated from interim BW

[8]Calculated from hot carcass weight adjusted to a common dressing percentage of 63%

[9]Intake variance for the adaptation period calculated by a common 18 d on feed

[10]Intake variance for the initial step on to the finishing diet calculated by a common 6 d on finishing feed

[11]Marbling score: 300 = Slight 0, 400 = Small 0

[12]Calculated YG = 2.5 + 6.35 (fat thickness, cm) – 2.06 (LM area, cm^2) + 0.2 (KPH fat, %) + 0.0017 (hot carcass weight, kg)

[13]Liver score: A = 3 or 4 abscesses; A+ = 4 or more abscesses